CAPITAL PROJECTS CONSTRUCTION STANDARDS

DENVER WATER

Volume 2 of 3
4th Edition

Standard Technical Specifications
Divisions 23-48

Capital Projects Construction Standards
Volume 2 of 3
4th Edition

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Capital Projects Construction Standards
Volume 2 of 3 – 4th Edition

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Capital Projects Construction Standards
July 2021

The Capital Projects Construction Standards, 4th Edition (CPCS) establishes the standard requirements for projects within the Denver Water service area including Denver Water Capital Projects. The CPCS includes General Conditions, Standard Technical Specifications, and Standard Details that are no longer referenced in the individual project Contract Documents. (The General Conditions apply exclusively to Denver Water Capital Projects.) Project-specific changes and additions to the CPCS in the form of the Supplementary Technical Specifications, bidding and other contract requirements, and Project Specific Details, will be prepared separately for each Capital Project. Used in conjunction with the Engineering Standards, projects approved under the Denver Water Plan Review process shall adhere to the Technical Specifications and Standard Details.

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Capital Projects Construction Standards
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List of Abbreviations and Acronyms

Technical Societies:

AA	The Aluminum Association
AAMA	American Architectural Manufacturers Association
AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ACI	American Concrete Institute
ADC	Air Diffusion Council
AEIC	Association of Edison Illuminating Companies
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AMCA	Air Movement and Control Association International
ANSI	American National Standards Institute
AOSA	Association of Official Seed Analysts
APA	American Plywood Association
API	American Petroleum Institute
ASCE	American Society of Civil Engineers
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASME	American Society of Mechanical Engineers
ASNT	American Society for Nondestructive Testing
ASTM	ASTM International
AWI	Architectural Woodwork Institute
AWPA	American Wood Preservers Association; American Wood Protection Association
AWS	American Welding Society
AWWA	American Water Works Association
BHMA	Builders Hardware Manufacturers Association
BIA	Brick Industry Association
CAN/ULC	Underwriters Laboratories of Canada
CBMA	Certified Ballast Manufacturers Association
CDOT	Colorado Department of Transportation
CDPHE	Colorado Department of Public Health and Environment
CFR	Code of Federal Regulations
CI	The Chlorine Institute
CISCA	Ceiling and Interior Systems Construction Association
CPPM	Capital Projects Procedures Manual
CPSC	Consumer Product Safety Commission
CRSI	Concrete Reinforcing Steel Institute
CSA	CSA Group
CWQCD	Colorado Water Quality Control Division
DIA	Denver International Airport
DOT	Department of Transportation
DW	Denver Water
EPA	Environmental Protection Agency
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FMG	FM Global
FS	Federal Specifications
FSC	Forest Stewardship Council
GA	Gypsum Association
G.E.	General Electric
GSA	General Services Administration
IAPMO-UES	International Association of Plumbing and Mechanical Officials – Uniform Evaluation Service
IBC	International Building Code
ICC-ES	International Code Council Evaluation Service, Inc.
ICEA	Insulated Cable Engineers Association

ICRI	International Concrete Repair Institute
IEEE	Institute of Electrical and Electronics Engineers, Inc.
IES	Illuminating Engineering Society of North America
IGMA	Insulating Glass Manufacturers Alliance
IMC	International Mechanical Code
IPC	International Plumbing Code
ISA	International Society of Automation
ISO	International Organization for Standardization
MHFD	Mile High Flood District
Mil. Spec.	Military Specification
MSS	Manufacturers Standardization Society
NAAMM	National Association of Architectural Metal Manufacturers
NACE	National Association of Corrosion Engineers
NAFS	North American Fenestration Standard
NCMA	National Concrete Masonry Association
NEC	National Electrical Code
NECA	National Electrical Contractors Association
NEMA	National Electrical Manufacturers Association
NETA	InterNational Electrical Testing Association
NFPA	National Fire Protection Association
NGA	National Glass Association with GANA
NICET	National Institute for Certification of Engineering
NIST	National Institute of Standards and Technology
NF	Française de Normalisation
NLGA	National Lumber Grades Authority
NOAA	National Oceanic and Atmospheric Administration
NPCA	National Precast Concrete Association
NPDES	National Pollutant Discharge Elimination System
NRCA	National Roofing Contractors Association
NRCS	National Resource Conservation Service
NRTL	Nationally Recognized Testing Laboratory
NSF	NSF International
OSHA	Occupational Safety and Health Administration
PCI	Precast/Prestressed Concrete Institute
RILEM	International Union of Laboratories and Experts in Construction Materials, Systems, and Structures
RIS	Redwood Inspection Service
SAE	SAE International
SDI	Steel Deck Institute
SJI	Steel Joist Institute
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SPIB	Southern Pine Inspection Bureau
SPRI	Single Ply Roofing Institute
SSPC	The Society for Protective Coatings
TCNA	Tile Council of North America
TMS	The Masonry Society
UBC	Uniform Building Code
UDFCD	Urban Drainage and Flood Control District
UL	Underwriters Laboratories, Inc.
WCLIB	West Coast Lumber Inspection Bureau
WDMA	Window and Door Manufacturers Association
WQCD	Water Quality Control Division
WWPA	Western Wood Products Association

General Abbreviations and Acronyms:

°C	Degrees Celsius
°F	Degrees Fahrenheit
ABS	Acrylonitrile Butadiene Styrene
AC	Alternating Current
ACQ	Alkaline Copper Quaternary
ADA	Americans with Disabilities Act
ADC	Amperes Direct Current

AHJ	Authority Having Jurisdiction
AMI	Advanced Metering Infrastructure
AMR	Automatic Meter Reading System; Automatic Reading System
ANS	Aquatic Nuisance Species
AO	Analog Output
ARMS	Arc Flash Reduction Maintenance System
AT	Acrylic-Tie
ATS	Acceptance Testing Specifications; Automatic Transfer Breaker Switch
AVR	Automatic Voltage Regulator
AWG	American Wire Gauge
B&B	Balled and Burlapped
BBU	Beam Bolster Upper
BF	Ballast Factor
BFPA	Backflow Prevention Assembly
BHN	Brinell Hardness Number
BIL	Basic Impulse Insulation Level
BSSTC	Bolted Split Sleeve Type Coupling
BSTC	Bolted Sleeve Type Coupling
Btu	British Thermal Unit
BUR	Buried
CAC	Ceiling Attenuation Class
CAT	Category
CBD	Complex Steel Building Structures
CBR	Major Steel Bridges
CCT	Correlated Color Temperature
CCTV	Closed Circuit Television
cf	Cubic Feet
CFC	Chlorofluorocarbon
cfm	Cubic Feet per Minute
CI	Cast Iron
CLCST	Cement-Lined Carbon Steel
CLDI	Cement-Lined Ductile Iron
CLS	Cost Loaded Schedule
CLSM	Cementitious Low Strength Material; Controlled Low Strength Material
cm	Centimeter
CM/GC	Construction Manager/General Contractor
CMAR	Construction Manager At Risk
CML	Cement Mortar Lining
CMU	Concrete Masonry Unit
CNA	Colorado Nursery Act
CO	Carbon Monoxide
CP	Carrier Pipe; Cathodic Protection
CPCS	Capital Projects Construction Standards
CPE	Chlorinated Polyethylene
CPM	Construction Project Manager; Critical Path Method
cps	Centipoise
CPU	Central Processing Unit
CPVC	Chlorinated Polyvinyl Chloride
CRF	Condensation Resistance Factor
CSE	Copper/Copper Sulfate Reference Electrode
CST-G	Carbon Steel – General Service
CT	Current Transformer
CTLA	Council of Tree and Landscape Appraisers
CWP	Cold Working Pressure
cy	Cubic Yard
dB	Decibel
DC	Direct Current; Double Check Valve
DCP	Distribution Control Panel
DFT	Dry Film Thickness
DI	Ductile Iron
DO	Dissolved Oxygen

DPDT	Double Pole Double Throw
dPF	Differential Pressure Filter
DR	Dimensional Ratio
dS	Decisiemens
DSL	Digital Subscriber Line
DW	Denver Water
EASE	Electronically Activated Streamer Emission
ECP	Environmental Control Panel
EDMS	Electronic Document Management System
EHH	Electrical Hand Hole
EHSP	Environmental Health and Safety Program
EI&C	Electrical, Instrumentation, and Control
EMI	Electromagnetic Interference
EMT	Electrical Metallic Conduit
EPDM	Ethylene Propylene Diene Monomer
EPO	Emergency Power Off
EPR	Ethylene Propylene Rubber
ER	Evaluation Report
ERT	Encoder-Receiver-Transmitter
ESA	Electrical Systems Analysis
ESAL	Equivalent Single Axle Load
ESD	Emergency Shut Down
ESR	Evaluation Service Report
EU	Electric Utility
EUH	Electric Unit Heater
EVT	Equiviscous Temperature
EXP	Exposed
fc	Foot-Candle
FCR	Frequency Correction Regulator
FDT	Factory Demonstration Test
FLA	Full Load Ampere
F’m	Compressive Strength of Masonry
FOB	Freight on Board
fpm	Feet per Minute
fps	Feet per Second; Foot per Second
FRP	Fiberglass Reinforced Plastic
ft	Feet; Foot
g	Grams
GBR	Geotechnical Baseline Report
GCP	Generator Control Panel
GFCT	Ground Fault Current Transformer
GICS	Generator Instrumentation and Control System
GP	Poorly Graded Gravel
gph	Gallons per Hour
gpm	Gallons per Minute
GPR	Ground Penetrating Radar
GPS	Global Positioning System; Generator Protection System
GTAW	Gas Tungsten Arc Welding
GUI	Graphical User Interface
GW	Well Graded Gravel
HBP	Hot Bituminous Pavement
HC	Hydrocarbon
HCl	Hydrochloric Acid
HDCLPE	High Density Cross Laminated Polyethylene Film
HDD	Horizontal Directional Drilling
HDG	Hot-Dipped Galvanized
HDPE	High Density Polyethylene
HID	High Intensity Discharge
HMI	Human Machine Interface
HMWPE	High Molecular Weight Polyethylene
hp	Horsepower

hr	Hour
HR	Hydrophilic Rubber
HVAC	Heating, Ventilating, and Air Conditioning
Hz	Hertz
I&C	Instrumentation and Controls
I/O	Inputs and Outputs
ICCP	Impressed Current Cathodic Protection
ID	Identification; Inside Diameter
IGBT	Insulated Gate Bipolar Transistors
IP	Iron Pipe
IPS	Iron Pipe Standard
in	Inch
IR	Current Resistance
K	Kelvin
kA	Kiloamperes
KAIC	Kiloamperes Interrupting Capacity
kg	Kilogram
KHz	Kilohertz
km	Kilometer
kN	Kilonewtons
ksi	Kips per Square Inch
kV	Kilovolt
kVA	Kilovolt-Amperes
kVAR	Kilovolt-Amperes Reactive
kW	Kilowatt
L	Liter
LA	Lightning Arrestor
lbf	Pound-Force per Square Foot
lbs	Pounds
LCD	Liquid Crystal Display
LCP	Local Control Panel
LED	Light Emitting Diodes
lf	Linear Feet; Linear Foot
LFMC	Liquid-Tight Flexible Metal Conduit
LLDPE	Linear Low Density Polyethylene
LS	Low Level Switch
LVDT	Linear Variable Differential Transformer
m	Meter
mA	Milliamperes
MARV	Minimum Average Roll Value
Mbps	Megabits per Second
MCC	Motor Control Center
MDFT	Minimum Dry Film Thickness
MDFTPC	Minimum Dry Film Thickness per Coat
MDI	Methylene Diphenyl Diisocyanate
MERV	Minimum Efficiency Reporting Value
MGS	Magnetic Guidance System
MHz	Megahertz
MIG	Metal Inert Gas
mil	Thousandth of an inch
MJ	Mechanical Joint
MLDT	Magneto-Restrictive Linear Displacement Transmitter
mm	Millimeter
MNPT	Male National Pipe Thread
MOC	Mechanism Operated Cell
MOV	Metal Oxide Varistor
MPR	Motor Protection Relay
MS	Material Specification
ms	millisecond
MSA	Mine Safety Appliance
MSDS	Material Safety Data Sheet

MTBF	Mean Time Between Failure
MTTR	Mean Time to Repair
MUTCD	Manual on Uniform Traffic Control Devices
mV	Millivolt
MVA	Megavolt Amperes
N	Nitrogen
NA	Numerical Aperture
NC	Normally Closed
NCR	Non-Conformance Report
NHT	National Hose Thread
No.	Number
NO	Normally Open
NOx	Nitrous Oxide
NPT	National Pipe Thread
NRC	Noise Reduction Coefficient
ns	Nanosecond
NST	National Standard Thread
OBD	Opposed Blade Damper
OD	Outside Diameter
ODP	Open Drip-Proof Enclosure
OEL	Over-Excitation Limiter
O&M	Operations and Maintenance
OCR	Optical Character Recognition
OPM	Optical Processor Module
OPS	Overcurrent Protection System
ORT	Operational Readiness Test
OTDR	Optical Time Domain Reflectometer
oz	Ounce
P2O5	Phosphate
P&ID	Process and Instrumentation Diagram
PA	Paint Application
PAT	Performance Acceptance Test
PAR	Parabolic Aluminized Reflector
PCB	Polychlorinated Biphenyl
PCC	Point of Common Coupling
PCCS	Piping Color Code Schedule
pcf	Pounds per Cubic Foot
PDS	Product Data Sheets
PE	Polyethylene
PEI	Pulse Endurance Index
perm-inch	permeability coefficient
pF	Pico Farad
PF	Power Factor
PFCC	Power Factor Correction Capacitor
PFM	Pulse Frequency Modulation
pH	Measure of the acidity or basicity of an aqueous solution
PI	Point of Intersection; Polarization Index
PLC	Programmable Logic Controller
PLS	Pure Live Seed
PLSS	Public Land Survey System
PMS	Pantone Matching System
PP	Polypropylene
PPDS	Paint Product Data Sheet
ppm	Parts per Million
PPT	Polypropylene Tubing
PRE	Permanent Reference Electrode
PRS	Pressure Regulating Stems
PS	Pressure Switch
PSDS	Paint System Data Sheet
psf	Pounds per Square Foot
psi	Pounds per Square Inch

psig	Pounds per Square Inch Gauge
PSW	Plastic Space Wheels
PT	Potential Transformer
PTFE	Polytetrafluoroethylene
PTI	Propiconazole Tebuconazole Imidacloprid
PU	Phone Utility
PV	Process Variable
PVB	Pressure Vacuum Breaker
PVC	Polyvinyl Chloride
PVC-T	Polyvinyl Chloride Tubing
PVDF	Polyvinylidene Fluoride
PWM	Pulse Width Modulation
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance and Quality Control
QP	Qualification Procedure
RAT	Reliability Acceptance Test
RE	Reynolds Number; Removability Modulus
RFI	Request for Information
RGS	Rigid Galvanized Steel
RMP	Risk Management Plan
rms	Root Mean Square
ROM	Read Only Memory
ROW	Right of Way
RP	Reduced Pressure Principle
rpm	Revolutions Per Minute
RPTFE	Reinforced Polytetrafluoroethylene
RTD	Resistance Temperature Detector
RTFE	Reinforced Tetrafluoroethylene
RTU	Remote Terminal Unit
S4S	Surfaced Four Sides
SAD	Silicon Avalanche Diode
SAL	Site Access Log
SAM	Seal-A-Matic
SBD	Conventional Steel Building Structures
SBR	Styrene Butadiene Rubber
SBS	Styrene Butadiene Styrene
SCADA	Supervisory Control and Data Acquisition
scfm	Standard Cubic Feet per Minute
SDL	Site Delivery Log
SDR	Standard Dimensional Ratio
SDS	Safety Data Sheet
SDT	Site Demonstration Test
sf	Square Feet; Square Foot
SF	Service Factor
sfpg	Square Feet per Gallon
sfpgpc	Square Feet per Gallon per Coat
SM	Silty Sand
SP	Surface Preparation; Poorly Graded Sand; Setpoint
SPD	Surge Protective Device
SPDT	Single-Pole, Double-Throw
SPM	Synchronous Motor Protection and Control
SPST	Single Pole Single Throw
sq	Square
SRW	Segmental Retaining Walls
SSD	Saturated Surface Dry
SSH	Safety Shower Eye/Face Wash
SST	Stainless Steel
STC	Sound Transmission Class
SUB	Submerged
SV	Setpoint Variable

SW	Well graded sand
SWMP	Stormwater Management Plan
SWP	Safe Working Pressure
sy	Square Yard
T	Thickness
TBD	To Be Determined
TDD	Total Demand Distortion
TEFC	Totally Enclosed, Fan Cooled Enclosure
TENV	Totally Enclosed, Non-Ventilated Enclosure
TFE	Tetrafluoroethylene (Teflon)
TGIC	Triglycidyl Isocyanurate
THD	Total Harmonic Distortion
TOC	Truck Operated Cell
TPE-R	Thermoplastic Elastomeric Rubber
TPST	Triple Pole Single Throw
TS	High Temperature Switch
TSCA	Toxic Substances Control Act
TVSS	Transient Voltage Surge Suppressors
TX	Transformer
UC2	Use Category 2
UC3B	Use Category 3B
UC4A	Use Category 4A
UC4B	Use Category 4B
UC4C	Use Category 4C
UCFA	Use Category FA
UCFB	Use Category FB
UEL	Under-Excitation Limiter
UFT	Unwitnessed Factory Test
UPS	Uninterruptible Power Supply
U.S.	United States
UTA	Universal Termination Assemblies
UV	Ultraviolet
V	Volt
VA	Volt Amperes
VAC	Volts Alternating Current
VDC	Volts Direct Current
VFD	Variable Frequency Drive
VLF	Very Low Frequency
VOC	Volatile Organic Compound
VPP	Volts Peak-to-Peak
W	Watt
WBS	Work Breakdown Structure
WC	Water Column
w/cm	Water/Cementitious Material Ratio
WOG	Water-Oil-Gas
WPI	Open Weather Protected Enclosure, Type I
WPII	Open Weather Protected Enclosure, Type II
WT shapes	Wide Flange Tee
XLP	Crosslinked Polyethylene

SECTION 23 05 00
COMMON WORK RESULTS FOR MECHANICAL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for common work results for mechanical.

B. Related Sections:

1. SECTION 01 40 00 – QUALITY REQUIREMENTS
2. SECTION 01 77 00 – CLOSEOUT PROCEDURES

1.2 REFERENCES

A. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE):

1. 15 & 34 – Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants

B. American Society of Mechanical Engineers (ASME):

1. B31.1 – Power Piping
2. Boiler and Pressure Vessel Code, Section IX – Welding and Brazing Qualifications

C. American Welding Society (AWS):

1. Welding Handbook

D. National Fire Protection Association (NFPA):

1. 90A – Standard for the Installation of Air-Conditioning and Ventilating Systems

1.3 SUBMITTALS

A. Administrative:

1. Complete itemized Bill of Material describing components and their interface with other disciplines. Reference Supplement A.
2. Submittals required in individual Plumbing Specification Sections.
3. Report to the ENGINEER Submittal review comments in written format and include original review comment. Provide documentation with responses in the resubmittal or as a supplemental information document on Submittal dispositions of Final for Construction or Final for Construction as Corrected.
4. Include the complete Manufacturer's descriptive information and Shop Drawings for equipment, material, and devices, including certified outline drawings, arrangement drawings, and dimensional layout drawings.
5. Equipment, models, options, extraneous text, etc. not being furnished and that do not apply shall be neatly crossed out.
6. Use Contract Document equipment and device labels, tags, and identification in Submittals.

B. Quality Control Submittals:

1. Provide welder's certificates, three copies of the welder qualifications, and welding procedures.
2. Provide information on the millwright's qualifications, certifications, and applicable experience.

C. Contract Closeout Submittals: Provide Record Documents as specified in SECTION 01 77 00.

D. Warranty Documentation:

1. Sample warranty.
2. Warranty.

1.4 QUALITY ASSURANCE

A. Welding Qualifications and Requirements:

1. A minimum of 5 years of documented experience in the Work of this Section.
2. Approved by the Manufacturer.
3. Qualified in accordance with ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications.
4. Welding procedures and testing: In accordance with ASME B31.1.0 and the AWS Welding Handbook.
5. Soldering and brazing procedures: In accordance with ASHRAE 15 & 34.
6. Pipe identification: Mark on the pipe, including size, ASTM material, class, ASTM specification, and pressure rating.

B. Regulatory Requirements: In accordance with NFPA 90A.

C. Provide QC as specified in SECTION 01 40 00.

D. Comply with qualification requirements.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Provide proper storage of materials and equipment and assume complete responsibility for losses. Follow the Manufacturer's instructions for storage.

B. Store equipment and materials out of the elements.

C. An item rusted from exposure to the elements shall not be used in the Work.

1.6 SITE CONDITIONS

A. Examine site and staging areas. Become familiar with existing local conditions affecting Work, such as access, obstructions, altitude, weather conditions, necessary cutting, and excavating or filling. Allowances will not be made for reasons of misunderstanding with respect to existing site conditions.

B. Furnish scaffolding, rigging, hoisting, and services necessary for the erection and delivery of equipment and apparatus into the premises, and remove items when they are no longer required.

C. Quiet Operation:

1. Equipment shall operate under the conditions of loading without objectionable sound or vibration as determined by the ENGINEER.

2. In the case of moving machinery, sound or vibration that is noticeable inside of an occupied space or excessive noise or vibration inside the equipment room will be considered objectionable and require correction at no additional cost to the OWNER.

D. Accessibility:
1. Sufficiently size shafts and chases for adequate clearance and proper installation of Work.
2. Cooperate with the CONTRACTOR and the Subcontractors whose Work is in the same space, and advise the CONTRACTOR of requirements. Such spaces and clearances shall be to the size required.
3. Locate equipment that needs to be serviced, operated, or maintained in fully accessible positions. If required for accessibility, furnish access doors, etc. for this purpose. Minor accessibility and any changes for accessibility shall be approved by the ENGINEER prior to making the change.
4. Provide the CONTRACTOR with exact locations of access panels for each concealed valve, control damper, or other device requiring service. Locations of access panels shall be submitted in sufficient time to be installed in the normal course of Work.

E. Altitude Correction:
1. The air moving equipment operating altitude shall be as shown on the Drawings.
2. The Manufacturer and Supplier shall make necessary adjustments to deliver the specified cfm and furnish the sheaves or motors required to produce the specified capacities at the operating altitude at no additional cost to the OWNER.

1.7 WARRANTY

A. Unless stipulated otherwise in individual specification sections, the warranty shall be for 1 year from the Substantial Completion date for the satisfactory performance and installation of the mechanical system and associated appurtenances.

B. Provide a warranty to repair or replace, at no cost to the OWNER, any part of the apparatus that may show defects during the warranty period, provided such defects are due to imperfect material or workmanship and not due to carelessness or improper use in the opinion of the OWNER.

C. Provide longer periods of warranty where it is customary for the piece of equipment or the system installed. If the Manufacturer’s warranty is longer than 1 year, it shall be used. Provide copies of the warranty to the OWNER.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 INSTALLATION

A. Workmanship:
1. Workmanship shall be first-rate. The finished appearance of mechanical Work is as important as the mechanical efficiency.
2. Perform Work in accordance with good commercial practices.
3. Install materials in accordance with the Manufacturer’s instructions and applicable governing codes.

B. Rough-In:
1. Field verify final locations for rough-ins with the requirements of actual equipment to be connected.
2. Include rough-in requirements in equipment criteria in the technical sections of manuals.

C. Clearance from Electrical Equipment:
1. Provide clearance above equipment and do not locate mechanical equipment or piping within 3 feet of the following:
   a. Transformers.
   b. Equipment control panels and disconnects.
   c. Switchgear.
   d. Switchboards.
   e. GCPs.
   f. Battery system equipment.
   g. MCCs.
   h. Standby power plant.
   i. Motors, except for branch piping to driven equipment.
2. Provide working clearances in accordance with the NEC for electrical panels, controllers, MCCs, disconnects, and similar equipment that can be opened to expose energized parts.
3. Configure, route, and locate piping, ductwork, equipment, and auxiliary items installed to maintain the required clearances.

D. Supervision: The mechanical foreman or superintendent shall be responsible for the Work of their Subcontractors and have questions or directions routed through them.

E. Preparation:
1. The ends of pipes and tubes shall be reamed to remove burrs; the plain ends of steel pipe shall be beveled.
2. Scale, slag, dirt, and debris shall be removed from the inside and the outside of piping and fittings before assembly.

F. Sequence, coordinate, and integrate the various elements of mechanical systems, materials, and equipment. Comply with the following requirements:
1. Coordinate mechanical systems and material installation with other building components and systems.
2. Coordinate interface between mechanical and electrical Work before submitting equipment for review or beginning installation.
3. Field verify dimensions.
4. Coordinate installation during the construction of required support devices and sleeves that are to be cut into concrete and other structural components.

5. Maintain an efficient flow of Work during installations of mechanical materials and equipment.
6. Where mounting heights are not specifically detailed or dimensioned, install systems, materials, and equipment to provide the maximum headroom possible.
7. Coordinate the connection of mechanical systems with underground utilities and services.
8. Systems, materials, and equipment installation shall be in accordance with the approved Submittal data to the greatest extent possible. Conform to arrangements shown on the Drawings recognizing that portions of Work are shown only in diagrammatic form. Where coordination requirements conflict with individual system requirements, request clarification from the ENGINEER.
9. Where exposed in finished spaces, install systems, materials, and equipment level and plumb, and parallel and perpendicular to other building systems and components.

G. Pipe Installation:
1. The Drawings show the general location and arrangement of the piping systems. The location and arrangement of piping layout shall take into consideration pipe sizing and friction loss, expansion, pump sizing, and other design considerations.
2. Installed piping shall be free of sags or bends. There shall be ample space between piping to permit proper insulation applications.
3. Piping shall be installed in shoes, and guides mounted tight to support steel, beams, joists, columns, walls, and other permanent elements of the structure.

H. Fittings and Specialties:
1. Fittings are required for changes in direction and branch connections.
2. New materials shall be furnished for remaking leaking joints.
3. Unions are required adjacent to each control valve, at the final connection to each piece of equipment and plumbing fixture having 2 inch and smaller connections, and elsewhere as dictated by good practice.
4. Flanges are required in 2 1/2 inch and larger pipe, where required, adjacent to each valve, and at the final connection to each piece of equipment.

I. Cutting and Patching:
1. During cutting and patching operations, the protection of adjacent installations shall be required.
2. Cutting, fitting, and patching of mechanical equipment and materials shall be required to:
   a. Uncover Work to provide for the installation of Work.
   b. Remove and replace defective Work.
   c. Remove and replace Work that fails to conform to the requirements of the Contract Documents.
   d. Uncover and restore Work to provide for observation of concealed Work upon written instructions from the ENGINEER.

3.2 STARTUP

A. Commissioning: Complete Work and ensure systems are in proper working order and placed in operation.

3.3 CLEANING

A. Clean equipment and remove debris and construction materials from the premises.

3.4 SUPPLEMENTS

A. Supplement A – Example Bill of Material

END OF SECTION

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SUPPLEMENT A – EXAMPLE BILL OF MATERIAL

Administration Building HVAC

Contract #: --

Submittal #: --

Equipment/ Specification:	Item	Qty.	Description	Manufacturer	Complete Manufacturer Part No. (with options):	DW Device Abbrev/Tag

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SECTION 23 05 19
METERS AND GAUGES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for meters and gauges.

B. Related Sections:

1. SECTION 01 33 00 – SUBMITTAL PROCEDURES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):

1. B40.1 – Pressure Gauges and Gauge Attachments

1.3 SUBMITTALS

A. Meet Submittal requirements specified in SECTION 01 33 00.

B. Product Data: Submit the Manufacturer's technical product data, including installation instructions for each type of meter and gauge. Include scale range, ratings, and calibrated performance curves, certified where indicated. Submit a meter and gauge schedule showing the Manufacturer's figure number, scale range, location, and accessories for each.

C. Flow measuring devices to be provided shall be reviewed and approved by the Test and Balance Subcontractor and the Temperature Control Subcontractor for proper scale, rangeability and function prior to submitting Shop Drawings. The Test and Balance CONTRACTOR and the Temperature Control Subcontractor shall provide a typed letter stating this review has been completed and include it with Shop Drawing Submittals.

D. Maintenance Data: Submit maintenance data and spare parts lists for each type of meter and gauge. Include this data and product data in the maintenance manual; as specified in SECTION 01 78 23.

1.4 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in the manufacture of meters and gauges, of the types and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

B. Codes and Standards:

1. ANSI compliance: Comply with applicable portions of ANSI standards pertaining to construction and installation of meters and gauges.
2. Certification: Provide meters and gauges whose accuracies, under specified operating conditions, are certified by the Manufacturer.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Glass Thermometers:

1. Ernst Gauge Co.
2. Marshalltown Instruments, Inc.
3. Miljoco Corp.
4. Weiss Instruments, Inc.
5. Dwyer
6. Trerice

B. Temperature Gauge Connector Plugs:

1. Fairfax Company
2. Peterson Equipment Co.
3. Universal Lancaster
4. Sisco
5. MG Piping Products Co.
6. Trerice

C. Pressure Gauges:

1. Ametek/U.S. Gauge
2. Marsh Instrument Co.; Unit of General Signal
3. Marshalltown Instruments, Inc.
4. Miljoco Corp.
5. Weiss Instruments, Inc.
6. MG Piping Products Co.
7. Dwyer
8. Trerice

D. Pressure Gauge Connector Plugs:

1. Fairfax Company
2. Peterson Equipment Co.
3. Universal Lancaster
4. Sisco
5. MG Piping Products Co.
6. Miljoco Corp.
7. Trerice

E. Calibrated Balancing Valves:

1. Bell & Gossett ITT; Fluid Handling Division
2. Flowset – Flow Design, Inc.
3. Thrush Products, Inc.

4. Tour and Anderson, Inc.
5. Gerand Balvalve Indicator
6. Griswold
7. Preso

2.2 MATERIALS

A. Glass Thermometers:
1. General: Provide glass thermometers of the materials, capacities, and ranges indicated, designed and constructed for use in the service indicated.
2. Case: Die cast aluminum finished in baked epoxy enamel, glass front, spring secured, 9 inches long.
3. Adjustable joint: Die cast aluminum, finished to match case, 180-degree adjustment in vertical plane, 360-degree adjustment in horizontal plane, with locking device.
4. Tube and capillary: Non-toxic spirit filled, 1% scale range accuracy, shock-mounted.
5. Scale: Satin faced, non-reflective aluminum, permanently etched markings.
6. Stem: Copper-plated steel, or brass, for separable socket, length to suit installation.
7. Range: Conform to the following:
   a. Hot Water: 30°F to 240°F with 2°F scale divisions.

B. Thermometer Wells: Provide thermometer wells constructed of brass or SST, pressure rated to match piping system design pressure. Provide a 2-inch extension for insulated piping. Provide cap nut with chain fastened permanently to thermometer well.

C. Temperature Gauge Connector Plugs: Provide temperature gauge connector plugs pressure rated for 500 psi and 200°F. Construct of brass and finish in nickel-plate, equip with 1/2 inch nominal pipe size fitting, with self-sealing valve core type neoprene gasketed orifice suitable for inserting 1/8 inch OD probe assembly from dial type insertion thermometer. Equip orifice with gasketed screw cap and chain. Provide extension, length equal to insulation thickness, for insulated piping.

D. Pressure Gauges:
1. General: Provide pressure gauges of the materials, capacities, and ranges indicated, designed and constructed for use in the service indicated.
2. Type: General use, 1% accuracy, in accordance with ANSI B40.1 Grade A, phospher bronze bourdon type, bottom connection.
3. Case: SST, drawn steel, or brass, glass lens, 4 1/2 inch diameter.
4. Connector: Brass with 1/4 inch male NPT. Provide protective syphon when used for steam service.
5. Scale: White coated aluminum, with permanently etched markings.
6. Range:
   a. Vacuum: 30 inch Hg (mercury) – 15 psi.
   b. Water: Between 0 psi and 100 psi.
   c. Steam: Between 0 psi and 200 psi.

E. Pressure Gauge Cocks:
1. General: Provide pressure gauge cocks between pressure gauges and gauge tees on piping systems. Construct gauge cock of brass with 1/4 inch female NPT on each end, and T-handle brass plug.
2. Syphon: 1/4 inch straight coil constructed of brass tubing with 1/4 inch male NPT on each end.
3. Snubber: 1/4 inch brass bushing with corrosion resistant porous metal disc, through which pressure fluid is filtered. Select disc material for fluid served and pressure rating.

F. Pressure Gauge Connector Plugs: Provide pressure gauge connector plugs pressure rated for 500 psi and 200°F. Construct of brass and finish in nickel-plate equip with 1/2 inch nominal pipe size fitting, with self-sealing valve core type neoprene gasketed orifice suitable for inserting 1/8 inch OD probe assembly from dial type insertion pressure gauge. Equip orifice with gasketed screw cap and chain. Provide extension, length equal to insulation thickness, for insulated piping.

G. Calibrated Balancing Valves:
1. General: Provide as indicated, calibrated balance valves equipped with readout valves to facilitate connecting of differential pressure meter to balance valves. Provide with locking handle. Equip each readout valve with integral EPT check valve designed to minimize system fluid loss during monitoring process. Provide calibrated nameplate to indicated degree of closure of precision machined orifice. Construct balancing valve with internal EPT O-ring seals to prevent leakage around rotating element. Provide balance valves with preformed polyurethane insulation suitable for use on heating and cooling systems, and to protect balance valves during shipment.
2. The Balancing Valve Manufacturer shall select valve sizes to provide meter readings between 7 inch and 25 inch water gauge at rated gpm.

PART 3 EXECUTION

3.1 GENERAL

A. Inspection: Examine areas and conditions under which meters and gauges are to be installed. Do not proceed with Work until unsatisfactory conditions have been corrected in a manner of acceptable to the ENGINEER.

B. Installation:
1. Temperature gauges:
   a. Install in vertical upright position and tilted to be easily read by an observer standing on the floor.
   b. Install at the inlet and outlet of each hydronic coil in air handling units, built-up central systems, and elsewhere as indicated.
2. Temperature gauge connector plugs: Install in piping tee where indicated, located on the pipe at the most readable position. Secure cap. Provide portable temperature gauge for each plug connection.

3. Pressure gauges:
    a. Install in the piping tee with pressure gauge cock, located on the pipe at the most readable position.
    b. Install at the suction and discharge of each hydronic coil in air handling units, and elsewhere as indicated:
    c. Cocks: Install in the piping tee with snubber. Install syphon for steam pressure gauges.
    d. Connector plugs: Install in the piping tee where indicated, located on the pipe at the most readable position. Secure cap. Provide portable pressure gauge for each plug connection.
    e. Shall have coil syphon and isolation gauge cock, snubber valve, to service the gauge and isolate it from the pipe system service without having to drain the piping system.

3.2 ADJUSTING

A. Adjust faces of meters and gauges to the proper angle for the best visibility.

3.3 CLEANING

A. Clean windows of meters and gauges and factory-finished surfaces. Replace cracked or broken windows, repair any scratched or marred surfaces with the Manufacturer's touch-up paint.

END OF SECTION

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SECTION 23 05 53
MECHANICAL IDENTIFICATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products and execution for mechanical identification.

B. Related Sections:

1. SECTION 01 33 00 – SUBMITTAL PROCEDURES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA

1.2 REFERENCES

A. American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME):

1. A13.1 – Scheme for the Identification of Piping Systems

1.3 SUBMITTALS

A. Meet Submittal requirements specified in SECTION 01 33 00.

B. Product Data: Submit the Manufacturer's technical product data and installation instructions for each identification material and device required.

C. Schedules: Submit a valve schedule for each piping system, typewritten and reproduced on 8 1/2 inch by 11 inch bond paper. Tabulate valve number, piping system, system abbreviation (as shown on tag), location of valve (room or space), size of valve, and variations for identification (if any). Only tag valves which are intended for emergency shutoff and similar special uses, such as valve to isolate individual system risers, individual floor branches, or building system shut-off valves. Include in O&M manuals as specified in SECTION 01 78 23.

1.4 QUALITY ASSURANCE

A. Manufacturer's Qualifications: Firms regularly engaged in the Manufacturer of identification devices of types and sizes required, whose products have been in satisfactory use in similar service for not less than 5 years.

B. Codes and Standards:

1. Existing Building Standards: In accordance with the existing lettering size, length of color field, colors and identification method as presently exists in the existing building unless otherwise indicated.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Brady (W.H.) Co.; Signmark Division

B. Brimar Industries, Inc.

C. Industrial Safety Supply Co., Inc.

D. Seton Name Plate Corp.

E. Holbi

2.2 MATERIALS

A. Mechanical Identification Materials: Provide the Manufacturer's standard products of the categories and types required for each application. Where more than single type is specified for application, selection is the Installer's option, but provide single selection for each product category.

B. Plastic Pipe Markers:

1. For piping located on the roof, markers shall be rated for exterior use and constructed of a UV-resistant material.
2. Snap-on type: Provide the Manufacturer's standard pre-printed, semi-rigid snap-on, color-coded pipe markers, in accordance with ANSI/ASME A13.1.
3. Insulation: Furnish 1 inch thick molded fiberglass insulation with jacket for each plastic pipe marker to be installed on uninsulated pipes subjected to fluid temperatures of 125°F or greater. Cut length to extend 2 inches beyond each end of plastic pipe marker.
4. Small pipes: For external diameters less than 6 inches (including insulation if any), provide full-band pipe markers, extending 360 degrees around pipe at each location, fastened by one of the following methods:
   a. Snap-on application of pre-tensioned semi-rigid plastic pipe marker.
   b. Taped to pipe, or insulation, with color-coded plastic adhesive tape, not less than 3/4 inch wide; full circle at both ends of pipe marker, tape lapped 1 1/2 inch.
5. Lettering: In accordance with piping system nomenclature as specified, scheduled, shown, or to match existing building lettering nomenclature system and abbreviate only as necessary for each application length.
6. Arrows: Print each pipe marker with arrows indicating direction of flow, either integrally with piping system service lettering, to accommodate both directions, or as separate unit of plastic.

C. Valve Tags:

1. SST tags: Furnish a 16 gauge SST identification plate securely mounted on each valve. Plate shall bear 1/4 inch high engraved block type black enamel filled equipment identification number and letters as indicated on the Drawings.
2. Valve tag fasteners: Provide the Manufacturer's standard SST chain, wire link or beaded type, and solid brass S-hooks of the sizes required for proper attachment of tags to valves, and manufactured specifically for that purpose.

D. Valve Schedule:

1. Printed on company letterhead and shall include the following columns:
   a. Valve tag number: E.g., HWS-1.
   b. Service: E.g., ISOLATE AHU-1 HEATING COIL.
   c. Room number: Location of valve.
   d. Size of valve.
   e. Type of valve.
   f. Normal position of the valve: Open or closed.

2. Provide a three-ring binder with project information labeled on the outside for containment of the valve tag schedule.

PART 3 EXECUTION

3.1 GENERAL

A. Coordination: Where identification is to be applied to surfaces which require insulation, painting, or other covering or finish, including valve tags in finished mechanical spaces, install identification after completion of covering and painting. Install identification prior to installation of acoustical ceilings and similar removable concealment.

B. Piping system identification:
1. Application: New piping that is installed and existing piping that currently contains identification will need identification.
2. General: Install pipe markers of the following type on each system indicated to receive identification, and include arrows to show normal direction of flow. Existing building identification shall match the existing method which exists in the building.
3. Plastic pipe markers, with application system as indicated in this Section. Install on pipe insulation segment where required for hot non-insulated pipes.
4. Near each branch, excluding short take-offs for fixtures and terminal units; mark each pipe at branch, where there could be question of flow pattern.
5. Near locations where pipes pass through walls or floors/ceilings, or enter non-accessible enclosures.
6. At access doors, manholes, and similar access points which permit view of concealed piping.
7. Near major equipment items and other points of origination and termination.
8. Spaced intermediately at maximum spacing of 25 feet along each piping run, except reduce spacing to 15 feet in congested areas of piping and equipment.
9. On piping above removable acoustical ceilings.

C. Valve Identification:
1. Provide valve tag on valves in each piping system. List each tagged valve in the valve schedule for each piping system.
   a. Each individual system major branch shutoff valves.
2. Provide the following columns and information for each valve:
   a. Valve tag number: E.g., HWS-1.
   b. Service: E.g., ISOLATE AHU-1 HEATING COIL.
   c. Room number: Location of valve.
   d. Size of valve.
   e. Type of valve.
   f. Normal position of the valve: Open or closed.
3. Mount valve schedule frames and schedules in mechanical equipment rooms where directed by the OWNER.
4. Where more than one major mechanical equipment room is shown for the Project, install a mounted valve schedule in each major mechanical equipment room, and repeat only main valves which are to be operated in conjunction with operations of more than a single mechanical equipment room.

3.2 ADJUSTING

A. Adjusting: Relocate any mechanical identification device which has become visually blocked by Work of this or other divisions.

3.3 CLEANING

A. Clean face of identification devices and glass frames of valve charts.

END OF SECTION

SECTION 23 05 93
HVAC SYSTEMS TESTING, ADJUSTING, AND BALANCING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for HVAC systems testing, adjusting, and balancing.

1.2 REFERENCES

A. Air Movement and Control Association International (AMCA):
   1. 203 – Field Performance Measurement of Fan Systems

B. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):
   1. HVAC Systems Testing, Adjusting, & Balancing

1.3 SUBMITTALS

A. Quality Control Submittals:
   1. Provide the qualifications and experience record of the air balancing and test agency.
   2. Provide verification of the calibration of testing and balancing equipment.
   3. Provide a balancing log report following completion of system adjustments including test results, adjustments, and rebalancing procedures.
   4. Recommend to the ENGINEER dampers that need to be added or replaced to obtain proper air control.

1.4 QUALITY ASSURANCE

A. Provide a qualified Professional Engineer registered in the State of Colorado or firm specializing in testing and balancing to adjust and balance the system.

B. Air Balancing and Test Agency Qualifications:
   1. A corporately and financially independent organization functioning as an unbiased testing authority.
   2. Professionally independent of Manufacturers, Suppliers, and Installers of the HVAC equipment being tested.
   3. Certified by a national balancing association.
   4. Have a proven record of at least 5 similar projects.
   5. An employer of engineers and technicians regularly engaged in testing and inspecting HVAC equipment and systems.
   6. Approved test agencies:
      a. Air-Right, Inc.
      b. TAB Services, Inc.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 GENERAL

A. Calibrate test instruments to a recognized standard before beginning the Work.

B. Adjust and balance the systems in accordance with SMACNA's HVAC Testing, Adjusting, and Balancing Manual.

3.2 QUALITY CONTROL

A. Adjusting and Balancing Air Side:
   1. Measure fan system performance in accordance with AMCA 203.
   2. In each system, test the system for both opened access hatches/manholes and closed access hatches/manholes.
   3. Adjust fan air volumes, if not constant speed and direct drive:
      a. Adjust fan speeds and motor drives for required equipment air volumes. Allowable variation: +10%, -0%.
      b. After final adjustments, do not operate the motor above the nameplate amperage on any phase.
      c. Provide and make drive and belt changes on motors or fans as required to adjust equipment to the specified conditions. Provide notice to the Air Handling Unit Manufacturer and the ENGINEER if a drive or a belt change was made.
   4. Read and record static pressures at unit inlet and discharge, filters, coils, dampers, on supply duct, return duct, and exhaust fan. Record the operating point on each fan curve.
   5. Airflow adjustments:
      a. Correct fan and airflow adjustments for the Work site elevation.
      b. Final adjustments:
         1) Mark final positions of balancing dampers with a red felt pen.
         2) When adjustments are made to a portion of the fan system, reread other portions of that same system to determine the effects imposed by the adjustments.

B. EHHs: Measure forced air performance and heater output; compare to the Manufacturer's stated performance outputs.

C. Balancing Log Report Requirements:
   1. Log and record information from every test, reading, and adjustment necessary to accomplish the services described. In addition, record the following:
      a. Equipment identification number.
      b. Equipment nameplate data including the Manufacturer, model, size, type, and serial number.
      c. Motor data (frame, hp, V, FLA, and rpm).
      d. Starter and heater data.
   2. Include an 11 inch by 17 inch set of drawings in the balance log showing the final flow readings for each system.
   3. Indicate the recorded Work site values and the velocity and mass correction factors used to provide equivalent standard air quantities.

4. Include a separate section in the log, if necessary, that describes operating difficulties in the systems that could not be eliminated by the specified procedures. Identify problems by system and location. Include an outline of a summary of the condition and its effect on the system, and describe corrective actions attempted.
5. After readjustment for vibration, measure and record the displacement only of the readjusted equipment to determine its conformance with the design.

D. Quality Control Verification: After adjustments are completed and balance logs submitted, the balancing and testing agency shall be available to demonstrate the air and water balancing procedures and vibration tests and verify the test results.
1. Perform spot tests on a maximum of 20% of the air and 20% of the water balance points, with measuring equipment used in the original tests, at random points selected by the ENGINEER.
2. Results of spot tests shall agree with the balance logs within ±10%. Where this accuracy cannot be verified, rebalance portions of the system as requested by the ENGINEER.
3. At completion of the rebalance procedures, perform another spot test to verify results.

END OF SECTION

SECTION 23 07 00
MECHANICAL INSULATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for mechanical insulation.

1.2 REFERENCES

A. ASTM International (ASTM):
   1. C 423 – Standard Test Method for Sound Absorption and Sound Absorption Coefficients by the Reverberation Room Method
   2. C 518 – Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
   3. C 533 – Standard Specification for Calcium Silicate Block and Pipe Thermal Insulation
   4. C 553 – Standard Specification for Mineral Fiber Blanket Thermal Insulation for Commercial and Industrial Applications
   5. C 665 – Standard Specification for Mineral-Fiber Blanket Thermal Insulation for Light Frame Construction and Manufactured Housing
   6. C 1071 – Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
   7. C 1338 – Standard Test Method for Determining Fungi Resistance of Insulation Materials and Facings
   8. D 1784 – Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
   9. E 84 – Standard Test Method for Surface Burning Characteristics of Building Materials

B. National Fire Protection Association (NFPA):
   1. 90A – Installation of Air Conditioning and Ventilating Systems
   2. 90B – Standard for the Installation of Warm Air Heating and Air-Conditioning Systems

C. North American Insulation Manufacturer's Association (NAIMA):
   1. Fibrous Duct Wrap Standard
   2. Fibrous Glass Duct Liner Standard
   3. Fibrous Glass Insulation Boards Standard
   4. Materials Standards

D. Underwriter's Laboratories (UL):
   1. 181 – Factory-Made Air Ducts and Connectors
   2. 723 – Tests for Surface Burning Characteristics of Building Materials

1.3 DEFINITIONS

A. Concealed: Ductwork in ceiling plenums, pipe and duct shafts, heated and unheated spaces.

B. Exposed: Ductwork visible inside the building.

C. Exterior: Ductwork in areas outdoors exposed to weather.

1.4 COORDINATION

A. Coordinate clearance requirements with the Piping Installer for piping insulation application, the Duct Installer for duct insulation application, and the Equipment Installer for equipment insulation application. Before preparing piping and ductwork Shop Drawings, establish and maintain clearance requirements for installation of insulation and field-applied jackets and finishes and for space required for maintenance.

1.5 SEQUENCING AND SCHEDULING

A. Schedule insulation application after pressure testing systems where required. Insulation application may begin on segments that have satisfactory test results.

1.6 SUBMITTALS

A. Product Data: Manufacturer's technical product data and installation instructions for each type of mechanical insulation. Information shall be provided in the form of a schedule that shall indicate the Manufacturer's product number, K value, thickness, and furnished accessories for each mechanical system requiring insulation.

1.7 QUALITY ASSURANCE

A. System Description:
   1. The following systems, equipment, and accessories shall be insulated, except where noted.
      a. Ductwork: HVAC supply and outside air ductwork.
      b. Piping: In accordance with the insulation schedule.

B. Fire-Test-Response Characteristics: Insulation and related materials shall have fire-test-response characteristics shown on the Drawings, as determined by testing identical products in accordance with ASTM E 84, and by a testing and inspecting agency acceptable to the AHJ. Factory label insulation and jacket materials and adhesive, mastic, tapes, and cement material containers, with appropriate markings of applicable testing and inspecting agency.
   1. Insulation installed indoors: Flame-spread index of 25 or less; smoke-developed index of 50 or less.
   2. Insulation installed outdoors: Flame-spread index of 75 or less; smoke-developed index of 150 or less.

1.8 DELIVERY, STORAGE, AND HANDLING

A. Storage and Protection: Protect insulation against dirt, water, chemical, or mechanical damage before, during, and after installation. Any such insulation or covering damaged prior to final acceptance of the work shall be satisfactorily repaired or replaced.

B. Packaging: Insulation material containers shall be marked by the Manufacturer with the appropriate ASTM standard designation, type and grade, and maximum use temperature.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Pipe Insulation:

1. Piping:
   a. Manville, Micro-Lok 650 with AP-T jacket
   b. Owens-Corning, Fiberglass ASJ/SSL-11
2. Calcium Silicate:
   a. Johns Mansville, Thermo-12 Gold
   b. Promat, Promasil-1000
   c. Thermal Pipe Shields, TPSX-12
3. Fittings covers:
   a. Childers
   b. Papco
   c. Speedline
   d. Zeston

B. Rectangular Duct Liner, Specification L:

1. CertainTeed, ToughGard
2. Johns Manville, Permacote Linacoustic
3. Knauf, Type E-M
4. Owens-Corning, Aeroflex

C. Sealant:

1. Superseal HV Sealant

2.2 MATERIALS

A. Pipe Insulation:

1. Piping:
   a. Insulate as shown on the pipe insulation schedule, with fiberglass insulation wrapped with factory-applied, kraft reinforced vapor barrier jacket with pressure-sensitive, self-sealing lap, UL rated. Cover insulated piping with field-applied PVC jacketing. Secure cover and wrap throat and seams with matching PVC tape.
   b. Circumferential joints: Seal with matching pressure-sensitive butt strips.
   c. PVC jackets: ASTM D 1784, minimum 10 mil thick, and factory pre-molded PVC fitting covers, UV-resistant, gloss white finish.
2. High heat piping:
   a. For temperatures over 200°F, including sections of compressed air discharge, water heater vents, generator exhaust, etc. Also, for underneath pipe hangars and saddles.
   b. Calcium silicate, ASTM C 533, Type 1, 1,200 degree rating,
   c. Kraft vapor barrier and aluminum jacket.
   d. Thickness: 1 1/2 inches for piping that is 3 inches in diameter or less; 2 1/2 inches for piping that is greater than 3 inches in diameter.
3. Fittings:
   a. Insulate with premolded insulation or mitered segments, wired in place, and finished with a thin coat of insulating cement, or wrapped with soft fiberglass insulation inserts. Cover fittings with premolded PVC fitting covers.
   b. Secure cover and wrap throat and seams with matching PVC tape.
4. Inserts:
   a. Provide at each pipe hanger or support installed between piping and hanger or support.
   b. Inserts shall consist of preformed rigid pipe insulation of thickness equal to adjoining insulation.
   c. Length: 12 inches and shall include vapor barrier.
5. Piping and insulation cover for outdoor piping:
   a. 0.020 inch thick aluminum jacket.
   b. Finish: Corrugated.
   c. Hold jacket in place by a continuous friction type joint, providing a positive weatherproof seal over entire length of jacket. Seams shall be on the bottom of the pipe or on the off-weather side of the pipe.
   d. Secure circumferential joints with preformed snap straps containing weatherproof sealant.
   e. Fittings covers: Matching preformed aluminum jackets, two-piece elbows and flange covers, secured with SST bands:
6. Insulation schedule:

Description	Pipe Size	Insulation Thickness	
		Indoor	Outdoor
Refrigerant Piping	All	N/A	1 inch
Condensate Drain Piping	All	N/A	1 inch
Compressed Air Piping	All	1 inch	N/A

B. Duct Liner:
1. General:
a. Duct liner shall be in accordance with NFPA 90A, NFPA 90B, UL 181 Class 1, ASTM C 1071, and NAIMA, Materials Standards; Type 200, flame spread 25 maximum and smoke development 50 maximum.
b. Duct liner shall not absorb more than 1% moisture when tested in accordance with ASTM C 553.
c. Duct liner shall not cause corrosion of duct material (aluminum or galvanized steel) when tested in accordance with ASTM C 665.
d. Duct liner shall not breed or promote growth of fungi or bacteria when tested in accordance with ASTM C 1338, G-21, and G-22. Coating shall include an EPA-registered anti-microbial agent.
e. Air-stream surface and transverse edge shall be factory-coated with a tough composite material to provide a maximum average velocity rating of 5,000 fpm or better at 250°F when tested in accordance with ASTM C 1071.
f. Duct liner shall have a nominal K value of 0.25 (Btu*in)/(h*ft^2*degF) or less (1 inch thickness, 1 lb/ft3) when tested in accordance with ASTM C 518 at 75°F mean temperature.
g. Duct liner shall have a sound absorption coefficient (1 inch thickness, 1 lb/ft3) of 0.72 or higher at 1,000 Hz when tested in accordance with ASTM C 423, Type A mounting. Round duct liner shall have a noise reduction coefficient of 0.70 or better when tested in accordance with ASTM C 423, Type A mounting.
2. Duct sizes shown on the Drawings are clear internal dimensions and do not include liner.
3. Duct insulation and lining schedule:

System	Thickness	Vapor Seal Required
Exterior	2 inches	Yes
Exposed or concealed	1 inch	Yes

PART 3 EXECUTION

3.1 PREPARATION
A. Verify that piping, ductwork and equipment have been tested before applying insulation materials.
B. Verify that surfaces are clean, foreign material removed, and dry.

3.2 INSTALLATION
A. Special Techniques:
1. General:
a. Install materials in accordance with the Manufacturer’s instructions.
b. Where applicable, install materials in accordance with NAIMA Fibrous Glass Insulation Boards Standard, NAIMA Fibrous Glass Duct Liner Standard, and NAIMA Fibrous Duct Wrap Standard.
c. Insulation surfaces shall be Class A in accordance with UL 723.
d. Where insulation butts against flanges or is discontinued, taper insulation to the pipe to allow for the finish jacket to completely seal off the end of insulation. Extend insulation on valve bodies up to valve bonnet. Protect insulation at supports or hangers by means of pipe saddles or with steel shields. Fill void in saddles with insulation and seal the joints.
e. Where existing piping or insulation is disturbed, re-insulate to match existing.
f. Do not apply insulation to piping until the system has been tested and there is complete assurance that any leaks have been eliminated. Thoroughly clean piping of dirt, rust, and moisture before insulation is applied.
g. Provide removable and replaceable covers on equipment, flanges, unions and removable ends of strainers requiring insulation that need to be opened periodically for inspection, cleaning, or repair.
h. Install insulation materials with smooth and even surfaces, jackets drawn tight and cemented down smoothly at longitudinal and end laps. Do not use scrap pieces of insulation where a full length section will fit.
i. Install insulation, jackets, and coatings continuous through wall and floor openings and sleeves. For penetrations of fire or smoke rated walls and floors, insulation shall not be continuous, and fire retardant sealant shall be used. Vapor barrier shall be continuous.
j. Standing seams and projections in ductwork or casings shall have insulation applied so that at least 1/4 inch of insulation will cover such projections.
k. Insulation and vapor barrier shall be continuous around and under standoff brackets used for mounting control devices on ductwork.
2. Piping:
a. Insulate in accordance with Manufacturer's instructions including types of insulating cements, lagging adhesives, and weatherproof mastics if different from those specified.
b. Apply insulation over clean, dry surfaces with joints butted firmly together, but not until piping system has been pressure tested and any leaks corrected.
c. Do not extend insulation beyond flanges nor cover nameplates or code inspection stamps.
d. Run insulation continuous through wall openings, ceiling openings, and pipe sleeves, unless otherwise shown on the Drawings.

e. Insulate valve bodies, flanges, and pipe couplings.
   1) For piping exposed to weather and as recommended by the Insulation Manufacturer, apply two coats of an emulsion type weatherproof mastic for hot service and vapor barrier mastic for cold service. Embed glass tape in the first coat. Overlap tape not less than 1 inch and the adjoining metal jacket not less than 2 inches.
f. Install insulation with jacket drawn tight and side laps and end joint butt strips secured. End joint butt strip shall be minimum 3 inch wide and of material identical to jacket. On interior insulated piping and fittings, locate insulation and cover seams in least visible locations.
g. For insulated cold pipes conveying fluids below ambient temperature:
   1) Provide factory-applied or field-applied vapor barrier jackets.
   2) Continue insulation through walls, sleeves, pipe hangers, and other pipe penetrations except for roof penetrations.
   3) Insulate the entire system including fittings, valves, unions, flanges, and strainers. Insulate fittings, joints, and valves with molded insulation of like material and thickness as adjacent pipe.
h. Inserts and shields:
   1) Shields: Galvanized steel between pipe hangers, supports or pipe hanger rolls and inserts.
   2) Insert location: Between support shield and piping and under the finish jacket.
   3) Insert configuration: Minimum 12 inches long, of same thickness and contour as adjoining insulation; may be factory fabricated.
   4) Insert material: Hydrous calcium silicate insulation or other heavy density insulating material suitable for the planned temperature range.

3. Ductwork:
   a. Duct liner:
      1) For velocities up to 2,000 fpm, duct liner shall be applied with 100% coverage of fire-retardant adhesive. Duct liner shall be cut to assure snug corner joints. The coated or most dense surface of the liner shall face the airstream. The liner shall be additionally secured with mechanical fasteners that shall compress the duct liner sufficiently to hold it firmly in place. They shall start within 3 inches of the leading edge of each duct section (and any line transverse joints within the duct section) and shall be spaced no more than 12 inches o.c. around the perimeter of the duct, except they need to be no closer than 9 inches to a corner break. Elsewhere, they shall be a maximum of 18 inches o.c., except they shall be placed not more than 6 inches from a cut edge, nor 12 inches from a corner break. Exposed edges and the leading edge of cross joints of the liner shall be coated with the same adhesive used to secure the duct liner to the metal surface.
      2) For velocities between 2,000 to 5,000 fpm, and for ducts exposed to weather, installation shall be the same as for velocities under 2,000 fpm except that mechanical fasteners shall be spaced no more than 6 inches o.c. around the perimeter of the duct, and they need be no closer than 6 inches to a corner break. Elsewhere, they shall be a maximum of 10 inches o.c., except they shall be placed not more than 6 inches from a cut edge nor 12 inches from a corner break. Also, metal nosing shall be installed to protect leading edges.
      3) Install liner in both straight duct and fittings in accordance with the Manufacturer's recommendations. Gaps and tears or abrasions shall be filled and sealed in accordance with the Manufacturer's recommendations. Any edges exposed to the airstream shall also be coated with Superseal HV sealant.
4. Other requirements:
   a. Provide removable insulation sections to cover parts of equipment that need to be opened periodically for maintenance; include metal vessel covers, fasteners, flanges, frames, and accessories.
   b. Repair damaged sections of existing mechanical insulation, both previously damaged and damaged during this construction period. Use insulation of same thickness as existing insulation; install new jacket lapping and seal over existing.
   c. Replace damaged insulation that cannot be repaired satisfactorily, including units with vapor barrier damage and moisture saturated units.

B. Tolerances: Substituted insulation materials shall provide thermal resistance within 10% at normal conditions, as materials shown on the Drawings.

END OF SECTION

SECTION 23 09 00
HVAC CONTROLS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for HVAC controls.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
2. SECTION 01 91 00 (.01 or .02) – COMMISSIONING

1.2 REFERENCES

A. International Organization for Standardization (ISO):

1. 9001 – Quality Management Systems – Requirements

B. National Electrical Manufacturers Association (NEMA):

1. 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)

1.3 SUBMITTALS

A. Product Data: Specifications, descriptive drawings, catalog data, and descriptive literature. Include the make, model, dimensions, weight, and electrical schematics for control system components.

B. Shop Drawings:

1. Complete system power, interlock, control, and data transmission wiring diagrams that are 11 inches by 17 inches at a minimum.
2. Complete drawings and schematics of the proposed control system, including panel power requirements.
3. Integrate the HVAC controls and wiring diagrams with the control diagrams provided by the I&C Subcontractor. Provide a written statement, signed by both integrators, attesting to the fact that both the HVAC controls provider and the I&C Subcontractor have reviewed and approved the interfaces between their systems.

C. Quality Control Submittals:

1. Certificates: The Manufacturer's certificate of proper installation.
   a. Preliminary submittals shall include the proposed certificate of proper installation forms, a list of companies providing the Manufacturer’s services, and the scope of their responsibilities.
   b. Submit signed certificate of proper installation with the final Submittals.
2. Recommended procedures for the protection and handling of equipment and materials prior to installation.
3. Experience and qualifications of the Controls Supplier.
4. Detailed information on structural, mechanical, electrical, or other changes or modifications that are necessary to adapt the arrangement or details shown on the Drawings to the equipment and materials furnished.
5. HVAC control system commissioning and startup Submittals: Submit plans and procedures for testing, verification, and documentation of the entire HVAC control system with the facility commissioning and startup plan and the facility commissioning and startup procedures as specified in SECTION 01 91 00.

D. Contract Closeout Submittals:

1. Record documents: Complete As-Built wiring diagrams.
2. O&M manuals.
3. Recommended spare parts list:
   a. Quantities and replacement frequency.
   b. Current list prices that are valid for 90 days after the Substantial Completion date.
   c. Availability and nearest distributor.
4. Record of system adjustments.

E. Extra Materials Submittals: Furnish the box and tag and clearly mark on the exterior the Manufacturer’s name, description, and part number for shipment and long-term storage, and deliver the following items prior to the Substantial Completion date:

1. Spare light bulbs: Furnish one for each four pilot lights, a minimum of one per panel.

F. Warranty Documentation:

1. Sample warranty.
2. Warranty.

1.4 QUALITY ASSURANCE

A. System Description:

1. Furnish a complete, functional HVAC control system with supplementary electric or electronic devices, as required, to perform the sequence of operations as defined in the Contract Documents.
2. Design requirements:
   a. Furnish the controls necessary for the entire system to have fail-safe operation.
   b. Interface controls properly with factory-supplied components of mechanical systems.
   c. Coordinate special control interfacing requirements.
   d. For equipment requiring special interfacing with the control system, furnish equipment with the integral controls necessary to operate properly with the control system or furnish accessory devices required for the operation of the total mechanical system.
   e. Control components:
      1) Field or computer adjustable to the actual SP or ranges as required; also furnish adjustability to other settings that will provide proper operation of the entire control system.
      2) Of proper sensitivities to preclude cycling and to maintain control points that are adequately close to SPs for acceptable offset.
3. Performance requirements: In accordance with the Contract Documents.

4. Control types:
    a. Environmental control system: Furnish control of equipment and devices in accordance with the Contract Documents.
    b. Packaged control system: Furnish the complete packaged control system, with interface for I/O.
    c. Motorized damper control: Furnish a motor operator for each adjustable motorized damper that is arranged to open damper blades when energized.
5. General sequence of operation: In accordance with ECP drawings and associated logic.

B. Controls Supplier Qualifications: Capable of providing factory trained technicians, competent to provide instruction, routine maintenance, and emergency service on-site within 2 days after receipt of request.

C. Manufacturer Qualifications:
1. A minimum of 10 years of documented experience in the Work of this Section.
2. Certificate of ISO 9001 compliance.

D. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

1.5 SITE CONDITIONS

A. Environmental Requirements: Materials and equipment shall be designed and constructed for continuous operation, at rated current and voltage, at 104°F ambient and 95% relative humidity.

1.6 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the HVAC controls system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. HVAC Equipment and Devices:
1. Differential PSs with range suitable for filter bank pressure drop:
    a. Dwyer, 1910 Series
2. Damper actuators with spring return:
    a. Honeywell
    b. Johnson Controls

B. ECP:
1. Hoffman

2.2 MATERIALS

A. Electrical, Instrumentation, and Control: The Contract Documents expand on the electrical, instrumentation, and control requirements of the HVAC system and this Section:
1. Furnish the functions and components necessary for the complete operational system of controls that provide specified performance and functionality in accordance with the Contract Documents and as recommended by the Manufacturer.
2. Furnish items of incidental nature that are necessary for proper system operation and performance.
3. Furnish the ECP and devices as shown on the Drawings. The ECP shall be furnished and installed by the I&C Subcontractor.
4. The HVAC Subcontractor shall furnish a recommended sequence of operation in automatic and manual modes and coordinate with the I&C Subcontractor to furnish an ECP and the control requirements required for a complete operational system, as intended by the Contract Documents and approved by the ENGINEER.
5. The Manufacturer shall review the sequence of operation and equipment and certify proper operation and compliance with the HVAC Subcontractor's recommendations.
6. Alarms and control instruments:
    a. Suitable to perform the indicated function directly or through auxiliary devices.
    b. Furnish the following devices at a minimum and mount on HVAC system equipment as listed herein:
        1) PS.
        2) TS.
        3) LS.
        4) dPF across filters.

B. HVAC Equipment and Devices:
1. Temperature sensors: In accordance with the Contract Documents.
2. Humidity sensors: In accordance with the Contract Documents.
3. Differential PSs: Furnish tubing and tips for air filter application.
4. Damper actuators: Sized for damper requirements.

C. ECP: Furnished and installed by the I&C Systems Subcontractor; in accordance with the Contract Documents.
1. Construction:
    a. In accordance with NEMA 250.
    b. Hinged front door with locking handle.
    c. Flush mount manual switches, pilot lights, and direct-reading gauges on the front panel face.
    d. Identify front panel-mounted devices and ECP by engraved laminated plastic nameplates with black letters on a white background.
    e. Furnish a system schematic for mechanical equipment using laminated labels and symbols.
2. Control devices:
    a. Mount inside ECP.
    b. Prewired internally.

c. Terminate wires leaving ECP at separately numbered terminal strips (one terminal pair per circuit).
d. Furnish individual connectors for every item of mechanical equipment, integral and remote pilot lights, and other devices described for each panel.
e. Identify wires by color coding or numerical tags at both ends.
f. Wire control devices without splices to terminal strip.
g. Furnish integral circuit protection for panel-mounted control devices.

3. Terminal blocks:
   a. One-piece molded plastic blocks with screw type terminals and barriers rated for 300 V.
   b. Double-sided and supplied with removable covers to prevent accidental contact with live circuits.
   c. Furnish permanent, legible identification, clearly visible with the protective cover removed.
   d. Terminate wires at terminal blocks with crimp type, pre-insulated, ring-tongue lugs.
   e. Size lugs for terminal block screws and for the number and size of wires terminated.
4. Schematic diagrams:
   a. Furnish a multi-colored graphic of smooth or engraved laminated plastic.
   b. Mount on the inside of ECP showing equipment within respective systems.
5. Miscellaneous accessories:
   a. Furnish As-Built electrical wiring diagrams for ECP and controlled equipment, and secure to the inside of the panel door or enclose in plastic jackets placed inside each panel.
   b. Furnish plastic or stick-on labels on interior control devices to identify them in conjunction with wiring schematics.
   c. The description shall include the device and its normal operation.

PART 3 EXECUTION

3.1 INSTALLATION

A. Control System:
   1. Mount ECPs level, plumb, and securely to a wall or a column. Verify that adequate clearance is provided to allow for full front panel swing.
   2. Conceal control wiring where possible; exposed wiring shall be unobtrusive.
   3. Mount room thermostats level with the bottom 5 feet above the floor.
   4. Nameplates: Furnish engraved, laminated plastic adjacent to control devices, and for equipment whose function is not readily apparent in accordance with the Drawings.

3.2 QUALITY CONTROL

A. Manufacturer's Field Services: Provide a Manufacturer's Representative at the site for installation assistance, the inspection and certification of proper installation, equipment testing, startup assistance, and the training of the OWNER's personnel and as specified in SECTION 01 44 33.
   1. Manufacturer’s certificate of proper installation: Provide one certificate for each piece of equipment or packaged system.
      a. Provide a signed draft of the certificate of proper installation to the ENGINEER prior to proceeding with equipment commissioning and further operation of the equipment or packaged system.

3.3 ADJUSTING

A. Adjust and calibrate the entire control system.

B. Calibrate control devices at the time of installation to ensure measuring and reading accuracy. Provide calibration reports to the ENGINEER.

C. Inspection:
   1. Prior to the Substantial Completion date, thoroughly demonstrate the entire control system by simulating each control function in the presence of the ENGINEER to determine if the system performs in accordance with the Contract Documents.
   2. Correct deficiencies and demonstrate the system performs as specified in presence of the ENGINEER.
   3. Provide a final report to the ENGINEER describing the actions taken.
   4. Upon notice from the ENGINEER, assist the ENGINEER in making a review and an operating check of the control system.

D. Provide a complete Record Document of system adjustments and indicate deviations from specified temperatures, flow rates, and pressures.

END OF SECTION

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SECTION 23 23 00
REFRIGERANT PIPING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for refrigerant piping.

B. Related Sections:

1. SECTION 01 32 16 (.01 or .02) – COST LOADED SCHEDULE
2. SECTION 01 44 33 – MANUFACTURER'S SERVICES
3. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
4. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
5. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
6. SECTION 08 31 01 – ACCESS HATCHES AND DOORS FOR ROOF ACCESS
7. SECTION 23 05 00 – COMMON WORK RESULTS FOR MECHANICAL
8. SECTION 23 05 53 – MECHANICAL IDENTIFICATION
9. SECTION 23 62 00 – PACKAGED OUTDOOR AIR-CONDITIONING UNITS

1.2 REFERENCES

A. Air-Conditioning, Heating and Refrigeration Institute (AHRI):

1. 495 – Performance Rating of Refrigerant Liquid Receivers
2. 730 – Flow Capacity Rating of Suction Line Filters and Suction Line Filter Driers
3. 750 – Performance Rating of Thermostatic Refrigerant Expansion Valves

B. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE):

1. 15 & 34 – Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants

C. American Society of Mechanical Engineers (ASME):

1. B16.22 – Wrought Copper and & Copper Alloy Solder-Joint Pressure Fittings
2. B31.5 – Refrigeration Piping and Heat Transfer Components
3. Boiler and Pressure Vessel Code, Section IX – Welding and Brazing Qualifications

D. American Welding Society (AWS):

1. A5.8 – Specification for Filler Metals for Brazing and Braze Welding
2. Brazing Handbook, Pipe and Tube Chapter

E. ASTM International (ASTM):

1. B 32 – Standard Specification for Solder Metal
2. B 88 – Standard Specification for Seamless Copper Water Tube
3. B 828 – Standard Practice for Making Capillary Joints by Soldering of Copper and Copper Alloy Tube and Fittings

F. Manufacturers Standardization Society (MSS):

1. SP-58 – Pipe Hangers and Supports – Materials, Design, and Manufacture, Selection, Application, and Installation

G. Underwriter's Laboratory, Inc. (UL):

1. 207 – Refrigerant-Containing Components and Accessories, nonelectrical

1.3 SUBMITTALS

A. Warranty documentation as specified in SECTION 01 60 00.

B. O&M documentation as specified in SECTION 01 78 23.

C. Product Data: For each type of valve, refrigerant piping, and piping specialty.

1. Include pressure drop, based on the Manufacturer's test data, for the following:
   a. Thermostatic expansion valves.
   b. Solenoid valves.
   c. Hot-gas bypass valves.
   d. Filter dryers.
   e. Strainers.
   f. Pressure regulating valves.

D. Welding certificates.

E. Field QC reports.

F. O&M Special Requirements: O&M data requirements as specified in SECTION 01 78 23 and SECTION 01 32 16 (.01 or .02).

1.4 QUALITY ASSURANCE:

A. Installer Qualifications: A minimum of 3 years of documented experience in the Work of this Section.

B. Approved by the Manufacturer.

C. Design Criteria:

1. Welding qualifications: Qualify procedures and personnel in accordance with ASME Boiler and Pressure Vessel Code, Section IX.
2. In accordance with ASHRAE 15 & 34.
3. In accordance with ASME B31.5.

D. Factory/site demonstration testing requirements as specified in SECTION 01 91 00 and SECTION 23 05 00.

E. Training requirements for Manufacturer's training on the equipment as specified in SECTION 01 44 33 and SECTION 23 05 00.

1.5 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00. Also, piping with end caps shall be stored in place to ensure the piping interior and exterior are clean when installed.

1.6 WARRANTY

A. As specified in SECTION 01 60 00 and SECTION 23 05 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Valves and Specialties:
   1. Diaphragm packless valves:
      a. Danfoss Inc.
      b. Heldon Products; Henry Technologies
      c. Parker Hannifin Corporation
   2. Packed angle valves:
      a. Danfoss Inc.
      b. Heldon Products; Henry Technologies
      c. Parker Hannifin Corporation
   3. Check valves:
      a. Danfoss Inc.
      b. Emerson Climate Technologies
      c. Heldon Products; Henry Technologies
      d. Parker Hannifin Corporation
   4. Service valves:
      a. Danfoss Inc.
      b. Emerson Climate Technologies
      c. Heldon Products; Henry Technologies
      d. Parker Hannifin Corporation
      e. Paul Mueller Company
   5. Safety relief valves:
      a. Danfoss Inc.
      b. Heldon Products; Henry Technologies
      c. Parker Hannifin Corporation
   6. Thermostatic expansion valves:
      a. Danfoss Inc.
      b. Emerson Climate Technologies
      c. Heldon Products; Henry Technologies
   7. Straight type strainers:
      a. Danfoss Inc.
      b. Heldon Products; Henry Technologies
   8. Angle type strainers:
      a. Danfoss Inc.
      b. Heldon Products; Henry Technologies
   9. Moisture/liquid indicators:
      a. Danfoss Inc.
      b. Emerson Climate Technologies
      c. Heldon Products; Henry Technologies
   10. Permanent filter dryers:
      a. Danfoss Inc.
      b. Emerson Climate Technologies
      c. Heldon Products; Henry Technologies
   11. Mufflers:
      a. Danfoss Inc.
      b. Emerson Climate Technologies
   12. Liquid accumulators:
      a. Emerson Climate Technologies
      b. Heldon Products; Henry Technologies

B. Refrigerants:
   1. ASHRAE 15 & 34, R-410A (pentafluoroethane/difluoromethane):
      a. Arkema Inc.
      b. DuPont Fluorochemicals Division
      c. Genetron Refrigerants; Honeywell International Inc.

2.2 MATERIALS

A. Copper Tube and Fittings:
   1. Drawn copper tube: ASTM B 88, Type K or L.
   2. Wrought copper fittings: ASME B16.22.
   3. Wrought copper unions: ASME B16.22.
   4. Solder filler metals: ASTM B 32. Use 95-5 tin antimony or alloy HB solder to join copper socket fittings on copper pipe.

5. Brazing filler metals: AWS A5.8.
6. Flexible connectors:
    a. Body: Tin-bronze bellows with woven, flexible, tinned-bronze wire-reinforced protective jacket.
    b. End connections: Socket ends.
    c. Offset performance: Capable of minimum 3/4 inches misalignment in minimum 7 inches long assembly.
    d. Working pressure rating: Factory test at minimum 500 psig.
    e. Maximum operating temperature: 250°F.

2.3 COMPONENTS

A. Valves and Specialties:
1. Diaphragm packless valves:
    a. Body and bonnet: Forged brass or cast bronze; globe design with straight-through or angle pattern.
    b. Diaphragm: Phosphor bronze and SST with SST spring.
    c. Operator: Rising stem and hand wheel.
    d. Seat: Nylon.
    e. End connections: Socket, union, or flanged.
    f. Working pressure rating: 500 psig.
    g. Maximum operating temperature: 275°F.
2. Packed angle valves:
    a. Body and bonnet: Forged brass or cast bronze.
    b. Packing: Molded stem, back seating, and replaceable under pressure.
    c. Operator: Rising stem.
    d. Seat: Nonrotating, self-aligning PTFE.
    e. Seal cap: Forged brass or valox hex cap.
    f. End connections: Socket, union, threaded, or flanged.
    g. Working pressure rating: 500 psig.
    h. Maximum operating temperature: 275°F.
3. Check valves:
    a. Body: DI, forged brass, or cast bronze; globe pattern.
    b. Bonnet: Bolted DI, forged brass, or cast bronze; or brass hex plug.
    c. Piston: Removable PTFE seat.
    d. Closing spring: SST.
    e. End connections: Socket, union, threaded, or flanged.
    f. Maximum opening pressure: 0.50 psig.
    g. Working pressure rating: 500 psig.
    h. Maximum operating temperature: 275°F.
4. Service valves:
    a. Body: Forged brass with brass cap including key end to remove core.
    b. Core: Removable ball type check valve with SST spring.
    c. Seat: PTFE.
    d. End connections: Copper spring.
    e. Working pressure rating: 500 psig.
5. Thermostatic expansion valves:
    a. In accordance with AHRI 750.
    b. Body, bonnet, and seal cap: Forged brass or steel.
    c. Diaphragm, piston, closing spring, and seat insert: SST.
    d. Packing and gaskets: Non-asbestos.
    e. Capillary and bulb: Copper tubing filled with refrigerant charge.
    f. Reverse-flow option (for heat pump applications).
    g. End connections: Socket, flare, or threaded union.
6. Straight type strainers:
    a. Body: Welded steel with corrosion-resistant coating.
    b. Screen: 100-mesh SST.
    c. End connections: Socket or flare.
    d. Working pressure rating: 500 psig.
    e. Maximum operating temperature: 275°F.
7. Angle type strainers:
    a. Body: Forged brass or cast bronze.
    b. Drain plug: Brass hex plug.
    c. Screen: 100-mesh monel.
    d. End connections: Socket or flare.
    e. Working pressure rating: 500 psig.
    f. Maximum operating temperature: 275°F.
8. Moisture/liquid indicators:
    a. Body: Forged brass.
    b. Window: Replaceable, clear, fused glass window with indicating element protected by filter screen.
    c. Indicator: Color-coded to show moisture content in ppm.
    d. Minimum moisture indicator sensitivity: Indicate moisture above 60 ppm.

e. End connections: Socket or flare.
f. Working pressure rating: 500 psig.
g. Maximum operating temperature: 240°F.

9. Permanent filter dryers:
   a. In accordance with AHRI 730.
   b. Body and cover: Painted steel shell.
   c. Filter media: 10 micron, pleated with integral end rings; SST support.
   d. Desiccant media: Activated charcoal.
   e. End connections: Socket.
   f. Access ports: Nominal pipe size 1/4 connections at entering and leaving sides for pressure differential measurement.
   g. Maximum pressure loss: 2 psig.
   h. Rated flow: As shown on the Drawings
   i. Working pressure rating: 500 psig.
   j. Maximum operating temperature: 240°F.
10. Mufflers:
   a. Body: Welded steel with corrosion-resistant coating.
   b. End connections: Socket or flare.
   c. Working pressure rating: 500 psig.
   d. Maximum operating temperature: 275°F.
11. Receivers:
   a. In accordance with AHRI 495.
   b. In accordance with UL 207; listed and labeled by a NRTL.
   c. Body: Welded steel with corrosion-resistant coating.
   d. Tappings: Inlet, outlet, liquid level indicator, and safety relief valve.
   e. End connections: Socket or threaded.
   f. Working pressure rating: 500 psig.
   g. Maximum operating temperature: 275°F.
12. Liquid accumulators:
   a. In accordance with AHRI 495.
   b. Body: Welded steel with corrosion-resistant coating.
   c. End connections: Socket or threaded.
   d. Working pressure rating: 500 psig.
   e. Maximum operating temperature: 275°F.

B. Refrigerants:
   1. ASHRAE 15 & 34, R-410A: Pentafluoroethane/difluoromethane.

PART 3 EXECUTION

3.1 PREPARATION

A. Installation of condensing units and coils.

3.2 INSTALLATION

A. Piping Applications for Refrigerant:
   1. Suction lines Nominal pipe size 1 1/2 inch and smaller for conventional air conditioning applications: Copper, Type ACR, annealed-temper tubing and wrought copper fittings with brazed or soldered joints.
   2. Hot-gas and liquid lines: Copper, Type ACR, annealed-temper tubing and wrought copper fittings with brazed or soldered joints.
   3. Safety relief valve discharge piping: Copper, Type ACR, drawn-temper tubing and wrought copper fittings with soldered joints.

B. Valve and Specialty Applications:
   1. As specified in SECTION 23 62 00 for valve applications associated with packaged compressor and condenser units.
   2. Install service valves for gauge taps at inlet and outlet of hot-gas bypass valves and strainers if they are not an integral part of valves and strainers.
   3. Install a check valve at the compressor discharge and a liquid accumulator at the compressor suction connection.
   4. Except as otherwise shown on the Drawings, install diaphragm packless or packed angle valves on the inlet and outlet side of filter dryers.
   5. Install thermostatic expansion valves as close as possible to distributors on evaporators.
      a. Install valve so diaphragm case is warmer than bulb.
      b. Secure bulb to clean, straight, horizontal section of suction line using two bulb straps. Do not mount bulb in a trap or at the bottom of the line.
      c. If external equalizer lines are required, make the connection where it will reflect suction line pressure at the bulb location.
   6. Install safety relief valves in accordance with ASME Boiler and Pressure Vessel Code. Pipe safety relief valve discharge line to the outside in accordance with ASHRAE 15 & 34.
   7. Install moisture/liquid indicators in the liquid line at the inlet of the thermostatic expansion valve or at the inlet of the evaporator coil capillary tube.

8. Install strainers upstream from and adjacent to the following unless they are furnished as an integral assembly for the device being protected:
   a. Thermostatic expansion valves.
   b. Hot-gas bypass valves.
   c. Compressor.
9. Install filter dryers in the liquid line between the compressor and thermostatic expansion valve**.**
10. Install receivers sized to accommodate pump down charge, if required by the Manufacturer.

C. Piping Installation:
1. Drawings, schematics, and diagrams show the general location and arrangement of piping systems; with locations and arrangements where used to size pipe and calculate friction loss, expansion, pump sizing, and other design considerations. Install piping as shown on the Drawings unless deviations to layout are approved on the Shop Drawings. Piping shall not be routed above electrical equipment where possible, provide galvanized steel drip tray above electrical equipment where routing above is unavoidable.
2. Install refrigerant piping in accordance with ASHRAE 15 & 34.
3. Install piping in concealed locations unless otherwise shown on the Drawings and except in equipment rooms and service areas.
4. Install piping as shown on the Drawings to be exposed and piping in equipment rooms and service areas at right angles or parallel to building walls. Diagonal runs are prohibited unless specifically shown on the Drawings otherwise.
5. Install piping above accessible ceilings to allow sufficient space for ceiling panel removal.
6. Install piping adjacent to machines to allow service and maintenance.
7. Install piping free of sags and bends.
8. Install fittings for changes in direction and branch connections.
9. Select system components with a pressure rating equal to or greater than system operating pressure.
10. Install piping as short and direct as possible, with a minimum number of joints, elbows, and fittings.
11. Arrange piping to allow inspection and service of refrigeration equipment. Install valves and specialties in accessible locations to allow for service and inspection. Install access doors or panels as specified in SECTION 08 31 01 if valves or equipment requiring maintenance is concealed behind finished surfaces.
12. Install refrigerant piping in protective conduit where installed below ground.
13. Install refrigerant piping in rigid or flexible conduit in locations where exposed to mechanical injury.
14. Slope refrigerant piping as follows:
    a. Install horizontal hot-gas discharge piping with a uniform slope downward away from compressor.
    b. Install horizontal suction lines with a uniform slope downward to compressor.
    c. Liquid lines may be installed level.
15. When brazing or soldering, remove solenoid valve coils and sight glasses; also remove valve stems, seats, and packing, and accessible internal parts of refrigerant specialties. Do not apply heat near expansion valve bulb.
16. Install piping with adequate clearance between pipe and adjacent walls and hangers or between pipes for insulation installation.
17. Identify refrigerant piping and valves as specified in SECTION 23 05 53.
18. Install escutcheons for piping penetrations of walls, ceilings, and floors as specified in SECTION 23 05 00.

D. Pipe Joint Construction:
1. Ream ends of pipes and tubes and remove burrs.
2. Remove scale, slag, dirt, and debris from inside and outside of pipe and fittings before assembly.
3. Soldered joints: Construct joints in accordance with ASTM B 828.
4. Brazed joints: Construct joints in accordance with the AWS Brazing Handbook, Chapter: Pipe and Tube.
   a. Use Type BCuP (copper-phosphorus) alloy for joining copper socket fittings with copper pipe.
   b. Use Type BAg (cadmium-free silver) alloy for joining copper with bronze or steel.
5. Flanged joints: Select appropriate gasket material, size, type, and thickness for service application. Install gasket concentrically positioned. Use suitable lubricants on bolt threads.

E. Hangers and Supports:
1. Install the following pipe attachments:
   a. Adjustable steel clevis hangers for individual horizontal runs less than 20 feet long.
   b. Roller hangers and spring hangers for individual horizontal runs 20 feet or longer.
   c. Pipe roller: MSS SP-58, Type 44 for multiple horizontal piping 20 feet or longer, supported on a trapeze.
   d. Spring hangers to support vertical runs.
   e. Copper-clad hangers and supports for hangers and supports in direct contact with copper pipe.
2. Install hangers for copper tubing with the following maximum spacing and minimum rod diameters:
   a. Nominal pipe size 1/2: Maximum span, 60 inches; minimum rod, 1/4 inches.
   b. Nominal pipe size 5/8: Maximum span, 60 inches; minimum rod, 1/4 inches.
   c. Nominal pipe size 1: Maximum span, 72 inches; minimum rod, 1/4 inches.
   d. Nominal pipe size 1 1/4: Maximum span, 96 inches; minimum rod, 3/8 inches.
   e. Nominal pipe size 1 1/2: Maximum span, 96 inches; minimum rod, 3/8 inches.
3. Support multi-floor vertical runs at least at each floor.

F. System Charging:
1. Charge system using the following procedures:
   a. Install core in filter dryers after leak test but before evacuation.

b. Evacuate entire refrigerant system with a vacuum pump to 500 micrometers. If vacuum holds for 12 hours, the system is ready for charging.
c. Break vacuum with refrigerant gas, allowing pressure to build up to 2 psig.
d. Charge system with a new filter-dryer core in charging line.

3.3 QUALITY CONTROL

A. Testing requirements as specified in SECTION 23 05 00. Specific requirements in addition to these Sections shall be:
1. Line test pressure for refrigerant R-410A:
a. Suction lines for air conditioning applications: 300 psig.
b. Suction lines for heat pump applications: 535 psig.
c. Hot-gas and liquid lines: 535 psig.

B. Installation site visits as specified in SECTION 23 05 00.

C. Other Tests:
1. Perform the following tests and inspections:
a. In accordance with ASME B31.5, Chapter VI.
b. Test refrigerant piping, specialties, and receivers. Isolate compressor, condenser, evaporator, and safety devices from test pressure if they are not rated above the test pressure.
c. Test high-pressure and low-pressure side piping of each system separately at not less than the pressures shown in this Section.
1) Fill system with nitrogen to the required test pressure.
2) The system shall maintain test pressure at the manifold gauge throughout duration of test.
3) Test joints and fittings with electronic leak detector or by brushing a small amount of soap and glycerin solution over joints.
4) Remake leaking joints using new materials, and retest until satisfactory results are achieved.
2. Prepare test and inspection reports.

3.4 STARTUP

A. Startup and commissioning requirements for the equipment specified herein as specified in SECTION 01 91 00 and SECTION 23 05 00.

3.5 ADJUSTING

A. Adjust high-pressure and low-pressure switch settings to avoid short cycling in response to fluctuating suction pressure.

B. Adjust SP temperature of air conditioning or chilled water controllers to the system design temperature.

C. Perform the following adjustments before operating the refrigeration system, in accordance with the Manufacturer's instructions:
1. Open shutoff valves in the condenser water circuit.
2. Verify that compressor oil level is correct.
3. Open compressor suction and discharge valves.
4. Open refrigerant valves except bypass valves that are used for other purposes.
5. Check open compressor motor alignment and verify lubrication for motors and bearings.

D. Replace core of the replaceable filter dryer after the system has been adjusted and after design flow rates and pressures are established.

END OF SECTION

SECTION 23 31 00
DUCTWORK AND ACCESSORIES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for ductwork and accessories.

B. Related Sections:

1. SECTION 23 07 00 – MECHANICAL INSULATION

1.2 REFERENCES

A. Air Diffusion Council (ADC):

1. FD72 – Flexible Duct Code

B. Air Movement and Control Association International (AMCA):

1. 500-D – Laboratory Methods of Testing Dampers for Rating

C. ASTM International (ASTM):

1. A 36 – Standard Specification for Carbon Structural Steel
2. A 653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
3. B 209 – Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
4. E 96 – Standard Test Methods for Water Vapor Transmission of Materials

D. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):

1. 1966 – HVAC Duct Construction Standards – Metal and Flexible

1.3 SUBMITTALS

A. Product Data:

1. The Manufacturer's data and descriptive literature for duct accessories.
2. Detailed information on structural, mechanical, electrical, or other modifications necessary to adapt the arrangement or details shown on the Drawings to the ductwork installation.

B. Shop Drawings: Provide dimensioned layout drawings of ductwork showing joint locations and details, sizes, and material thicknesses, include hanger support locations and details.

C. Spare Parts: Provide two sets of spare filters for each aluminum filter box.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Low and Medium Pressure, Round or Flat Oval Ductwork:

1. Spiral duct:
   a. Hranec Sheet Metal, Inc.
   b. McGill AirFlow LLC, Spiral Uni-Seal
2. Fittings:
   a. Joint seal material:
      1) Hardcast, Type DT tape and HD-20 adhesive
      2) United, duct sealer
      3) McGill AirFlow LLC, duct sealer
   b. Fitting:
      1) Hranec Sheet Metal, Inc.
      2) McGill AirFlow LLC, Uni-Seal

B. Mechanical Joint Option:

1. Transverse joints:
   a. Ductlok, J/E duct connector systems
   b. Ductmate, 25/35 duct connector systems
   c. WDCI, Heavy/Lite duct connector systems

C. Duct Accessories:

1. Rectangular elbows:
   a. Duro-Dyne
   b. Elgen
2. Flexible connections to non-internally spring-isolated rotating fan equipment:
   a. Duro-Dyne, Durolon
   b. Ventfabrics, Ventglas
3. PVC butterfly damper:
   a. Ruskin, PVC 12 with electric actuator, used with PVC vent piping
4. Round control butterfly damper:
   a. Ruskin, CDR 25 with seals

D. Backdraft and Pressure Relief Dampers:

1. Air Balance, Inc.
2. American Warming and Ventilating
3. Duro Dyne Corp.
4. Greenheck
5. Penn Ventilation Company, Inc.
6. Prefco Products, Inc.
7. Ruskin Company
8. Vent Products Company, Inc.

E. Control Dampers:
   1. Air Balance, Inc.
   2. American Warming and Ventilating
   3. Duro Dyne Corp.
   4. Greenheck
   5. McGill AirFlow Corporation
   6. METALAIRE, Inc.
   7. Nailor Industries Inc.
   8. Penn Ventilation Company, Inc.
   9. Ruskin Company
   10. Vent Products Company, Inc.
F. Manual Volume Dampers:
   1. Air Balance, Inc.
   2. American Warming and Ventilating
   3. Flexmaster U.S.A., Inc.
   4. McGill AirFlow Corporation
   5. METALAIRE, Inc.
   6. Nailor Industries Inc.
   7. Penn Ventilation Company, Inc.
   8. Ruskin Company
   9. Vent Products Company, Inc.
G. Duct Inspection Doors:
   1. Duro-Dyne
   2. Ventlok
H. Joint Tape:
   1. Interior ductwork:
      a. Hardcast, Lag-Rite Tape and Bonder
      b. RayChem, Shrink Tape
   2. Exterior ductwork:
      a. Hardcast, Outdoor Tape and Rosin
I. Air Outlets:
   1. As shown on the Drawings

2.2 MATERIALS

A. Metal Ductwork For Below Grade Structures and Exterior Non-Insulated:
   1. Material: Aluminum in accordance with ASTM B 209, Alloy 3003, mill finish for concealed ducts, and bright finish for ductwork exposed to view.
B. Metal Ductwork for Above Grade Structures:
   1. Material: Galvanized sheet steel in accordance with ASTM A 653, lock forming quality with G90 zinc coating, and mill phosphate finishes for surfaces exposed to view.
C. Flexible Ductwork:
   1. In accordance with NFPA 90A, NFPA 90B, ADC FD72, and ASTM E 96.
   2. In accordance with SMACNA 1966 for acceptable materials, material thicknesses, and duct construction methods unless otherwise shown on the Drawings.
D. General Construction Requirements:
   1. Fabricate in accordance with the SMACNA 1966, Chapter 6.
   2. Furnish wye or conical tee fittings for round duct takeoffs from round mains.
   3. Furnish bellmouth or conical tee fittings for round duct takeoffs from rectangular mains.
   4. Provide 45 degree entry fittings in accordance with SMACNA's requirements for rectangular takeoffs from rectangular or round mains.
   5. The duct sizes shown on the Drawings are inside clear dimensions. For lined ducts, maintain sizes inside lining.
   6. Balancing dampers: 90% unobstructed free area.
   7. Increase duct sizes gradually, not to exceed 15 degrees divergence, maximum 30 degrees divergence upstream of equipment and 45 degrees convergence downstream.
E. Hanger Rod, Straps, Half and Full Rounds: ASTM A 36 galvanized steel and applicable to attaching method and supports.
F. Low and Medium Pressure Ductwork:
   1. Medium pressure ductwork (2 inch to 6 inch WC) includes ductwork between the air supply units and the air terminal devices.
   2. Round or flat oval ductwork:
      a. Fittings: Furnish a complete separate fitting for branch takeoffs from spiral ducts.
      b. Branch takeoffs: Conical laterals, conical tees, or as shown on the Drawings.
G. Mechanical Joint Option:
   1. Fabricate ducts and joints, including gauge and reinforcing, in accordance with the SMACNA 1966.
   2. When using the WDCI Heavy/Lite system, construct ductwork in accordance with the Manufacturer's instructions.
   3. When using Ductlok J/E duct connector systems, construct ductwork in accordance with the Manufacturer's instructions.
   4. For longitudinal seams, use the Pittsburgh lock seam sealed internally with a permanently elastic sealant.

5. Class A sealing requirements in accordance with SMACNA 1966.

H. Duct Accessories:
   1. Butterfly dampers: Size as shown on the Drawings.
   2. Elbows:
      a. Rectangular:
         1) Fit square-turn elbows with vane side rails.
         2) Shop fabricate double-blade turning vanes of the same material as the ductwork.
         3) Fabricate with equal inlet and outlet sizes.
         4) Rectangular radius elbows with an inside radius of 3/4 of duct width in the direction of the turn.
      b. Round: Furnish five-piece segmented type elbows with centerline radius of 1 1/2 times the duct diameter.
      c. Fabricate elbows from aluminum material used for ductwork.

I. Turning Vanes:
   1. Supply on every 45 degree and greater bend, and as shown on the Drawings.
   2. Install turning vanes with a 2 inch radius and at 1 1/2 inch spacing.
   3. Flexible connections to non-internally spring-isolated rotating fan equipment:
      a. Furnish neoprene-coated, fire-resistant glass fabric, with 2 inches of clearance between the casing and the ductwork at a minimum.
      b. Coat outdoor flexible connectors with Hypalon.

J. Backdraft and Pressure Relief Dampers:
   1. Dampers integral to the building envelope shall be equipped with motorized dampers with a maximum leakage rate of 3 cfm/ft2 at 1.0 inches water gauge when tested in accordance with AMCA 500.
   2. Exception: Gravity (non-motorized) dampers are permitted to be used in smaller structures and in accordance with the Drawings.
   3. Description: Gravity balanced.
   4. Maximum air velocity: 1000 fpm.
   5. Maximum system pressure: 2 inches water gauge.
   6. Frame: Hat-shaped, 0.05 inch thick SST, with welded corners or mechanically attached and mounting flange.
   7. Blades: Multiple single-piece blades, center pivoted, maximum 6 inches width, 0.025 inch thick, roll-formed aluminum with sealed edges.
   8. Blade action: Parallel.
   9. Blade seals: Neoprene, mechanically locked.
   10. Blade axles:
       a. Material: Nonferrous.
       b. Diameter: 0.20 inch.
   11. Tie bars and brackets: Galvanized steel.
   12. Return spring: Adjustable tension.
   13. Bearings: Steel ball or synthetic pivot bushings.
   14. Accessories:
       a. Adjustment device to permit setting for varying differential static pressure.
       b. Counterweights and spring-assist kits for vertical airflow installations.
       c. Electric actuators.
       d. Chain pulls.
       e. Screen mounting: Rear mounted.
       f. Screen material: Aluminum.
       g. Screen type: Insect.
       h. 90-degree stops.

K. Control Dampers:
   1. Low-leakage rating and bearing AMCA's certified ratings seal for both air performance and air leakage.
   2. Frames:
      a. Hat-shaped, U-shaped, or angle-shaped.
      b. 0.094 inch thick, galvanized sheet steel.
      c. Mitered and welded corners.
   3. Blades: Aluminum airfoil blade, internally insulated polyurethane foam and thermally broken where shown on the Drawings.
      a. Multiple blade with maximum blade width of 6 inches.
      b. Opposed blade design.
      c. SST.
      d. 0.064 inch thick single skin or 0.0747 inch thick dual skin.
      e. Blade edging: Closed-cell neoprene.
   4. Blade axles: 1/2 inch diameter; SST; blade linkage hardware of zinc-plated steel and brass; ends sealed against blade bearings.
      a. Operating temperature range: From -40°F to 200°F.
   5. Bearings:
      a. Oil-impregnated bronze, molded, oil-impregnated SST sleeve, or SST sleeve.
      b. Dampers in ducts with pressure classes of 3 inches water gauge or less shall have axles the full length of damper blades and bearings at both ends of the operating shaft.
      c. Thrust bearings at each end of every blade.

L. Manual Volume Dampers:
1. General description: Factory fabricated, with required hardware and accessories. Stiffen damper blades for stability. Include locking device to hold single-blade dampers in a fixed position without vibration. Close duct penetrations for damper components to seal duct consistent with pressure class.
2. Standard, steel, manual volume dampers:
a. Standard leakage rating.
b. Suitable for horizontal or vertical applications.
c. Frames:
1) Frame: Hat-shaped, 0.094 inch thick, galvanized sheet steel.
2) Mitered and welded corners.
3) Flanges for attaching to walls and flangeless frames for installing in ducts.
d. Blades:
1) Multiple or single blade.
2) Parallel-blade or opposed-blade design.
3) Stiffen damper blades for stability.
4) Galvanized steel, 0.064 inch thick.
e. Blade axles: Galvanized steel.
f. Bearings:
1) Oil-impregnated bronze, molded synthetic, oil-impregnated SST sleeve, or SST sleeve.
2) Dampers in ducts with pressure classes of 3 inches water gauge or less shall have axles the full length of damper blades and bearings at both ends of the operating shaft.
g. Tie bars and brackets: Galvanized steel.

M. Duct Inspection Doors:
1. Size: As shown on the Drawings (12 inch by 12 inch minimum) with sealed gasket around the parameter.
2. Panels: Hinged, insulated, and fabricated of the same material as ductwork.
3. Sheet metal plenums:
a. Fabricate from 18 gauge metal at a minimum of the same material as the ductwork. Use standing seam construction.
b. Brace with an angle frame for rigidity.

N. Air Outlets:
1. Rectangular construction of the same material as ductwork.
2. Continuous sponge rubber gasket at face flange.
3. Reference drawings for schedule.

O. Aluminum filter box: Fabricate from 18 gauge aluminum sheet metal and brace with SST V-channels.

P. Insulation: As specified in SECTION 23 07 00.

PART 3 EXECUTION

3.1 INSTALLATION

A. General:
1. Install sheet metalwork and flexible ductwork in accordance with SMACNA 1966.
2. Cross-break horizontal surfaces of rectangular metal ducts.
3. Install additional bracing as required to prevent ballooning, breathing, or swaying.
4. For interior ductwork, tape joints with Hardcast Lag-Rite tape and bonder or Ray-Chem shrink tape.
5. For exterior ductwork, tape joints with Hardcast outdoor tape and rosin.
6. Tape joints in accordance with the following table:

Pressure Class	Sealing Required
2 inch WC or less	Transverse joints
More than 2 inch WC	Transverse joints and longitudinal seams

7. Seal joints of ductwork in accordance with the Manufacturer's instructions.
8. Provide balancing dampers for grilles and diffusers in the branch duct as near the main as possible. Add or remove balancing dampers as requested by the air balancing firm for the necessary control of air.
9. Make duct size transitions with the maximum inclusive angle of 30 degrees, unless otherwise shown on the Drawings.
10. Make offsets with a maximum angle of 45 degrees.

B. Mechanical Joint Option: Install specified transverse duct joints in accordance with the Manufacturer's instructions and installation manuals.

C. Duct Inspection/Access Doors: Install in accordance with the Manufacturer's instructions at each duct-mounted fire damper, duct-mounted smoke or ionization detector, electric duct heater, booster coil, humidifier, motorized damper, and sail switch. Inspection/access doors shall provide an air tight seal and be sized to provide full maintenance accessibility.

D. Internal Insulation/Sound Attenuation: Install in accordance with SMACNA 1966 and the Manufacturer's recommendations.

E. Install diffusers, grilles, and registers tight on their respective mounting surfaces, level, plumb, and true with room dimensions. Provide appropriate frame and boot to adapt to mounting surface.

F. Duct Penetrations through Wall and Floors:
   1. Provide 1 inch angle collars for exposed ducts passing through walls, ceilings, or floors. Anchor collars in position after installation is complete.
   2. Where vertical ducts pass through floors, supporting angles shall be rigidly attached to ducts and to the floor. Angles shall be galvanized and of approved sizes to properly support the ductwork. The supporting angles shall be placed on at least two sides of the duct.
   3. Where horizontal ducts pass through walls and vertical ducts pass through floors, the opening shall be tightly sealed off to provide a tight seal between the duct and the opening. Refer to Part 2 of this Section for approved fire stop materials to be used at the rated walls and floors.

G. Hangers and Supporting Systems:
   1. Support horizontal ducts less than 4 sf at maximum space of 8 ft.
   2. Install support systems in accordance with SMACNA 1966.
   3. Anchor support systems to structural steel, and not metal roof deck, for overhead ductwork.

H. Dampers:
   1. Install control dampers at inlet of exhaust fans or exhaust ducts as close as possible to exhaust fan.
   2. Install volume dampers at points on supply, return, and exhaust systems where branches extend from larger ducts. Where dampers are installed in ducts having duct liner, install dampers with hat channels of the same depth as liner, and terminate liner with nosing at hat channel.

3.2 QUALITY CONTROL

A. Duct Systems:
   1. Clean ductwork internally of dust and debris as it is installed. Clean external surfaces of foreign substances that might cause corrosive deterioration of metal or, where ductwork is to be painted, might interfere with painting or cause paint deterioration.
   2. Strip protective paper from stainless ductwork surfaces and repair finish wherever it has been damaged.
   3. Operate dampers to verify full range of movement.
   4. Inspect locations of access doors and verify the purpose of access door can be performed.
   5. Inspect turning vanes for proper and secure installation.
   6. Operate remote damper operators to verify the full range of movement of the operator and damper.

END OF SECTION

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SECTION 23 34 00
HVAC FANS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for HVAC fans.

1.2 REFERENCES

A. Air Movement and Control Association International (AMCA):
   1. 210 – Laboratory Methods of Testing Fans for Certified Aerodynamic Performance Rating

B. National Fire Protection Association (NFPA):
   1. 90A – Standard for the Installation of Air-Conditioning and Ventilating Systems
   2. 90B – Standard for the Installation of Warm Air Heating and Air-Conditioning Systems

1.3 SUBMITTALS

A. Product Data: Provide specifications, descriptive drawings, catalog data, and descriptive literature. Include the make, model, dimensions, weight, fan noise data, and electrical schematics for the products specified.

B. Quality Control Submittals:
   1. Certificates of conformance: Motors, premium efficiency type and fans.
   2. Recommended procedures for the protection and handling of products prior to installation.
   3. Detailed information on structural, mechanical, electrical, or other modifications necessary to adapt the arrangement or details shown on the Drawings to the equipment furnished.

C. Closeout Submittals: O&M manuals for the equipment specified.

D. Material Submittals:
   1. Furnish, tag, and box for shipment and storage the following spare parts:
      a. Belts: One complete set per unit.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Exhaust Fans (EF Series):
   1. As shown on the Drawings.

2.2 MATERIALS

A. General:
   1. Fan units: Furnish fused disconnects.
   2. Shafts and drive belts:
      a. Furnish multiple drive belts where motor hp is 2 or greater.
      b. Belt guards: Meet federal and State of Colorado OSHA requirements for safety protection, and be easily removable by one person.
      c. Tachometer access holes: Large enough to accept a standard tachometer drive shaft.
      d. Shall have a center punch fan shaft to accommodate tachometer readings.
   3. Fan equipment: Rated and tested in accordance with AMCA 210 for Class I service.
   4. Ball bearings:
      a. For forward-curved fans: Size for a minimum life L-10 of over 100,000 hours.
      b. For airfoil and backward inclined fans: Size for a minimum life L-10 of over 40,000 hours, with an average life L-50 of over 200,000 hours.
   5. Drives for belt-driven fans:
      a. Sheaves capable of providing 150% of motor hp.
      b. Mount motors on adjustable motor brackets.
      c. Furnish motors 10 hp and less with adjustable speed sheaves that allow for 20% speed variation.
      d. Furnish belt-driven fans with CI or flanged steel sheaves.
   6. Coordinate selection (size, voltage, and configuration) of motor operators for dampers with HVAC controls as shown on the Drawings.
   7. Air filters, fans, air handlers, and air conditioners: In accordance with NFPA 90A and NFPA 90B.
   8. Provide lifting lugs for fan equipment that weighs more than 100 lbs.

B. Exhaust Fans, EF Series:
   1. Nameplate with cfm, static pressure, and maximum fan rpm.
   2. Capacity at given altitude: In accordance with the Contract Documents.

PART 3 EXECUTION

3.1 INSTALLATION

A. Fans:
   1. Isolate sheet metal duct connections from non-internally spring-isolated fan units or other rotating equipment.
   2. Locate units to provide for access spaces that are required for filter changing, motor, drive, and bearing servicing, and fan shaft and coil removal.

3.2 CLEANING

A. Do not operate units until filters are installed. If units are operated without filters, completely clean the coils and the interior of units.

3.3 ADJUSTING

A. Fans: Lubricate nonsealed bearings prior to startup.

END OF SECTION

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SECTION 23 36 00
AIR TERMINAL UNITS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for air terminal units.

B. Related Sections:
   1. SECTION 01 32 16 (.01 or .02) – COST LOADED SCHEDULE
   2. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   3. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
   4. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   5. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
   6. SECTION 23 05 00 – COMMON WORK RESULTS FOR MECHANICAL
   7. SECTION 23 05 53 – MECHANICAL IDENTIFICATION
   8. SECTION 23 31 00 – DUCTWORK AND ACCESSORIES
   9. SECTION 23 62 00 – PACKAGED OUTDOOR AIR-CONDITIONING UNITS

1.2 REFERENCES

A. Air-Conditioning, Heating, and Refrigeration Institute (AHRI):
   1. 210/240 – Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment
   2. 880 – Performance Rating of Air Terminals

B. ASTM International (ASTM):
   1. C 916 – Standard Specification for Adhesives for Duct Thermal Insulation
   2. C 1071 – Standard Specification for Fibrous Glass Duct Lining Insulation (Thermal and Sound Absorbing Material)
   3. E 84 – Standard Test Method for Surface Burning Characteristics of Building Materials

C. American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE):
   1. 52.2 – Method of Testing General Ventilation Air-Cleaning Devices for Removal Efficiency by Particle Size
   2. 62.1 –Ventilation for Acceptable Indoor Air Quality
   3. 90.1 – Energy Standard for Buildings except Low-Rise Residential Buildings

D. National Fire Protection Association (NFPA):
   1. 70 – National Electric Code (NEC)
   2. 90A – Installation of Air Conditioning and Ventilating Systems
   3. 90B – Standard for the Installation of Warm Air Heating and Air-Conditioning Systems

E. North American Insulation Manufacturers Association (NAIMA):
   1. Fibrous Glass Duct Liner Standard

F. Sheet Metal and Air Conditioning Contractors National Association (SMACNA):
   1. HVAC Duct Construction Standards – Metal and Flexible

1.3 SUBMITTALS

A. Product data:
   1. Include construction details, material descriptions, dimensions of individual components and profiles, and finishes.
   2. Include rated capacities, operating characteristics, electrical characteristics, and furnished specialties and accessories.

B. Shop Drawings:
   1. Drawings, elevations, sections, and mounting details.
   2. Details of equipment assemblies. Indicate dimensions, weights, loads, and required clearances, method of field assembly, components, and location and size of each field connection.
   3. Diagrams for power, signal, and control wiring.
   4. Hangers and supports, including methods for duct and building attachment and vibration isolation.

C. Informational Submittals:
   1. Coordination Drawings: Reflected ceiling Drawings, drawn to scale, on which the following items are shown and coordinated with each other, using input from the installers of the items involved:
      a. Ceiling suspension assembly members.
      b. Size and location of initial access modules for acoustic tile.
      c. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
   2. Field QC reports.

D. O&M Special Requirements:
   1. O&M data requirements as specified in SECTION 01 78 23 and SECTION 01 32 16 (.01 or .02).
      a. O&M data: For ducted fan coil units and air terminal units to include in emergency, operation, and maintenance manuals.
         1) Instructions for resetting minimum and maximum air volumes.
         2) Instructions for adjusting software SPs.

1.4 QUALITY ASSURANCE

A. Manufacturer's Qualifications: A minimum of 5 years of documented experience in the Work of this Section.

B. Factory/Site Demonstration Testing requirements: As specified in SECTION 01 91 00 and SECTION 23 05 00.

C. Training requirements for Manufacturer's training on the equipment as specified in SECTION 01 44 33 and SECTION 23 05 00.
   1. Engage a factory-authorized service representative to train the OWNER's maintenance personnel to adjust, operate, and maintain ducted fan coil units and air terminal units.

1.5 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

1.6 WARRANTY

A. As specified in SECTION 01 60 00 and SECTION 23 05 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Ducted Fan Coil Units:
1. Carrier Corporation
2. ENVIRO-TEC; by Johnson Controls, Inc.
3. Titus
4. Trane

B. Shutoff, Single-Duct Air Terminal Units:
1. Anemostat Products; a Mestek Company
2. Carrier Corporation
3. ENVIRO-TEC; by Johnson Controls, Inc.
4. Nailor Industries
5. Titus
6. Trane

2.2 CAPACITY

A. As shown on the Drawings.

2.3 OPERATION

A. Control devices shall be compatible with the temperature controls system:
1. Electronic modulating damper actuator: 24 VDC, powered open, spring return.
2. Electronic two-position damper actuator: 120 VAC.
3. Electric thermostat: Wall-mounted electronic type with clock display, temperature display in Fahrenheit and Celsius, and space temperature SP.
4. Electronic velocity controller: Factory calibrated and field adjustable to minimum and maximum air volumes; maintain constant airflow dictated by thermostat within 5% of SP while compensating for inlet static pressure variations up to 4 inches water gauge; and have a multipoint velocity sensor at air inlet.
5. Terminal unit controller: Pressure independent, variable air volume controller with electronic airflow transducer with multipoint velocity sensor at air inlet, factory calibrated to minimum and maximum air volumes, and having the following features:
   a. Occupied and unoccupied operating mode.
   b. Remote reset of airflow or temperature SPs.
   c. Adjusting and monitoring with portable terminal.

B. Communication with the temperature control system:
1. Wall-mounted room sensor with temperature SP adjustment and access for connection of portable operator terminal.

2.4 COMPONENTS

A. Ducted Fan Coil Units:
1. Coil section insulation: 1 inch thick, foil-faced glass fiber in accordance with ASTM C 1071 and attached with adhesive in accordance with ASTM C 916.
   a. Surface-burning characteristics: Insulation and adhesive shall have a combined maximum flame spread index of 25 and smoke developed index of 50 when tested in accordance with ASTM E 84 by a qualified testing agency.
   b. Airstream surfaces: Surfaces in contact with the airstream shall be in accordance with ASHRAE 62.1.
2. Drain pans: Polymer. Fabricate pans and drain connections in accordance with ASHRAE 62.1.
3. Chassis: Galvanized steel where exposed to moisture, with baked-enamel finish and removable access panel.
4. Cabinets: Steel with baked-enamel finish in the Manufacturer's standard paint color.
5. Filters: Minimum arrestance and a minimum efficiency reporting value in accordance with ASHRAE 52.2 and all addendums.
6. Minimum efficiency reporting value rating: 8 when tested in accordance with ASHRAE 52.2.
7. Indoor refrigerant coils: Copper tube, with mechanically bonded aluminum fins spaced no closer than 0.1 inch and brazed joints at fittings. Requirements in accordance with AHRI 210/240, and leak test to minimum 450 psig for a minimum 300 psig working pressure. Include thermal expansion valve.
8. Direct-driven fans: Double width, forward curved, centrifugal; with permanently lubricated, multispeed motor resiliently mounted in the fan inlet. Aluminum or painted steel wheels, and painted steel or galvanized steel fan scrolls.
9. Belt-driven fans: Double width, forward curved, centrifugal; with permanently lubricated, single-speed motor installed on an adjustable fan base resiliently mounted in the cabinet. Aluminum or painted steel wheels, and painted steel or galvanized steel fan scrolls.
10. Remote condensing units as specified in SECTION 23 62 00.
11. Basic unit controls:
    a. Control voltage transformer:
       1) Variable air volume shall be supplied by 480 VAC, three-phase, 60 Hz power.
          a) Provide transformer capacity greater than the sum of the connected loads.
          b) Provide control voltage for the connected devices.

b. Wall-mounted temperature sensor.
12. Electrical connection: Factory wire motors and controls for a single electrical connection.

B. Shutoff, Single Duct Air Terminal Units:
1. Configuration: Volume damper assembly inside unit casing with control components inside a protective metal shroud.
2. Casing:
a. Wall: 0.034 inch thick galvanized steel, single wall.
b. Liner: In accordance with the requirements described herein.
c. Air inlet: Round stub connection or S-slip and drive connections for duct attachment.
d. Air outlet: S-slip and drive connections, size matching inlet size.
e. Access: Removable panels for access to parts requiring service, adjustment, or maintenance; with an airtight gasket.
f. Airstream surfaces: Surfaces in contact with the airstream shall be in accordance with ASHRAE 62.1.
3. Regulator assembly: System air powered bellows section incorporating PP bellows for volume regulation and thermostatic control. Bellows shall operate at temperatures from 0°F to 140°F, be impervious to moisture and fungus, be suitable for 10 inches water gauge static pressure, and be factory tested for leaks.
4. Volume damper: Galvanized steel with peripheral gasket and self-lubricating bearings.
a. Maximum damper leakage: AHRI 880 rated, 3% of nominal airflow at 3 inches water gauge inlet static pressure.
b. Damper position: Normally open.
5. Electric resistance heating coils: Nickel-chromium heating wire, free of expansion noise and hum, mounted in ceramic inserts in a galvanized steel housing with primary automatic, and secondary manual, reset thermal cutouts. Terminate elements in SST, machine staked terminals secured with SST hardware.
a. Stages: As shown on schedules.
b. Silicon controlled rectifier controlled.
c. Access door interlocked disconnect switch.
d. Downstream air temperature sensor with local connection to override discharge air temperature to not exceed a maximum temperature SP (adjustable).
e. Nickel-chrome 80/20 heating elements.
f. Airflow switch for proof of airflow.
g. Fan interlock contacts.
h. Fused in terminal box for overcurrent protection (for coils more than 48 A).
i. Electric switches and relays.
j. Magnetic contactor for each step of control for 480 V three-phase coils.

2.5 ACCESSORIES

A. Casing Liner:
1. Fibrous-glass duct liner, in accordance with ASTM C 1071, NFPA 90A, or NFPA 90B; and with NAIMA Fibrous Glass Duct Liner Standard.
a. Minimum thickness: 1 inch.
1) Maximum thermal conductivity:
a) Type I, flexible: 0.27 (Btu*in)/(h*ft^2*degF) at 75°F mean temperature.
b) Type II, rigid: 0.23 (Btu*in)/(h*ft^2*degF) at 75°F mean temperature.
b. Antimicrobial erosion-resistant coating: Apply to the surface of the liner that will form the interior surface of the duct to act as a moisture repellent and erosion-resistant coating. Antimicrobial compound shall be tested for efficacy by an NRTL and registered by the EPA for use in HVAC systems.
c. Water-based liner adhesive:
1) In accordance with NFPA 90A or NFPA 90B and with ASTM C 916.
2) VOC content of 80 g/L or less.

B. Equipment identification plates: Furnish 16 gauge SST identification plate securely mounted on each separate equipment component in a readily visible location. Plate shall bear 1/4 inch high engraved block type black enamel filled equipment identification number and letters as specified in this Section, Manufacturer’s model, and serial numbers.

PART 3 EXECUTION

3.1 GENERAL

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Compliance: Applicable requirements in ASHRAE 62.1, Section 5 and Section 7, and ASHRAE 90.1, Section 6.

3.2 INSTALLATION

A. Hanger and Support Installation
1. In accordance with the SMACNA HVAC Duct Construction Standards, Chapter 5.
2. Building attachments: Concrete inserts, powder-actuated fasteners, or structural steel fasteners appropriate for construction materials to which hangers are being attached.
a. Where practical, install concrete inserts before placing concrete.
b. Install powder-actuated concrete fasteners after concrete is placed and completely cured.
c. Use powder-actuated concrete fasteners for standard weight aggregate concretes and for slabs more than 4 inches thick.

d. Do not use powder-actuated concrete fasteners for lightweight aggregate concretes and for slabs less than 4 inches thick.
3. Hangers exposed to view: Threaded rod and angle or channel supports.
4. Install upper attachments to structures. Select and size upper attachments with pull-out, tension, and shear capacities appropriate for supported loads and building materials where used.

B. Ducted Fan Coil Unit Installation:
1. Install fan coil units level and plumb and in accordance with NFPA 90A.
2. Suspend fan coil units from structure with elastomeric hangers.
3. Verify locations of thermostats and other exposed control sensors with Drawings and room details before installation. Install devices 48 inches above finished floor.
4. Install new filters in each fan coil unit within 2 weeks after Substantial Completion.
5. Connections:
a. Piping installation requirements are specified in other Sections. Drawings indicate general arrangement of piping, fittings, and specialties. Specific connection requirements are as follows:
1) Install piping adjacent to machine to allow service and maintenance.
2) Connect condensate drain to indirect waste.
a) Install condensate trap of adequate depth to seal against fan pressure. Install cleanouts in piping at changes of direction.
b. Connect supply-air and return-air ducts to fan coil units with flexible duct connectors in accordance with the safety requirements in UL 1995 for duct connections.
c. Connect wiring as specified in SECTION 26 05 19.

C. Terminal Unit Installation:
1. Install air terminal units level and plumb and in accordance with NFPA 90A. Maintain sufficient clearance for normal service and maintenance.
2. Install wall-mounted thermostats.

D. Connections:
1. Where installing piping adjacent to air terminal unit, allow space for service and maintenance.
2. As specified in SECTION 23 31 00 for connecting ducts to air terminal units.
3. Make connections to air terminal units with flexible connectors.

E. Identification: Label each air terminal unit with Drawing number, nominal airflow, and maximum and minimum factory-set airflows. As specified in SECTION 23 05 53 for equipment labels and warning signs and labels.

3.3 QUALITY CONTROL

A. Installation site visits as specified in SECTION 23 05 00.

B. Other tests:
1. Manufacturer's field service: Engage a factory-authorized service representative to test and inspect components, assemblies, and equipment installations, including connections.
2. Perform the following tests and inspections with the assistance of the factory-authorized service representative:
a. After installing ducted fan coil units and air terminal units and after electrical circuitry has been energized, test for compliance with requirements.
b. Operational test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.
c. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
3. Ducted fan coil units and air terminal units will be considered defective if they do not pass tests and inspections.
4. Prepare test and inspection reports.

3.4 STARTUP

A. Equipment Startup and Commissioning Requirements: As specified in SECTION 01 91 00 and SECTION 23 05 00.
1. Engage a factory-authorized service representative to perform startup service.
a. Complete installation and startup checks in accordance with Manufacturer's written instructions.
b. Verify that inlet duct connections are as recommended by the Ducted Fan Coil Unit and Air Terminal Unit Manufacturer to achieve proper performance.
c. Verify that controls and control enclosure are accessible.
d. Verify that control connections are complete.
e. Verify that nameplate and identification tag are visible.
f. Verify that controls respond to inputs as specified.

END OF SECTION

SECTION 23 37 13
DIFFUSERS, REGISTERS, AND GRILLES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for diffusers, registers, and grilles.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT

1.2 REFERENCES

A. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):

1. 70 – Method of Testing the Performance of Air Outlets and Air Inlets

1.3 SUBMITTALS

A. Product Data:

1. Data sheet: Show materials of construction, finish, and mounting details; and performance data including throw and drop, static-pressure drop, and noise ratings.
2. Diffuser, register, and grille schedule: Show Drawing designation, room location, quantity, model number, size, and accessories furnished.

B. Samples for Initial Selection: For diffusers, registers, and grilles with factory-applied color finishes.

C. Samples for Verification: For diffusers, registers, and grilles, in the Manufacturer's standard sizes to verify color selected.

D. Coordination Drawings: Reflected ceiling drawings, drawn to scale, on which the following items are shown on the drawings and coordinated with each other, using input from Installers of the items involved:

1. Revise Subparagraphs herein to suit the Project.
2. Ceiling suspension assembly members.
3. Method of attaching hangers to building structure.
4. Size and location of initial access modules for acoustical tile.
5. Ceiling-mounted items including lighting fixtures, diffusers, grilles, speakers, sprinklers, access panels, and special moldings.
6. Duct access panels.

E. Source QC reports.

1.4 QUALITY ASSURANCE

A. Verification of Performance: Rate diffusers, registers, and grilles in accordance with ASHRAE 70.

1.5 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00. Specific requirements in addition to SECTION 01 60 00 shall be as follows:

1. Provide proper storage of materials and equipment and assume complete responsibility for losses. Follow the Manufacturer’s instructions for storage.

1.6 WARRANTY

A. As specified in SECTION 01 60 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Fabricators: Subject to compliance with requirements, provide products by one of the following:

1. Rectangular and Square Ceiling Diffusers:
   a. Titus
   b. Krueger
   c. A-J Manufacturing Co., Inc.
   d. Anemostat Products; a Mestek company
   e. Carnes
   f. Hart & Cooley Inc.
   g. METALAIRE, Inc.
   h. Nailor Industries Inc.
   i. Price Industries
   j. Tuttle & Bailey
2. Adjustable Register:
   a. Titus
   b. Krueger
   c. A-J Manufacturing Co., Inc.
   d. Anemostat Products; a Mestek company
   e. Carnes
   f. Dayus Register & Grille Inc.
   g. Hart & Cooley Inc.
   h. METALAIRE, Inc.
   i. Nailor Industries Inc.
   j. Price Industries
   k. Tuttle & Bailey
3. Adjustable Grille:
   a. Titus
   b. Krueger
   c. A-J Manufacturing Co., Inc.

d. Anemostat Products; a Mestek company
e. Carnes
f. Dayus Register & Grille Inc.
g. Hart & Cooley Inc.
h. METALAIRE, Inc.
i. Nailor Industries Inc.
j. Price Industries
k. Tuttle & Bailey

2.2 COMPONENTS

A. Ceiling Diffusers:
1. Rectangular and square ceiling diffusers:
a. Devices shall be specifically designed for variable air volume flows.
b. Material: Aluminum.
c. Finish: Aluminum/metal finish to match ductwork in unfinished spaces. Baked enamel, white in finished spaces.
d. Face size: 24 inches by 24 inches.
e. Face style: Plaque.
f. Mounting: T-bar.
g. Pattern: Adjustable.
h. Dampers: Radial opposed blade.

B. Registers and Grilles:
1. Adjustable register:
a. Material: Aluminum.
b. Finish: Aluminum/metal finish to match ductwork in unfinished spaces. Baked enamel, white in finished spaces.
c. Face blade arrangement: Vertical spaced 3/4 inches apart.
d. Core construction: Integral.
e. Rear-blade arrangement: Horizontal spaced 3/4 inches apart.
f. Frame: 1 inch wide.
g. Mounting: Countersunk screw.
h. Damper type: Adjustable opposed blade.
i. Accessories: Rear-blade gang operator.
2. Adjustable grille:
a. Material: Aluminum.
b. Finish: Aluminum/metal finish to match ductwork in unfinished spaces. Baked enamel, white in finished spaces.
c. Face blade arrangement: Horizontal spaced 3/4 inches apart.
d. Core construction: Integral.
e. Rear-blade arrangement: Vertical spaced 3/4 inches apart.
f. Frame: 1 inch wide.
g. Mounting frame: Filter.
h. Mounting: Countersunk screw.

PART 3 EXECUTION

3.1 PREPARATION

A. Examine areas where diffusers, registers, and grilles are to be installed for compliance with requirements for installation tolerances and other conditions affecting the performance of equipment.
B. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install diffusers, registers, and grilles level and plumb.
B. Ceiling-Mounted Outlets and Inlets: Drawings show the general arrangement of ducts, fittings, and accessories. Air outlet and inlet locations have been shown to achieve design requirements for air volume, noise criteria, airflow pattern, throw, and pressure drop. Make final locations as shown on the Drawings, as much as practical. For units installed in lay-in ceiling panels, locate units in the center of panel. Where architectural features or other items conflict with installation, notify the ENGINEER for a determination of the final location.
C. Install diffusers, registers, and grilles with airtight connections to ducts and to allow service and maintenance of dampers, air extractors, and fire dampers.

3.3 ADJUSTING

A. After installation, adjust diffusers, registers, and grilles to the air patterns shown on the Drawings, or as directed, before starting air balancing.

END OF SECTION

SECTION 23 37 23
HVAC GRAVITY VENTILATORS

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for HVAC gravity ventilators.
- B. Related Sections:
  1. SECTION 01 32 16 (.01 or .02) – COST LOADED SCHEDULE
  2. SECTION 01 44 33 – MANUFACTURER'S SERVICES
  3. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
  4. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
  5. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
  6. SECTION 07 62 00 – SHEET METAL FLASHING AND TRIM
  7. SECTION 07 92 00 – JOINT SEALANTS
  8. SECTION 23 05 00 – COMMON WORK RESULTS FOR MECHANICAL
  9. SECTION 23 05 53 – MECHANICAL IDENTIFICATION
  10. SECTION 23 31 00 – DUCTWORK AND ACCESSORIES

1.2 REFERENCES
- A. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
  1. 62.1 – Ventilation for Acceptable Indoor Air Quality
  2. 90.1 – Energy Standard for Buildings except Low-Rise Residential Buildings
- B. American Welding Society (AWS)
  1. D1.2 – Structural Welding Code – Aluminum
  2. D1.3 – Structural Welding Code – Sheet Steel
- C. ASTM International (ASTM):
  1. A 653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
  2. A 666 – Standard Specification for Annealed or Cold-Worked Austenitic Stainless Steel Sheet, Strip, Plate, and Flat Bar
  3. A 780 – Standard Practice for Repair of Damaged and Uncoated Areas of Hot-Dip Galvanized Coatings
  4. B 209 – Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
  5. B 221 – Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
  6. D 1187 – Standard Specification for Asphalt-Base Emulsions for Use as Protective Coatings for Metal
  7. E 488 – Standard Test Methods for Strength of Anchors in Concrete Elements

1.3 COORDINATION
- A. Coordinate sizes and locations of roof curbs, equipment supports, and roof penetrations with actual equipment provided.

1.4 SUBMITTALS
- A. Product data: For each type of product. For louvered penthouse ventilators specified to bear the AMCA seal, include printed catalog pages, showing specified models with appropriate AMCA certified ratings seals.
- B. Shop Drawings for Gravity Ventilators:
  1. Include Drawings, elevations, sections, details, ventilator attachments to curbs, and curb attachments to roof structure.
  2. Show weep paths, gaskets, flashing, sealant, and other means of preventing water intrusion.
- C. Samples: For each exposed product and for each color and texture specified.
- D. Informational Submittals:
  1. Coordination Drawings: Roof-framing drawings and other details, drawn to scale, and coordinated with each other, based on input from installers of the items involved.
  2. Welding certificates.
- E. O&M Special Requirements: O&M data requirements as specified in SECTION 01 78 23 and SECTION 01 32 16 (.01 or .02).

1.5 QUALITY ASSURANCE
- A. Welding Qualifications: Qualify procedures and personnel in accordance with the following:
  1. AWS D1.2.
  2. AWS D1.3.
- B. Performance Requirements:
  1. Structural performance: Ventilators shall withstand the effects of gravity loads and the following loads and stresses within limits and under conditions indicated herein without permanent deformation of ventilator components, noise, or metal fatigue caused by ventilator blade rattle or flutter, or permanent damage to fasteners and anchors. Wind pressures shall be considered to act normal to the face of the building.
     - a. Wind loads: Roof-mounted equipment shall be able to withstand a uniform pressure of 100 lbf/sf, acting inward or outward.
     - b. Snow load: Unit to withstand a minimum of 20 lbf/sf snow load or as required by structural Drawings whichever is higher.
  2. ASHRAE 90.1 compliance: In accordance with ASHRAE 90.1.
  3. ASHRAE 62.1 compliance: In accordance with Section 5 and Section 7.
  4. Thermal movements: Allow for thermal movements from ambient and surface temperature changes, without buckling, opening of joints, overstressing of components, failure of connections, or other detrimental effects.
     - a. Temperature change (range):
       - 1) Ambient: 120°F.

2) Material surfaces: 180°F.
5. Water entrainment: Limit water penetration through unit in accordance with ASHRAE 62.1.
6. Capacities and characteristics (refer to schedules as shown on the Drawings):
a. Type: Hooded penthouse.
b. Maximum air pressure drop: Not more than 0.10 inches water gauge static pressure drop.
c. Maximum free area velocity: 500 fpm intake and 1000 fpm relief.
d. Function: Intake or relief.
C. Factory/site demonstration testing requirements as specified in SECTION 01 91 00 and SECTION 23 05 00.
D. Training requirements for Manufacturer’s training on the equipment as specified in SECTION 01 44 33 and SECTION 23 05 00.

1.6 DELIVERY, STORAGE, AND HANDLING
A. As specified in SECTION 01 60 00.

1.7 WARRANTY
A. As specified in SECTION 01 60 00 and SECTION 23 05 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
A. ACME
B. Greenheck
C. Loren Cook

2.2 MATERIALS
A. Aluminum Extrusions: ASTM B 221, Alloy 6063-T5 or T-52.
B. Aluminum Sheet: ASTM B 209, Alloy 3003 or 5005, with temper as required for forming or as otherwise recommended by the metal producer for required finish.
C. Galvanized Steel Sheet: ASTM A 653, G90 zinc coating, mill phosphatized.
D. SST Sheet: ASTM A 666, Type 304, with No. 4 finish.
E. Fasteners: Same basic metal and alloy as fastened metal or 300 Series SST unless otherwise shown on the Drawings. Do not use metals that are incompatible with joined materials.
1. Use types and sizes to suit unit installation conditions.
2. Use hex head or Phillips pan head screws for exposed fasteners unless otherwise shown on the Drawings.
F. Post-Installed Fasteners for Concrete and Masonry: Torque-controlled expansion anchors made from SST components, with capability to sustain without failure a load equal to four times the loads imposed for concrete, or six times the load imposed for masonry, as determined by testing in accordance with ASTM E 488, conducted by a qualified independent testing agency.
G. Bituminous Paint: Cold-applied asphalt emulsion in accordance with ASTM D 1187.

2.3 COMPONENTS
A. Hooded Ventilators:
1. Description: Hooded rectangular penthouse for intake or relief air.
2. Source limitations: Obtain hooded ventilators from a single Manufacturer.
3. Construction:
a. Material: Aluminum, of the thickness required to be in accordance with structural performance requirements, but not less than 0.063 inch thick base and 0.050 inch thick hood; suitably reinforced.
b. Insulation: None.
c. Bird screening: Aluminum, 1/2 inch square mesh or flattened, expanded aluminum, 3/4 inch diamond mesh wire.
d. Insect screening: Aluminum, 18 inch by 16 inch mesh wire.
4. Galvanized steel finish:
a. Surface preparation: Clean surfaces of dirt, grease, and other contaminants. Clean welds, mechanical connections, and abraded areas, and repair galvanizing in accordance with ASTM A 780. Apply a conversion coating suited to the organic coating to be applied over it.
b. Factory priming for field-painted finish: Where field painting after installation is as shown on the Drawings, apply an air-dried primer immediately after cleaning and pretreating.
c. Baked enamel finish: Immediately after cleaning and pretreating, apply the Manufacturer's standard finish consisting of prime coat and thermosetting topcoat, with a minimum DFT of 1 mil for topcoat and an overall DFT of 2 mils.
1) Color and gloss: As indicated by the Manufacturer's designations.
5. Dampers:
a. Location: Hood neck.
b. Control: Motorized.

2.4 FABRICATION
A. Factory or shop fabricate gravity ventilators to minimize field splicing and assembly. Disassemble units to the minimum extent as necessary for shipping and handling. Clearly mark units for reassembly and coordinated installation.
B. Fabricate frames, including integral bases, to fit in openings of the sizes shown on the Drawings, with allowances made for fabrication and installation tolerances, adjoining material tolerances, and perimeter sealant joints.
C. Fabricate units with closely fitted joints and exposed connections accurately located and secured.
D. Fabricate supports, anchorages, and accessories required for complete assembly.
E. Perform shop welding by AWS certified procedures and personnel.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install gravity ventilators level, plumb, and at indicated alignment with adjacent Work.

B. Secure gravity ventilators to roof curbs with zinc-plated hardware that in accordance with the wind fastening requirements. Use concealed anchorages where possible.

C. Install goosenecks on curb base where throat size exceeds 9 inches by 9 inches.

D. Install gravity ventilators with clearances for service and maintenance.

E. Install perimeter reveals and openings of uniform width for sealants and joint fillers.

F. Install concealed gaskets, flashings, joint fillers, and insulation as installation progresses. Install as specified in SECTION 07 92 00 for sealants applied during installation.

G. Label gravity ventilators as specified in SECTION 23 05 53.

H. Protect galvanized and nonferrous metal surfaces from corrosion or galvanic action by applying a heavy coating of bituminous paint on surfaces that will be in contact with concrete, masonry, or dissimilar metals.

I. Repair finishes damaged by cutting, welding, soldering, and grinding. Restore finishes, so no evidence remains of corrective Work. Return items that cannot be refinished in the field to the factory, make required alterations, and refinish the entire unit or provide new units.

J. As specified in SECTION 07 62 00 for flashing and counterflashing of roof curbs.

K. Connections: Duct installation and connection requirements shall be as specified in SECTION 23 31 00. Drawings show the general arrangement of ducts and duct accessories.

3.2 QUALITY CONTROL

A. Hydraulic testing requirements as specified in SECTION 23 05 00.

B. Installation site visits as specified in SECTION 23 05 00.

3.3 STARTUP

A. Startup and commissioning requirements for the equipment specified herein as specified in SECTION 01 91 00 and SECTION 23 05 00.

3.4 ADJUSTING

A. Adjust damper linkages for proper damper operation.

END OF SECTION

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SECTION 23 62 00
PACKAGED OUTDOOR AIR CONDITIONING UNITS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for packaged outdoor air conditioning units.

B. Related Sections:

1. SECTION 01 32 16 (.01 or .02) – COST LOADED SCHEDULE
2. SECTION 01 44 33 – MANUFACTURER'S SERVICES
3. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
4. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
5. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
6. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE
7. SECTION 07 53 00 – ELASTOMERIC MEMBRANE ROOFING
8. SECTION 23 05 00 – COMMON WORK RESULTS FOR MECHANICAL

1.2 REFERENCES

A. Air-Conditioning, Heating and Refrigeration Institute (AHRI):

1. 340/360 – Performance Rating of Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment

B. American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE):

1. 15 & 34 – Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants
2. 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings, Section 6: Heating, Ventilating, and Air-Conditioning

C. American Society of Mechanical Engineers (ASME):

1. Boiler Pressure Vessel Code

D. National Fire Protection Association (NFPA):

1. 70 – National Electric Code (NEC)
2. 90A – Standard for the Installation of Air-Conditioning and Ventilating Systems

1.3 COORDINATION

A. Where applicable, coordinate sizes and locations of concrete bases. Cast anchor bolt inserts into bases.

B. Coordinate installation of roof curbs, equipment supports, and roof penetrations.

C. Coordinate location of piping and electrical rough-ins.

1.4 SUBMITTALS

A. Product Data: For each compressor and condenser unit. Include rated capacities, operating characteristics, and furnished specialties and accessories. Include equipment dimensions, weights and structural loads, required clearances, method of field assembly, components, and location and size of each field connection.

B. Shop Drawings: For compressor and condenser units. Include Drawings, elevations, sections, details, and attachments to other Work.

C. Wiring Diagrams: For power, signal, and control wiring.

D. Delegated-design Submittal: For compressor and condenser units as shown on the Drawings and in accordance with performance requirements and design criteria, including analysis data shall be prepared, signed, and sealed by the Professional Engineer registered in the State of Colorado.

1. Vibration isolation base details: Detail fabrication including anchorages and attachments to structure and to supported equipment. Include adjustable motor bases, rails, and frames for equipment mounting.
2. Design calculations: Calculate requirements for selecting vibration isolators and for designing vibration isolation bases.

E. Informational Submittals:

1. Coordination Drawings: Drawings, drawn to scale, on which the following items are as shown on the Drawings and coordinated with each other, based on input from installers of the items involved:
   a. Structural members to which compressor and condenser units will be attached.
   b. Liquid and vapor pipe sizes.
   c. Refrigerant specialties.
   d. Piping including connections, oil traps, and double risers.
   e. Compressors.
   f. Evaporators.

F. Closeout Submittals: O&M data for compressor and condenser units to include in emergency, operation, and maintenance manuals.

G. O&M Special Requirements: O&M data requirements as specified in SECTION 01 78 23 and SECTION 01 32 16 (.01 or .02).

1.5 QUALITY ASSURANCE

A. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, by a qualified testing agency, and marked for intended location and application.

B. Fabricate and label refrigeration system in accordance with ASHRAE 15 & 34.

C. ASHRAE 90.1 Compliance: In accordance with ASHRAE 90.1, Section 6.

D. ASME Compliance: Fabricate and label water-cooled compressor and condenser units in accordance with ASME Boiler Pressure Vessel Code , Section VIII, and Division 1.

E. Factory/Site Demonstration Testing Requirements: As specified in SECTION 01 91 00 and SECTION 23 05 00.

F. Minimum Efficiency Ratio: 12.2.

G. Ultra-Quiet Operation: Average A-weighted sound power = 84.6 dbA or less.

H. Training Requirements: Training requirements for Manufacturer's training on the equipment as specified in SECTION 01 44 33 and SECTION 23 05 00.

1.6 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

1.7 WARRANTY

A. As specified in SECTION 01 60 00 and SECTION 23 05 00. Specific requirements in addition to these sections shall be:

1. Special warranty: Manufacturer's standard form in which the Manufacturer agrees to repair or replace components of compressor and condenser units that fail in materials or workmanship within the specified warranty period.
   a. Failures include, but are not limited to, the following:
      1) Compressor failure.
      2) Condenser coil leak.
   b. Warranty period (compressor only): 10 years from date of Substantial Completion.
   c. Warranty period (components other than compressor): 5 years from date of Substantial Completion.
   d. Warranty period (condenser coil only): 5 years from date of Substantial Completion.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Carrier
B. Daikin
C. Trane

2.2 COMPONENTS

A. Compressor and Condenser Units, Air Cooled, 1 to 5 Tons:

1. Factory assembled and tested; consisting of compressor, condenser coil, fan, motors, refrigerant reservoir, and operating controls.
2. Compressor: Scroll, direct drive, hermetically sealed, with rubber vibration isolators.
   a. Motor: Single speed, and includes thermal-sensitive and current-sensitive overload devices, start capacitor, relay, and contactor.
   b. Two-speed compressors may not be available from each Manufacturer listed herein.
   c. Two-speed compressor: Include manual-reset, high-pressure switch and automatic-reset, low-pressure switch.
   d. One of the accumulators listed herein is available only on 4-ton and 5-ton units.
   e. Accumulator: Suction tube.
3. Refrigerant: R-410A.
4. Condenser coil: Seamless copper-tube, aluminum-fin coil; circuited for integral liquid sub-cooler, with removable drain pan and brass service valves with service ports.
5. Condenser fan: Direct-drive, aluminum propeller fan; with permanently lubricated, totally enclosed fan motor with thermal-overload protection and ball bearings.
6. Accessories:
   a. Hail guard.
   b. Cycle protector: Automatic-reset timer to prevent rapid compressor cycling.
   c. Evaporator freeze thermostat: Temperature-actuated switch that stops unit when evaporator reaches freezing temperature.
   d. Filter-dryer.
   e. High-pressure switch: Automatic-reset switch cycles compressor off on high refrigerant pressure.
   f. Liquid-line solenoid.
   g. Low-pressure switch: Automatic-reset switch cycles compressor off on low refrigerant pressure.
   h. Pre-charged and insulated suction and liquid tubing.
   i. Thermostatic expansion valve.
   j. Time-delay relay: Continues operation of evaporator fan after compressor shuts off.
   k. Unit casing: Galvanized steel, G90, finished with baked enamel; with removable panels for access to controls, weep holes for water drainage, and mounting holes in base. Mount service valves, fittings, and gauge ports on exterior of casing. Provide 1 inch thick neoprene coated glass fiber insulation with minimum R-value of 12, conforming to NFPA 90A requirements.
7. Capacities and characteristics: Compressor and condenser units as shown on the Drawings.

B. Compressor and Condenser Units, Air Cooled, 6 to 20 Tons:

1. Factory assembled and tested, air cooled; consisting of casing, compressors, condenser coils, condenser fans and motors, and unit controls.
2. Compressor: Hermetic scroll compressor designed for service with crankcase sight glass, crankcase heater, and backseating service access valves on suction and discharge ports.
3. Capacity control: On-off compressor cycling.
4. Refrigerant: R-410A.
5. Condenser coil: Seamless copper-tube, aluminum-fin coil, including sub cooling circuit and back seating liquid-line service access valve. Factory pressure test coils, then dehydrate by drawing a vacuum and fill with a holding charge of nitrogen or refrigerant.
6. Condenser fans: Propeller-type vertical discharge; either directly or belt driven. Include the following:
   a. Permanently lubricated, ball-bearing totally enclosed motors.
   b. Separate motor for each fan.
   c. Dynamically and statically balanced fan assemblies.

7. Operating and safety controls include the following:
    a. Manual-reset, high-pressure cutout switches.
    b. Automatic-reset, low-pressure cutout switches.
    c. Low-oil-pressure cutout switch.
    d. Compressor-winding thermostat cutout switch.
    e. Three-leg, compressor-overload protection.
    f. Control transformer.
    g. Magnetic contactors for compressor and condenser fan motors.
    h. Timer to prevent excessive compressor cycling.
8. Manifold two-stage compressors.
9. Accessories:
    a. Hail guard.
    b. Filter-dryer.
    c. Gauge panel: Package with refrigerant circuit suction and discharge gauges.
    d. Thermostatic expansion valve.
    e. Hot-gas bypass kit.
    f. Part-winding-start timing relay, circuit breakers, and contactors.
10. Unit casings: Designed for outdoor installation with weather protection for components and controls and with removable panels for required access to compressors, controls, condenser fans, motors, and drives. Additional features include the following:
    a. Steel, galvanized with G90 zinc coating, for exposed casing surfaces; treated and finished with the Manufacturer's standard paint coating.
    b. Perimeter base rail with forklift slots and lifting holes to facilitate rigging.
    c. Gasketed control panel door.
    d. Non-fused disconnect switch, factory mounted and wired, for single external electrical power connection.
    e. Insulation: 1 inch thick neoprene coated glass fiber with minimum R-value of 12, conforming to NFPA 90A requirements.
    f. Condenser coil hail guard.
11. Capacities and characteristics: Compressor and condenser units as shown on the Drawings.

C. Dampers:
1. Galvanized air-foil type, SST sleeve bearings, parallel blade configuration.
2. Leakage shall be less than 2% when fully closed and operating against a pressure differential of 1/2 inch water gauge.
3. Equipped with modulating electric actuators.
4. Gaskets: Provide tight fitting dampers with edge gaskets.

D. Damper Actuators:
1. 120 V with gear train sealed in oil.
2. Minimum outside air SP.

E. Supply Fan:
1. Forward curved double inlet centrifugal type, resiliently mounted with belt drive, and rubber isolated hinge-mounted motor. Provide adjustable pitch pulley for ±20% speed adjustment.
2. Motor: Standard Manufacturer supplied motor.
3. Fan wheel shall be double width double inlet type with forward curve blades, dynamically balanced to operate smoothly throughout the entire range of operation.
4. Bearings shall be heavy duty, self-aligning, sealed ball type in a pillow block CI housing selected for a minimum L50 life in excess of 200,000 hours at maximum operating speed.

F. Disconnect Switch: Factory mounted on equipment.

G. Shafts, Drive Belts, and Sheaves:
1. Furnish multiple drive belts where motor horsepower is 2 hp or larger.
2. Sheaves capable of providing 150% of motor horsepower. Adjustable speed variation of +/-20% is required.
3. Belt guards: Meet federal and State of Colorado OSHA requirements for safety protection, and be easily removable by one person.
4. Tachometer access holes: Large enough to accept standard tachometer drive shaft.
5. Center punch fan shaft to accommodate tachometer readings.

H. Convenience Outlet: Unit shall contain a 120 VAC GFCI convenience outlet.

I. Controls:
1. Standard safety features:
    a. Loss of charge/low pressure switch.
    b. High pressure switch.
    c. Evaporator coil freeze protection thermostat.
    d. Compressor short cycle protection.
    e. Air proving switch.
    f. Return air smoke sensor.
2. Terminal strip control interface with the ECP:
    a. Fan on/off.
    b. Cooling on/off.
    c. Outside supply air and return air damper position.

d. Alarms.
e. Smoke detector output.

J. Air Filters: 2 inch thick, MERV 8.

2.3 ACCESSORIES

A. 6 Inches High Concrete Equipment Pad: As specified in SECTION 03 30 00.
B. Roof Curbs: Roof curbs as specified in SECTION 07 72 13.
C. Equipment Identification Plates: Furnish a 16 gauge SST identification plate securely mounted on each separate equipment component in a readily visible location. Plate shall bear 1/4 inch high engraved block type black enamel filled equipment identification number and letters as specified in this Section, and the Manufacturer’s model and serial numbers.

PART 3 EXECUTION

3.1 PREPARATION

A. Examine substrates, areas, and conditions, with installer present, for compliance with requirements for installation tolerances and other conditions affecting performance of compressor and condenser units.
B. Examine roughing-in for refrigerant piping systems to verify actual locations of piping connections before equipment installation.
C. Examine walls, floors, and roofs for suitable conditions where compressor and condenser units will be installed.
D. Proceed with installation only after unsatisfactory conditions have been corrected.

3.2 INSTALLATION

A. Install units level and plumb, firmly anchored in locations as shown on the Drawings.
B. Install roof-mounting units on equipment supports as shown on the Drawings with roofing as specified in SECTION 07 53 00.
C. Equipment Mounting:
1. Install compressor and condenser units on cast-in-place concrete equipment bases. Bases and foundations as specified in SECTION 03 30 00.
2. In accordance with vibration isolation devices.
D. Vibration:
1. Statically and dynamically balance fan equipment.
2. Perform field testing on rotating equipment to determine actual operating vibration.
3. If vibration limits described therein are exceeded, rebalance equipment in-place, if directed by the ENGINEER, until design tolerances are met.
4. Provide open spring vibration isolators (with neoprene waffle base pads top and bottom) selected for a minimum of 1 1/2 inch deflection (unless otherwise specified).
E. Maintain the Manufacturer's recommended clearances for service and maintenance.
F. Loose Components: Install electrical components, devices, and accessories that are not factory mounted.
G. Connections:
1. Where installing piping adjacent to equipment, allow space for service and maintenance of equipment.
2. Connect pre-charged refrigerant tubing to the unit's quick-connect fittings. Install tubing so it does not interfere with access to the unit. Install furnished accessories.
3. Connect refrigerant piping to air-cooled compressor and condenser units; maintain required access to unit. Install furnished field-mounted accessories.
4. Connect refrigerant and condenser-water piping to water-cooled compressor and condenser units. Maintain clear tube removal space. Install shutoff valve and union or flange at each water supply connection; install balancing valve and union or flange at each return connection.

3.3 QUALITY CONTROL

A. Verification of Performance: Rate compressor and condenser units in accordance with AHRI 340/360.
B. Energy Efficiency: Equal to or greater than prescribed by ASHRAE 90.1, Section 6.
C. Test and inspect shell and tube condensers in accordance with ASME Boiler Pressure Vessel Code, Section VIII, and Division 1.
D. Perform tests and inspections.
1. Manufacturer's field service: Engage a factory-authorized service representative to inspect, test, and adjust components, assemblies, and equipment installations, including connections, and to assist in testing.
E. Tests and Inspections:
1. Perform each visual and mechanical inspection and electrical test. Certify compliance with test parameters.
2. Leak test: After installation, charge system with refrigerant and oil and test for leaks. Repair leaks, replace lost refrigerant and oil, and retest until no leaks exist.
3. Operational test: After electrical circuitry has been energized, start units to confirm proper motor operation and unit operation, product capability, and compliance with requirements.
4. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.
5. Verify proper airflow over coils.
F. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
G. Compressor and condenser units will be considered defective if they do not pass tests and inspections.
H. Prepare test and inspection reports.

3.4 STARTUP

A. Startup and commissioning requirements for the equipment specified herein as specified in SECTION 01 91 00 and SECTION 23 05 00.

B. Startup Service:
   1. Engage a factory-authorized service representative to perform startup service.
      a. Complete installation and startup checks in accordance with the Manufacturer's instructions and perform the following:
         1) Inspect for physical damage to unit casing.
         2) Verify that access doors move freely and are weathertight.
         3) Clean units and inspect for construction debris and comb out bent sections of condenser coils.
         4) Verify that bolts and screws are tight.
         5) Adjust vibration isolation and flexible connections.
         6) Verify that controls are connected and operational.
   2. Lubricate bearings on fan motors.
   3. Verify that fan wheel is rotating in the correct direction and is not vibrating or binding.
   4. Adjust fan belts to proper alignment and tension.
   5. Start unit in accordance with the Manufacturer's instructions and complete the Manufacturer's startup checklist.
   6. Measure and record airflow and air temperature rise over coils.
   7. Verify proper operation of condenser capacity control device.
   8. Verify that vibration isolation and flexible connections properly dampen vibration transmission to structure.
   9. After startup and performance test, lubricate bearings, and replace air filters with new, permanent filters.

C. Demonstration: Engage a factory-authorized service representative to train the OWNER's maintenance personnel to adjust, operate, and maintain compressor and condenser units.

END OF SECTION

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SECTION 23 74 00
PACKAGED OUTDOOR HVAC EQUIPMENT

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for packaged outdoor HVAC equipment.
- B. Related Sections:
  1. SECTION 01 33 00 – SUBMITTAL PROCEDURES
  2. SECTION 01 44 33 – MANUFACTURER’S SERVICES
  3. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
  4. SECTION 23 05 00 – COMMON WORK RESULTS FOR MECHANICAL
  5. SECTION 23 05 93 – HVAC SYSTEMS TESTING, ADJUSTING, AND BALANCING
  6. SECTION 23 09 00 – HVAC CONTROLS
  7. SECTION 26 70 00 – MOTORS

1.2 REFERENCES
- A. Air-Conditioning, Heating and Refrigeration Institute (AHRI):
  1. 410 – Forced-Circulation Air-Cooling and Air-Heating Coils
- B. American Bearing Manufacturers Association (ABMA):
  1. 9 – Load Ratings and Fatigue Life for Ball Bearings
  2. 11 – Load Ratings and Fatigue Life for Roller Bearings
- C. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
  1. 15 & 34 – Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants
  2. 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings
- D. National Fire Protection Association (NFPA):
  1. 90A – Standard for the Installation of Air Conditioning and Ventilating Systems
- E. Underwriter’s Laboratories (UL):
  1. 900 – Air Filter Units

1.3 SUBMITTALS
- A. Meet Submittal requirements as specified in SECTION 01 33 00 and SECTION 23 05 00.
- B. Shop Drawings:
  1. Specifications, descriptive drawings, catalog cuts, and descriptive literature which shall include make, model, dimensions, performance at site conditions, weight of products, fuse type/rating/manufacturer, and electrical schematics.
  2. Manufacturer's installation and startup instructions.
  3. Complete unit control drawings with legend, abbreviations, identification of components and any other ancillary devices; legibly indicate all electrical connections internal, electrical interface connections external.
- C. Quality Control Submittals:
  1. Manufacturer's certificate of conformance for the air conditioning units and motors.
  2. Recommended procedures for protection and handling of equipment and materials prior to installation.
  3. Detailed information on structural, mechanical, electrical, or other modifications necessary to adapt the arrangement or details shown to the equipment furnished.
- D. Contract Closeout Submittals: O&M manuals and maintenance data.
- E. Warranty Documentation:
  1. Sample warranty.
  2. Warranty.
- F. Extra Materials:
  1. Furnish, tag, and box for shipment and storage the following spare parts and materials:
     - a. Filters: Provide four complete sets per unit.
     - b. Drive belts: Provide one complete set per unit.
     - c. Fuses: Provide two compete sets per unit.

1.4 WARRANTY
- A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the packaged outdoor HVAC equipment system and associated appurtenances.
- B. Warranty for 10 years from the Substantial Completion date for the satisfactory performance and installation of the packaged outdoor HVAC heat exchanger system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
- A. Make Up Air Unit:
  1. Carrier
  2. Daikin
  3. Trane
  4. Greenheck
- B. Air Handling Unit:
  1. Carrier
  2. Daikin
  3. Trane
  4. Greenheck

C. Filter Media:
 1. MERV 8

2.2 MATERIALS

A. General:
 1. Fans:
  a. Forward curved double inlet centrifugal type, resiliently mounted with belt drive, and rubber isolated hinge mounted motor. Provide adjustable pitch pulley for ±20% speed adjustment.
  b. Fan wheel shall be double width double inlet type with forward curve blades, dynamically balanced to operate smoothly throughout the entire range of operation.
  c. Motor: As specified in SECTION 26 70 00.
 2. Bearings and drives:
  a. Bearings: Heavy duty pillow block housing type, self-aligning, grease-lubricated ball bearings with ABMA 9 L-50 life of 200,000 hours, or roller bearings ABMA 11 L-50 life of 200,0000 hours. Regreasable ports shall be located inside an access panel with extended grease lines secured to a support bracket within eye sight from outside the unit.
  b. Shafts: Solid, hot-rolled steel, ground and polished, with key-way, and protectively coated with lubricating oil.
  c. V-belt drive: CI or steel sheaves, dynamically balanced, bored to fit shafts and keyed. Variable and adjustable pitch sheaves for motors 15 hp and under selected so required rpm is obtained with sheaves set at mid-position; fixed sheave for 20 hp and over, matched belts, and drive rated as recommended by the Manufacturer or minimum 1 1/2 times nameplate rating of motor.
  d. Belt guard: 0.106 inch thick, 3/4-inch diamond mesh wire screen welded to steel angle frame, prime coated. Secure to fan or fan supports without short circuiting vibration isolation, with provision for adjustment of belt tension, lubricated, and use of tachometer with guard in place.
 3. Filters:
  a. Filter box: Section with filter guides, access doors from both sides, for side loading with gaskets and blank-off plates.
  b. Filter media: UL 900 listed, MERV 8 pre and final filters.
 4. Dampers:
  a. Galvanized steel with double-skin airfoil design, compressible jamb seals and extruded-vinyl blade-edge seal on the blades.
  b. Damper leakage: In accordance with ASHRAE 90.1.
  c. Damper actuator: As specified in SECTION 23 09 00.
 5. Power:
  a. Units shall provide full heating and/or cooling capacity at the rated voltage and altitude without using the SF.
  b. Units shall contain a 1.5 SF.
  c. Units shall contain a 120 VAC GFCI convenience outlet.
 6. Controls:
  a. As shown on the Drawings and as specified in SECTION 23 09 00.
  b. Standard safety features:
   1) Loss of charge/low pressure switch.
   2) High pressure switch.
   3) Air proving switch.

B. Make Up Air Unit:
 1. Unit tag: MAU6880.
 2. General description: Slab-mounted, self-contained, packaged, factory assembled and pre-wired, consisting of cabinet and frame, supply fan, air filters, electric heating coil, and smoke detector. Refer to Drawings for capacities and design parameters.
 3. Heating equipment:
  a. General: Electric open coil heating element, induced draft.
  b. Modified for high altitude operation, and capacities corrected to meet stated outputs at site conditions. Reference the Drawings for required capacities.
  c. Efficiency: Premium.
  d. Silicon controlled rectifier control to allow for heat output modulation up to max heating capacity.

C. Air Handling Unit:
 1. Unit tag: AHU6890.
 2. General description: Slab-mounted unit, factory assembled and pre-wired, consisting of cabinet and frame, supply fan, air filters, direct expansion cooling coil, economizer functionality, and mixing box. Capacities and design parameters as shown on the Drawings.
 3. Direct expansion coil:
  a. Performance shall be certified in accordance with AHRI 410.
  b. Design and tested in accordance with ASHRAE 15 & 34.
  c. Seamless copper tubes with aluminum fins. Headers shall be copper with brazed joints.
  d. Right side connections.
 4. Filter mixing box section:
  a. Access doors as shown on the Drawings.
  b. Return and outside air intake with opposed blade modulating damper.
  c. 2-inch angle filters.

2.3 ACCESSORIES

A. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 lbs.

B. Equipment Identification Plates: Furnish a 16 gauge SST identification plate securely mounted on each separate equipment component in a readily visible location. Plate shall bear 1/4 inch high engraved block type black enamel filled equipment identification number and letters as specified in this Section.

2.4 FABRICATION:

A. Cabinet: 18 gauge, G90 galvanized steel with baked enamel finish. Access doors or removable access panels with multiple hinges and latch system. Base frame shall be minimum 16 gauge and be a full perimeter design, with access doors or removable panels of minimum 18 gauge. Slide out aluminum or SST condensate pan.

B. Insulation: Minimum 3/4 inch thick fiberglass with a foil face surface. Insulation shall be glued to the panel as well as mechanically fastened.

C. Air Filters: 2 inch thick, 65% efficient glass fiber disposable media.

D. Seal: Supply and return air openings shall be sealed to prevent any water from entering the building.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with the Manufacturer's instructions.

B. Install in accordance with NFPA 90A.

3.2 QUALITY CONTROL

A. Manufacturer's Services: Provide a Manufacturer's representative at the site for a minimum 2 person-days, and as specified in SECTION 01 44 33, for installation assistance, inspection and certification of proper installation, equipment testing, startup assistance, and training of OWNER's personnel for specified equipment.

B. Testing and Performance: Equipment commissioning and testing shall be as specified in SECTION 01 91 00 and SECTION 23 05 00.

3.3 ADJUSTING

A. Test and balance fans and motors as specified in SECTION 23 05 93.

END OF SECTION

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SECTION 23 76 00
EVAPORATIVE AIR COOLING EQUIPMENT

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for evaporative air cooling equipment.

B. Related Sections:

1. SECTION 23 05 93 – HVAC SYSTEMS TESTING, ADJUSTING, AND BALANCING

1.2 REFERENCES

A. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):

1. 90A – Energy Conservation in New Building Design

B. National Electrical Manufacturers' Association (NEMA):

1. MG 1 – Motors and Generators

1.3 SUBMITTALS

A. Product Data:

1. Submittals shall include a complete itemized Bill of Material, including assemblies, subassemblies, components, devices, equipment, and materials with complete model number with options.
2. Published literature: Indicate dimensions, weights, capacities, ratings, gauges and finishes of materials, and electrical characteristics and connection requirements.
3. Filters: Data for filter media, filter performance data, filter assembly, and filter frames.
4. Fans: Performance and fan curves with specified operating point clearly plotted, power, rpm.
5. Sound power level data: Fan outlet and casing radiation at rated capacity.
6. Electrical requirements: Power supply wiring including wiring diagrams for interlock and control wiring, clearly indicating factory-installed and field-installed wiring.
7. Detailed power and control wiring diagrams, including numbered terminals, complete control schematics including equipment, devices, variable speed drives, etc.
8. Detailed electrical drawings showing the equipment dimensions, size, and locations of connections for equipment.

B. Shop Drawings: Indicate assembly, unit dimensions, weight loading, required clearances, construction details, field connection details, and electrical characteristics and connection requirements.

C. Manufacturer's Instructions: Include installation instructions.

D. Maintenance Data: Include instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams.

E. Contract Closeout Submittals:

1. O&M manuals and maintenance data. O&M manuals shall include Shop Drawing information and quality control Submittals.
2. Use the DW approved dropbox for Final as-built EI&C Drawings and provide quality hardcopy media, 11 inch by 17 inch format, and not folded.
3. Special guarantees.
4. Testing and balancing reports.

F. Extra Materials:

1. Furnish, tag, and box for shipment and storage the following spare parts and materials:
   a. Cooling media: One complete set.
   b. Drive belts: One complete set.
   c. Air filters: One complete set.

1.4 QUALITY ASSURANCE

A. Cooling Equipment: Minimum operating efficiencies, defined as coefficient of performance and energy efficiency ratio, in accordance with ASHRAE 90A, Chapter 6.

B. Factory Warranties: 2-year parts and labor.

C. Manufacturer Qualifications: A minimum of 3 years of documented experience in the Work of this Section.
Regulatory Requirements: Products requiring electrical connection shall be listed and classified by UL as suitable for the purpose specified and indicated.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Mountain States Equipment Company, Airex

2.2 MATERIALS

A. Capacity: As shown on the Drawings.

B. Altitude Operation: Performance ratings and airflow shall be for a site altitude of 5,400 feet above mean sea level. The ambient inlet conditions shall be the ASHRAE 99% summer conditions of 93°F dry bulb temperature and 59°F wet bulb temperature.

C. Evaporative Cooling Unit:

1. General: Self-contained unit with factory mounted and tested components; fan, media, spray nozzles and pump, float valve assembly, recirculating pump, access door, marine lights, and steel installation skid.
2. Evaporative section: SST, Type 304 or Type 316 construction.
3. Cooling media shall be 12 inch Celedek type.
4. Water delivery and circulation system:
   a. Submersible pump with low water cut off switch.
   b. Float valve assembly.
   c. Copper water distribution system.

d. Brass water make up valve.
5. Supply fan section:
   a. Foreword curved, double width, double inlet fan.
   b. Motor hp sized for full rating without considering SF.
6. Intake section:
   a. Prefilter/access section: Filters shall be a minimum of 2 inches thick, 65% efficient, easily replaceable with material as recommended by the Manufacturer.

D. Accessories:
1. Automatic freeze and timed drain system.
2. Outside air thermostat.
3. Unit mounted on a 6 inch structural steel base.
4. Filter mats.
5. Filter mat frame handles.
6. Duct smoke detector.
7. Clogged filter alarm.
8. Local fused disconnect integral to LCP-EC1 and LCP-EC2.
9. Interior marine type service lights.
10. Exterior electrical convenience outlet.
11. Full-size SST access doors.
12. ASCO 120 V fill and drain solenoid valves.
13. LCP-EC1 and LCP-EC2 shall be provided by the I&C Systems Integrator. Power and control interface between LCP-EC1, LCP-EC2, the evaporative cooling units, MCC1 and ECP-CHRY shall be performed by the Electrical Contractor and I&C Systems Integrator.

PART 3 EXECUTION

3.1 INSTALLATION

A. Fans and Air Handlers:
1. Isolate sheet metal duct connections from non-internally spring-isolated fan units or other rotating equipment.
2. Locate units to provide access spaces required for filter changing; motor, drive, and bearing servicing; and fan shaft and coil removal.

3.2 ADJUSTING

A. Air Balancing: As specified in SECTION 23 05 93.

B. Fans and Air Handlers:
1. Lubricate non-sealed bearings prior to startup.
2. Do not allow cooling media to become dirty.

C. Vibration:
1. Statically and dynamically balance fan equipment.
2. Perform field testing on rotating equipment, as specified in SECTION 23 05 93, to determine actual operating vibration. If vibration limits described therein are exceeded, rebalance equipment in-place, if directed by ENGINEER, until design tolerances are met.
3. Provide open spring vibration isolators (with neoprene waffle base pads top and bottom) selected for a minimum of 1 1/2 inch deflection (unless otherwise specified).

END OF SECTION

SECTION 23 80 00
DECENTRALIZED HVAC EQUIPMENT

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for decentralized HVAC equipment.

B. Related Sections:

1. SECTION 01 33 00 – SUBMITTAL PROCEDURES
2. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
3. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
4. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
5. SECTION 23 05 93 – HVAC SYSTEMS TESTING, ADJUSTING, AND BALANCING
6. SECTION 23 07 00 – MECHANICAL INSULATION
7. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES

A. Air-Conditioning, Heating, and Refrigeration Institute (AHRI):

1. 410 – Forced-Circulation Air-Cooling and Air-Heating Coils
2. 430 – Performance Rating of Central-Station Air-Handling Unit Supply Fans

B. Air Movement and Control Association International, Inc. (AMCA):

1. 99 – Standards Handbook
2. 300 – Reverberant Room Method for Sound Testing of Fans
3. 301 – Methods for Calculating Fan Sound Ratings from Laboratory Test Data
4. 500 – Laboratory Methods of Testing Dampers for Rating

C. American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE):

1. 15 & 34 – Safety Standard for Refrigeration Systems and Designation and Classification of Refrigerants
2. 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings

D. Underwriters Laboratories Inc. (UL):

1. 900 – Air Filter Units

1.3 SUBMITTALS

A. Meet the Submittal requirements specified in SECTION 01 33 00.

B. Shop Drawings: Indicate assembly, unit dimensions, weight loading, required clearances, construction details, field connection details, and electrical characteristics and connection requirements.

1. Electrical, I&C: Provide complete one-line, three-line and control schematic Drawings. Provide cut-sheets on equipment, devices, and components.

C. Product Data:

1. Published literature: Indicate capacities, ratings, gauges and finishes of materials, and electrical characteristics and connection requirements.
2. Filters: Data for filter media, filter performance data, filter assembly, and filter frames.
3. Fans: Performance and fan curves with specified operating point plotted, power, and rpm.
4. Sound power level data: Fan outlet and casing radiation at rated capacity.
5. Dampers: Include leakage, pressure drop, and sample calibration curves. Indicate materials, construction, dimensions, and installation details.
6. Electrical requirements: Power supply wiring including wiring diagrams for interlock and control wiring. Indicate factory installed and field installed wiring.
7. Motors: Provide documentation, or a letter from the Manufacturer, stating the motors have a 1.15 SF following derating for site altitude.

D. Closeout Submittals:

1. As specified in SECTION 01 78 23.
2. O&M data: Submit instructions for lubrication, filter replacement, motor and drive replacement, spare parts lists, and wiring diagrams. Include Shop Drawing information.

E. Extra Materials:

1. Furnish, tag, and box for shipment and storage the following spare parts and materials:
   a. Filters: Four complete sets per unit.
   b. Drive belts: One complete set per unit.
   c. Fuses: Two compete sets per unit.

F. Warranty Documentation:

1. Sample warranty.
2. Warranty.

1.4 QUALITY ASSURANCE

A. Damper Leakage: Test in accordance with AMCA 500.

B. Manufacturer Qualifications: Minimum of 5 years of documented experience in the Work of this Section.

1.5 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

B. Accept units and components on-site in factory protective containers, with factory shipping skids and lifting lugs. Inspect for damage.

C. Protect units from weather and construction traffic by storing in a dry, roofed location.

1.6 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for parts and 5 years for the cooling coil.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Air Handling Units:
1. Greenheck
2. Trane
3. Carrier
4. Diaken
5. Engineered Air

B. Fans:
1. Loren Cook
2. Twin City Fan & Blower Co.

C. Heat Transfer Coils:
1. Aerofin Services Inc.
2. Daikin
3. Heatcraft Inc.
4. Trane

2.2 MATERIALS

A. Air Handling Unit Sections:
1. Angle filter damper section:
   a. Bottom inlet return air.
   b. Back inlet outside air.
   c. Left side filter access when looking in the direction of airflow.
2. Direct expansion coil:
   a. Performance shall be certified in accordance with AHRI 410.
   b. Design and tested in accordance with ASHRAE 15 & 34.
   c. Seamless copper tubes with aluminum plate fins.
   d. Left side connections.
   e. SST drain pan.
   f. Compatible and sized to operate with HP1.
3. Fan section:
   a. Left access door when looking in the direction of airflow.
   b. Front-out discharge.

B. Casing:
1. Galvanized steel.
2. 1 inch, 1.5 lb density fiberglass foil face or double wall insulation.

C. Fans:
1. Type: Forward curved, double width, double inlet, centrifugal type fan.
2. Statically and dynamically balanced, continuous operation at maximum rated fan speed and motor hp.
3. Variable pitch sheaves with ±20% speed adjustment.
4. Performance ratings: In accordance with AHRI 430.
5. Sound ratings: In accordance with AMCA 301, tested to AMCA 300.

D. Motors: As specified in SECTION 26 70 00.

E. Filters:
1. Filter box: Section with filter guides, access doors, for side loading with gaskets and blank-off plates.
2. Filter media: UL 900 listed, 2 inch MERV 8.

F. Inspection and Access Panels and Access Doors:
1. Panel and door fabrication: Formed and reinforced, single-wall or double-wall and insulated panels of the same materials and thicknesses as casing.
2. Size: At least 18 inches wide by full height of unit casing up to a maximum height of 60 inches.

G. Condensate Drain Pans:
1. Fabricated with 1% slope in at least two planes to collect condensate from cooling coils (including coil piping connections, coil headers, and return bends) and from humidifiers and to direct water toward drain connection.
2. Single-wall, SST sheet.
3. Drain connection: Located at the lowest point of pan and sized to prevent overflow. Terminate with threaded nipple on one end of pan.

H. Dampers:
1. Galvanized steel with double-skin airfoil design, compressible jamb seals and extruded vinyl blade edge seals on the blades.
2. Damper leakage: In accordance with ASHRAE 90.1; shall not exceed 5 cfm/sf at 1 inch water gauge and 9 cfm/sf at 4 inches water gauge.
3. Damper actuators: Field installed actuators as specified in SECTION 40 50 00.

I. Controls: As specified in SECTION 40 50 00, and as shown on the Drawings.

J. Capacity: As shown on the Drawings.

K. Extra Materials: Furnish, tag, and box for shipment and storage the following spare parts and materials:
1. Filters: Provide four complete sets per unit.

2.3 ACCESSORIES

A. Lifting Lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 lbs.

B. Equipment identification plates: Furnish a 16 gauge SST identification plate securely mounted on each separate equipment component in a readily visible location. Plate shall bear 1/4 inch high engraved block type black enamel filled number and letters. The plate shall include equipment identification indicated in this Specification, Manufacturer's model number, and serial number.

C. Disconnect Switch: Furnished and installed by the Electrical Subcontractor.

2.4 FABRICATION

A. In accordance with AMCA 99.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with AHRI 430.

B. Install flexible connections between the unit and inlet and discharge ductwork. Install metal bands of connectors parallel with minimum 1 inch flex between the ductwork and fan while running.

C. Insulate coil headers located outside airflow as specified for piping. As specified in SECTION 23 07 00.

D. Install condensate piping with trap and route from drain pan as shown on the Drawings.

E. Suspend unit from the ceiling with spring isolators sized properly to keep the unit from swaying or transferring vibration into the structure.

F. Reference the Drawings and field verify building clearances to determine if the units need to be shipped in sections and field-assembled.

G. Refrigerant Coils: Install sight glass in liquid line within 12 inches of coil.

3.2 PROTECTION

A. Do not operate units until ductwork is clean, filters are in place, bearings lubricated, and fan has been test run under observation.

3.3 QUALITY CONTROL

A. Flush piping to coil to remove flux, solder, and debris prior to connecting to the heating or cooling coil.

B. Location descriptions of the equipment (left or right side) are referenced as if looking in the direction of the airflow.

C. Performance shall be as shown on the Drawings.

D. Manufacturer's Field Services: Provide a Manufacturer's representative as required to complete inspection and certification of proper installation.

3.4 STARTUP

A. Equipment commissioning and testing shall be as specified in SECTION 01 91 00.

3.5 CLEANING

A. Install temporary filters during the construction period. Replace with permanent filters at the Substantial Completion date.

3.6 ADJUSTING

A. Test and balance fans and motors as specified in SECTION 23 05 93.

END OF SECTION

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SECTION 23 82 00
CONVECTION HEATING AND COOLING UNITS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for convection heating and cooling units.

1.2 REFERENCES

A. American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE):
   1. 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings

1.3 SUBMITTALS

A. Product Data:
   1. Specifications, descriptive drawings, catalog data, and descriptive literature. Include the make, model, dimensions, weight, mounting requirements, and electrical schematics for the products specified.
   2. The Manufacturer's standard finish color selections for cabinet finishes.
   3. Detailed information on structural, mechanical, electrical, or other modifications necessary to adapt the arrangement or the details shown on the Drawings to the equipment furnished.

B. Closeout Submittals: O&M manuals.

1.4 QUALITY ASSURANCE

A. Heating Equipment: Meet the minimum operating efficiencies in accordance with ASHRAE 90.1, Chapter 6.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. EUH Series:
   1. Chromalox
   2. Modine
   3. Qmark
   4. Trane

2.2 MATERIALS

A. EUH Series:
   1. Characteristics:
      a. Multiblade propeller fan.
      b. Direct-drive motor.
      c. Heating coil.
      d. Cabinet-mounted.
      e. Power disconnect.
   2. Cabinet:
      a. Steel, 18 gauge, arranged for wall mounting with bracket.
      b. Baked enamel finish; color to be selected by the OWNER from the Manufacturer's standard colors.
   3. Electric heating coil:
      a. Low surface temperature type with sheath element inserted in finned-tube coil.
      b. Factory wiring to include operating and safety controls required by UL and NEC, and carry the UL label.
      c. Control wiring to include control transformer.
   4. Basis of design: Chromalox, LUH Series.
   5. Capacity: As shown on the Drawings.

2.3 ACCESSORIES

A. Equipment Identification Plates:
   1. Furnish and securely mount identification plates on each separate equipment component in a readily visible location.
   2. Material: SST, 16 gauge.
   3. Lettering:
      a. Height: 1/4 inch.
      b. Engraved block type, black enamel filled.
      c. Include the equipment identification number and letters as specified in this Section.

B. Lifting Lugs: Furnish and suitably attach lifting lugs for equipment assemblies and components weighing over 100 lbs.

PART 3 EXECUTION

3.1 INSTALLATION

A. Heating and Cooling Equipment:
   1. Install in accordance with the Manufacturer's instructions and applicable governing codes.
   2. Furnish the specialties needed for roof piping penetrations.

3.2 QUALITY CONTROL

A. Factory Tests and Adjustments: Test equipment identical to that furnished.

B. Functional Test: Perform the Manufacturer's standard test on equipment.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for common work results for electrical.

B. Related Sections:
   1. SECTION 27 00 00 – COMMUNICATIONS SYSTEMS
   2. SECTION 28 00 00 – SECURITY SYSTEM
   3. SECTION 28 46 00 – FIRE ALARM SYSTEM
   4. SECTION 40 41 00 – HEAT TAPE SYSTEMS
   5. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES

A. National Electrical Contractors Association (NECA):
   1. 1 – Standard for Good Workmanship in Electrical Construction

B. National Fire Protection Association (NFPA):
   1. 70 – National Electrical Code (NEC)
   2. 70B – Recommended Practice for Electrical Equipment Maintenance
   3. 70E – Standard for Electrical Safety in the Workplace

1.3 DEFINITIONS

A. AHJ: An organization, office, or individual responsible for enforcing the requirements of a code or standard in accordance with NFPA 70, Articles 90 and 100.

B. Communications SPD: Synonymous with TVSS.

C. EMI: Electrical interference or noise generated by electrical and electronic devices.

D. Field Interconnection: Conductor or cable from equipment, device, or enclosure to another enclosure, device, or equipment. Conductors and cables between equipment sections included in one overall enclosure (e.g., switchgear cubicles in one section) shall be considered field interconnection conductors and cables.

E. Ground Grid: Synonymous with Ground System.

F. Ground System: Synonymous with Ground Grid.

G. Low-Voltage Conductors: Applies to conductors and cables 600 V and below, including conductors and cables for power, instrumentation, control, communications, security, SCADA, and fire alarm systems.

H. Medium-Voltage Cables: Power conductors and cables 600 V through 69 kV.

I. THD: The combined effect of harmonic distortion on the AC waveform.

J. TVSS: Synonymous with Communications SPD.

1.4 COORDINATION

A. Utilities:
   1. Coordinate electric utility electrical equipment, overhead power lines, metering, and take-off structure equipment Work and modifications with and approved by the ENGINEER and the electric utility. Meet electric utility requirements for new and existing equipment installation, modifications, and demolition.
   2. Materials, methods, sizes, ratings, and settings shall be coordinated and approved by the electric utility. The point of interconnection and service interface shall meet requirements of the electric utility. Provide and install materials and equipment required by the electric utility to provide a point of interconnection and service as required by the electric utility and as intended in the Contract Documents.
   3. Coordinate power outages with the ENGINEER, the OWNER, and the electric utility.
   4. The OWNER will not be responsible for paying trip fees due to miscoordination on the schedule with the electric utility.
   5. Communications equipment, the communications incoming service lines Work, and modifications shall be coordinated with and approved by the ENGINEER and the communications utility. Meet the communications utility's requirements for new and existing equipment installation, modifications, and demolition.
   6. Cooperate with the CONTRACTOR and the Subcontractors whose Work is in the same space; advise the CONTRACTOR of requirements. Such spaces and clearances shall be to the size required.
   7. Coordinate Work with other utilities within Work site limits. Notify applicable utilities in writing prior to commencing Work, if damage occurs, or if conflicts or emergencies arise during Work.

B. Existing Equipment to be Reused: Existing equipment (e.g., conduits, junction boxes, terminal boxes, equipment, devices, and instrumentation) to be reused shall be cleaned and repaired. Cleaning plugs (pigs) and steel brushes shall be pulled through existing conduits to thoroughly clean the inside of the conduits. Verify the existing raceway system intended to be reused is safe to install conductors and cables without damaging them. Verify the mechanical integrity of any existing raceway system intended to be reused and submit an evaluation report for each conduit to be reused with details on the cleaning to the ENGINEER.

C. Load Balance:
   1. The Contract Documents indicate circuiting to electrical loads and distribution equipment. Balance the electrical load between phases as nearly as possible on distribution equipment.
   2. When loads need to be reconnected to different circuits to balance phase loads, obtain the ENGINEER's approval, maintain accurate record of changes made, and provide a circuit directory that lists the final circuit arrangement.
   3. Service continuity: Maintain continuity of electric service to functioning portions of the process or buildings during hours normally in use, generally 24 hours a day, 7 days a week. Temporary outages will be permitted during cutover Work at such times and places as can be pre-arranged and scheduled with the OWNER and the

ENGINEER. Such outages shall be kept to a minimum number and length of time. Remove temporary materials prior to the Substantial Completion date.

1.5 SUBMITTALS

A. Provide the complete itemized Bill of Material, including the complete model number indicating all options after the submittal table of contents in the format specified in Supplement A.

B. Contract Document equipment and device labels, tags, and identification shall be used in Submittals and in the Bill of Material.

C. Provide two hardcopies in quality, hard, three-ring binders, fully indexed with permanent numbered tabbed Section dividers and sequentially numbered pages. Section dividers with slide in paper tabs will not be accepted.

D. Equipment, material, and device Bill of Material item numbers shall be used for the Manufacturer's descriptive information and Shop Drawing sequential numbered tabbed dividers, unless otherwise approved by the ENGINEER. One equipment, material, and device item number shall be used in a Bill of Material that contains multiple pieces of equipment using the item.

E. Report to the ENGINEER Submittal review comments in written format and include original review comment. Provide documentation with responses in the resubmittal or as a supplemental information document on Submittal dispositions of Final for Construction or Final for Construction as Corrected.

F. Label Submittals binders on front and ends/binds with a minimum of Submittal number, Specification Section, Description, type of Submittal, and date.

G. Submittal drawings shall be 11 inches by 17 inches and not folded.

H. Include the complete Manufacturer's descriptive information and Shop Drawings for equipment, material, and devices, including certified outline drawings, arrangement drawings, dimensional layout drawings, elementary (schematic) diagrams, interconnection and connection diagrams, literature, capacity, special features required, schematic (elementary) control diagrams, equipment schedules, and characteristic curves for protective devices in accordance with provisions elsewhere in the Contract Documents.

I. Equipment, models, options, extraneous text, etc. not being furnished and that do not apply shall be neatly crossed out.

J. No more than two Manufacturers of specified materials such as raceway systems, conductors, cables, etc. shall be provided and included in a Submittal.

K. An Equipment Manufacturer certified letter stating that the equipment provided meets the site environmental conditions.

L. Provide additional information listed under individual Section items. Submittal information, including Shop Drawing Submittals, shall be included in the O&M manuals.

M. As-Built Drawings, including dimensioned locations and GPS points of raceways, grounding, layout, equipment, and devices. As-Builts shall legibly indicate number, size, tag numbers and type of equipment, devices, conductors, and cables. Where clarity of raceway locations cannot be established on floor plans, elevations shall be provided. Provide top elevation of underground raceways and grounding. As-Built Drawings shall include, but not be limited to, conduit/conductor schedules (including lengths), nameplates with exact text, schematic connection diagrams, control schematics, wiring diagrams, P&IDs, connection diagrams, wire tags, terminal numbers, and equipment tags.

   1. CONTRACTOR-acquired GPS points:
      a. Provide GPS points accurate to within 10 cm of the true location of the asset. GPS points shall be taken for underground or concrete embedded raceways, ductbanks, grounding, equipment, and devices.
      b. Include time, date, technician, asset name, and location reference as separate fields for each GPS point.
      c. Incorporate GPS data/locations into As-Builts.
      d. Provide GPS data as a shapefile and a CSV file.
      e. Provide a report detailing the processing of each GPS point. Show either real-time correction or post-processing of GPS data, and detail specific calculations or conversions used.
      f. Collect data in World Geodetic System 1984 Coordinate System, unless otherwise approved by the ENGINEER.
      g. Submit GPS data, including corrections and processing information, as part of the As-Built Drawing Submittals at 30%, 60%, 90%, and 100%
      h. Submit GPS hardware and software for approval.

N. SECTION 27 00 00, SECTION 28 00 00, SECTION 40 41 00, and SECTION 40 50 00 Submittals shall meet the general requirements in this Section. Additional detailed Submittal requirements are included in each individual Section.

O. Provide complete detailed Submittals for temporary power and communications, including the method of procedure for transfer to and from temporary power. Provide written report on the condition of existing raceways and equipment to be reused.

P. Submittals from other Sections and equipment shall not be combined.

Q. Submit electronically current As-Built Drawings, including conduit/conductor schedule and the photo album at 25%, 50%, 75%, and 100% of the Final Completion date. As-Built Drawings shall be provided in PDF and DWG formats. Photos shall be individually labeled with descriptions and dates and shall be in jpg format.

   1. Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: https://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
      a. Drawings shall be on a standard DW provided title block and border.
      b. As-Builts and Manufacturer's drawings shall be provided:
         1) On a standard DW provided title block and border.

2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
3) Text: Minimum 0.1 inch, maximum 0.2 inch.
4) Titles: 0.2 inch.

2. CONTRACTOR-provided EI&C As-Built Drawings shall be on a DW standard title block and have Drawing numbers in the format E-# and EI-#, starting 10 numbers past the last Drawing E-# & EI-#. The first CONTRACTOR-provided EI&C As-Built E-# and EI-# drawing(s) shall be the drawing index for the CONTRACTOR-provided EI&C As-Built Drawings. Drawing numbers shall be unique and approved by the ENGINEER.

1.6 QUALITY ASSURANCE

A. Provide OWNER contact information to Equipment Manufacturers as "owner of record" for warranties, recalls, updates (including software and firmware), notices, etc.

B. General Requirements:

1. Electrical Subcontractors shall provide documentation that includes the following information with the Bid or the Proposal Form at the Bid or the Proposal time:
   a. Subcontractors that will be used.
   b. Verification that the Electrical Subcontractor will provide and install the raceways and conductors for the complete project and systems including, but not limited to, HVAC and cathodic protection as specified in SECTION 27 00 00, SECTION 28 00 00, SECTION 28 46 00, SECTION 40 41 00, and SECTION 40 50 00.
   c. A letter describing what is considered the most difficult electrical parts of the Work.
   d. Organization chart: Showing the organizational structure for the company and this Project. Identify key personnel who will be assigned to do the Work.
   e. Qualification of personnel:
      1) Provide resumes of management personnel and technical qualifications of the Project manager, the Project Foreman, and key personnel shown on the organizational chart.
      2) Electrical Work shall be performed or supervised by an Electrical Foreman who is a Colorado Licensed Journeyman or Master Electrician. The Electrical Foreman shall not be replaced without written notice to the ENGINEER except under extraordinary circumstances. The ratio of Electrical Apprentices to Colorado Licensed Journeymen (or Masters) shall be no greater than two to one.
      3) The Electrical Subcontractor shall submit current copies of Colorado Journeyman Electrician's licenses, Master Electrician's licenses, or Apprentice registration information/licenses, for Foreman, Electricians, and Apprentices that perform Work.
   f. Provide a complete cost breakdown for equipment, materials, and Work including quantities and pricing in sufficient detail to serve as the basis to be used in conjunction with the CLS for progress payments during construction. Prices shall include an appropriate amount of overhead and profit.
   g. Indicate that EI&C Contractors shall be Subcontractors to the Electrical Subcontractor including, but not limited to, the I&C Systems Subcontractor, Systems Integrator, Communications Systems Subcontractor, Electrical Systems Commissioning Subcontractor, Electrical Systems Analysis Subcontractor, Security System Subcontractor, Cathodic Protection Subcontractor, and Fire Alarm Systems Subcontractor.
2. Submit documents required to obtain permits and pay fees required by the OWNER, the governmental agency having jurisdiction over the Work, and the authority having jurisdiction. Arrange and notify the ENGINEER in writing of inspections required by the agencies. Furnish satisfactory evidence to the ENGINEER that Work is acceptable to the regulatory authorities having jurisdiction.

C. Responsibility:

1. Equipment shall not exceed the sizes shown on the Contract Documents without written approval from the ENGINEER. Costs incurred (structural analysis and modifications) due to an increase in equipment size shall be the responsibility of the CONTRACTOR.
2. Complete systems in accordance with the Contract Documents.
3. Coordinate the details of facility equipment and construction that affect the Work covered in the Contract Documents.
4. Provide incidental items not actually shown on the Drawings or specified but which are required by good practice to provide complete functional systems.
5. Complete electrical installation in accordance with the applicable codes, ordinances, and regulations including, but not limited to: NFPA 70, NFPA 70B, NFPA 70E, and NECA 1.
6. The exact fitting of materials and equipment shall be the responsibility of the CONTRACTOR.

D. Intent of Drawings:

1. Drawings typically show only general locations of structures, piping, equipment, devices, and raceways. Properly route and install raceways, equipment, etc., and provide Submittals and As-Built Drawings with locations of raceways and equipment.
2. Enclosure sizes shown on the Drawings are the minimum acceptable size. Provide enclosures sized for actual equipment to meet clearance, cooling, raceway interface, and equipment operation requirements.
3. Control schematics and wiring diagrams:
   a. Controls are shown de-energized; valves and gates are shown closed.
   b. Control schematics and wiring diagrams show control function only. Incorporate other necessary functions for proper operation and protection of the system.
   c. Add auxiliary relays, where required, to provide proper control system operation and interface.
   d. Devices shown on control schematics and wiring diagrams shall be in equipment enclosures.
   e. Conduits and conductors shall be provided for circuits indicated in new panelboard schedules.

4. Overcurrent protection device sizes and types are estimated; provide and install the sizes and types required for the actual equipment ratings that are approved by the ENGINEER.

1.7 SITE CONDITIONS

A. Materials and equipment shall be designed and constructed for continuous operation, at rated current and voltage, at the Project elevation of 6,000 feet, 104°F ambient and 95% relative humidity. The Equipment Manufacturer shall submit a certified letter in the Shop Drawing Submittal stating the equipment provided meets this requirement.

B. Outdoor Equipment: Provide equipment and devices to be installed outdoors or in unheated enclosures capable of continuous operation within an ambient temperature range of -30°F to 104°F.

C. Inspection:

1. Drawings were developed from past As-Builts. Prior to submitting Bids or Proposals, verify dimensions and existing conditions including, but not limited to, structures, equipment, devices, conduits, etc.
2. Before submitting a Bid or a Proposal, the CONTRACTOR is required to determine conditions at the site and at existing structures to become familiar with existing conditions and electrical systems that will, in any way or manner, affect the Work required under the Contract. No subsequent increase in Contract Price will be allowed for additional Work required because of the CONTRACTOR's failure to fulfill this requirement.
3. Carry out any Work involving the shutdown of the existing services to any piece of equipment now functioning in existing areas at such time as to provide the least amount of inconvenience to the OWNER. Do such Work when approved by the ENGINEER.
4. During pre-construction activities, confer with the ENGINEER to verify, at each area of construction activity, the location of existing utilities, equipment, and structures and the requirements for adequately protecting them. Pay for required repairs if damage occurs during the Work.

PART 2 PRODUCTS

2.1 MATERIALS

A. In accordance with provisions elsewhere in the Contract Documents, the Manufacturer's names and catalog numbers stated herein are intended to indicate the type and quality of equipment or materials desired.

B. Provide first quality, new materials and equipment, free from any defects, in first-class condition, and suitable for the space provided. Provide materials and equipment listed by UL wherever standards have been established by that agency.

C. Standard Products:

1. Where two or more units of the same class of material or equipment are required, provide products of a single Manufacturer.
2. Provide materials and equipment that are the standard products of Manufacturers regularly engaged in the production of such materials and equipment. Provide the latest standard design that conforms to the Contract Documents.

2.2 FINISHES

A. Electrical and I&C equipment shall be provided with ANSI 61, light gray finish color.

PART 3 EXECUTION

3.1 GENERAL

A. Install materials and equipment in a workmanlike manner utilizing craftsmen skilled and licensed in the electrical trade. Provide Work that has a neat and finished appearance.

B. Coordinate electrical Work with the ENGINEER, the OWNER, Electric Utility, Communications Utility , and the Work of other trades to avoid conflicts, errors, delays, and unnecessary interference with operation of the plant during construction.

C. Check the approximate locations of raceways, light fixtures, devices, equipment, and other electrical system components shown on the Drawings for conflicts with openings, structural members, and components of other systems and equipment having fixed locations. In the event of conflicts, notify the ENGINEER in writing. The ENGINEER's decision shall govern. Make modifications and changes required to correct conflicts.

D. Cutting, Patching, and Drilling:

1. Layout Work carefully in advance. Do not cut or notch any structural member or building surface without specific approval of the ENGINEER. Carefully carry out any cutting, channeling, chasing, or drilling of floors, walls, partitions, ceiling, paving, or other surfaces required for the installation, support, or anchorage of conduit, raceways, or other electrical materials and equipment. Following such Work, restore surfaces neatly to original condition. Use skilled craftsmen of the trades involved.
2. Prior to core drilling or cutting existing structures, floors, walls, concrete slabs, etc., the proposed location shall be x-rayed, or by other ENGINEER-approved method, to ensure existing rebar, conduits, and utilities are not damaged. Provide photos or layout drawings of rebar, conduits, and utilities in the areas x-rayed. Repair existing damaged structures, conduits, and utilities.

3.2 PREPARATION

A. Temporary Power, Communications, and Controls:

1. Obtain permits, submit documents, and pay fees required for temporary power.
2. Provide and install equipment and devices necessary to provide required temporary power, controls, and communications.
3. Provide and install equipment and devices necessary to maintain power, controls, and communications to existing services and equipment.
4. Provide and install equipment, materials, and devices required for temporary power including, but not limited to, overcurrent protection devices, disconnects, transformers, conduit, conductors, poles, overhead power lines, terminations, and distribution equipment.

5. Reworked temporary power, control, and communications at various stages of the project.
6. Maintain power to facilities throughout the project, except for short outages coordinated with the OWNER and the ENGINEER.

B. Demolition or Relocation of Materials and Equipment:
1. Existing exposed raceways and raceway components that are not to be reused or reworked shall be demolished. Where existing raceways are embedded in building construction, they shall be cut flush with finished surfaces, plugged with a suitable and compatible plate, and abandoned in place. Existing wiring shall be removed.
2. Existing equipment, devices, materials, and components that are not to be reused or reworked shall be demolished. Existing wiring and raceways shall be removed. Demolished area surfaces shall be repaired and restored to new condition.
3. Where required, the existing raceway system shall be matched and extended to new outlet or device locations as required or as shown on the Drawings. In general, new raceways in finished areas shall be run concealed in building construction, above hung ceilings, in stud walls, etc. Obtain approval from the ENGINEER regarding the location and routing of any exposed raceways prior to installing the same.
4. Where existing materials and equipment are removed or relocated, remove materials no longer used such as studs, straps, conduits, and wires. Remove or cut off concealed or embedded conduit, boxes, or other materials and equipment to a point at least 3/4 inch below the final finished surface when directed by the ENGINEER.
   a. The OWNER reserves the right to salvage and retain removed electrical equipment. Coordinate with the ENGINEER prior to disposing of any removed electrical equipment.
5. Repair affected surfaces to conform to the type, quality, and finish of the surrounding surface in a neat and workmanlike manner. Follow any specific instructions provided elsewhere in the Contract Documents. Utilize skilled craftsmen of the trades involved.
6. Demolition and temporary construction sequence:
   a. The temporary power, control, and communications installation and materials shall be pre-approved by the ENGINEER.
   b. Demolish electrical, I&C equipment, and materials in accordance with the Contract Documents or by the ENGINEER. The ENGINEER will notify the CONTRACTOR of existing equipment and materials the OWNER wants salvaged and retained.
   c. The existing ground grid shall be repaired and restored to its original condition after the construction. The existing ground grid shall be connected to the new grounding, ductbanks, and equipment.
   d. It is the CONTRACTOR’s responsibility to adequately protect and/or support any existing electrical concrete ductbank if required. Replace the existing ductbank if damaged. Submit plans to protect the existing ductbank support for approval prior to implementing.

3.3 INSTALLATION

A. Follow the Manufacturer’s installation instructions explicitly. Wherever any conflict arises between the Manufacturer’s instructions, codes, and regulations, and the Contract Documents, follow the ENGINEER’s decision. Keep a copy of the Manufacturer’s installation instructions on the jobsite and available for review.

B. Use appropriate conduit and conductor entry fittings with enclosures that maintain the specified enclosure environmental capability after proper installation.

3.4 PROTECTION

A. Protect enclosures and other equipment containing electrical and I&C devices, including spare parts, from corrosion using corrosion-inhibiting vapor capsules.

B. Periodically replace capsules in accordance with the Capsule Manufacturer's recommendations. Replace capsules just prior to the Substantial Completion date.

C. Provide protection for materials and equipment against loss or damage in accordance with provisions in the Contract Documents. Follow the Manufacturer’s recommendations for storage (long-term and short-term storage). Protect Work from the effects of weather. Prior to installation, store items in clean, dry, indoor locations. Items subject to corrosion under damp conditions and items containing electrical insulation, such as equipment, transformers, conductors, motors, and controls shall be stored in indoor temperature and humidity controlled and heated locations. Energize space heaters furnished with equipment. Provide temporary heating, sufficient to prevent condensation in equipment, transformers, switchgear, switchboards, valve operators, motors, and MCCs that do not have space heaters. Temperature and humidity shall be monitored while in storage to ensure the Manufacturer’s storage requirements are met.

D. Following installation, protect materials and equipment from corrosion, physical damage, and the effects of moisture on insulation. When equipment intended for indoor installation is installed at the CONTRACTOR’s convenience in areas where it is subject to dampness, moisture, dirt, or other adverse atmosphere until the Final Completion date, ensure that adequate protection is provided that is acceptable to the ENGINEER. Cap conduit runs during construction with manufactured seals. Keep openings in boxes or equipment closed during construction. Energize space heaters furnished with equipment.

E. Protect existing equipment and facilities during construction from dirt, dust, moisture, and temperature conditions detrimental to equipment. This shall include, but not be limited to, protection of the facility floors with plywood or other ENGINEER-approved method, and protection of existing motors with suitable coverings to protect from dust and falling debris.

3.5 QUALITY CONTROL

A. Inspection: Allow materials, equipment, and workmanship to be inspected at any time by the ENGINEER. Correct Work, materials, or equipment not in accordance with the Contract Documents or that is found to be deficient or defective in a manner satisfactory to the ENGINEER.

B. Tests:
   1. Carry out tests specified hereinafter and as specified in other Sections.
   2. After the electrical system's installation is complete and at the time coordinated with the ENGINEER, perform an electrical system operating test for approval. Demonstrate that equipment operates in accordance with the requirements of the Contract Documents. Demonstrate that protective functions are operating properly and are properly incorporated in control and distribution system operation. Perform the test in the presence of the ENGINEER. Furnish instruments and personnel required for the tests.
   3. Voltage:
      a. When the installation is essentially complete and the facility is in operation, check the voltage at electrical distribution equipment. Check voltage amplitude and balance between phases for loaded and unloaded conditions.
      b. Record the voltage and balance between phases (all three phases simultaneous on the same graph) for 1 day (during a normal working day). Submit the recording with a letter of transmittal to the ENGINEER within 10 days of the date the test.
      c. If an unbalance exceeds 3% or if the voltage varies throughout the day and from loaded to unloaded conditions more than ±5% of nominal, determine the cause of the problem and submit it in writing to the ENGINEER.
   4. Equipment line current: Check the line current in each phase for each piece of equipment. If any phase current in any piece of equipment is above the rated nameplate current, determine the cause of the problem and submit it in writing to the ENGINEER.

3.6 STARTUP

A. Provide skilled craftsmen to checkout, troubleshoot, and startup various systems. Be available and coordinate with other crafts to checkout, troubleshoot, and startup various systems. Be available outside normal working hours when necessary.

B. CONTRACTOR employees working in areas with energized equipment and arc flash boundaries exceeding 1.2 cal/cm² shall be trained as NFPA 70E qualified personnel and wear required PPE.

3.7 CLEANING

A. Clean debris, dirt, dust, etc. from equipment.

B. Keep the premises free from the accumulation of waste material or rubbish. Remove materials, scraps, and debris from the premises and from the interior and exterior of devices and equipment. Touch up scratches, scrapes, or chips in interior and exterior surfaces of devices and equipment with finishes matching the type, color, and consistency of the surface of the original finish. If extensive damage to equipment paint surfaces occurs, refinish the entire piece of equipment in a manner that provides a finish equal to or better than the factory finish, that meets the requirements of the Contract Documents, and that is acceptable to the ENGINEER.

3.8 ADJUSTING

A. Motor Rotation: After final service connections are made, check and correct the rotation of motors. Coordinate rotation checks with the ENGINEER and the CONTRACTOR responsible for the driven equipment.

3.9 SUPPLEMENTS

A. Supplement A – Example Bill of Material

END OF SECTION

SUPPLEMENT A – EXAMPLE BILL OF MATERIAL
WTP Generators 1 & 2
Contract #: --
Project Tracker #: --
Submittal #: --

Equipment/ Specification:	Item	Qty.	Description	Manufacturer	Complete Manufacturer Part No. (with all options):	DW Device Abbrev/Tag
GCP/26 09 00	1	1	Protective relay, generator, functions (50P, 50N, 46, 51P, 51N, 46, 27, 47, 81, 32), 5 A phase current inputs, 48/125 VAC/DC power supply, H1 case, Modbus RS-485 communication	Basler	BE1-GPS100-E3N1H1N	GPS1, GPS2
LCP-GH/40 50 00	2	1	Analog link, fiber transmitter, 4 mA to 20 mA to fiber optic converter, ST connection	Ultra Electronics	2T20	ASFM2
ECP-PH/40 50 00	3	10	Aux relay, 120 VAC coil, DPDT, w/LED, socket mount, rated 3 A @ 150 VDC make/break	P&B	KUEP-11A35-120	FR#, MS#, AR#,
GCP/26 09 00	4	1	Line voltage over/under relay (27/59 A)	Basler	BE1-700 N3N2X7N	27/59L2
GCP/26 09 00	5	1	Low power relay (37G)	Basler	BE3-37-3E1A2	37GA
GCP/26 09 00	6	3	Voltage transducer	Yokogawa	2469-32-330-AHD-1	VTDL2, VTDG2, VTDB
GCP/26 09 00	7	2	Control switches	Electroswitch		CS1, CS2
GCP/26 09 00	8	5	Control Switches, lock out relay, four decks (sixteen sets of contacts), lights	Electroswitch	7805D	86L1, 86R1, 86G1, 86L2, 86G2
LCP-HPU2/40 50 00	9	1015	Diode, 3 A, 1000 V	Fairchild	1N5408	D#
LCP-SG1/26 24 19	10	33	Contactor, reversing, NEMA 1, open frame, 460 VAC motor voltage, three-phase, three-pole, 10 hp max, 27 A continuous current rating, 120 VAC coil voltage	GE	CR309C002CAA	LSG, CSG, RSG
GCP/26 09 00	11	2	Genset control for multiple unit operation (EasyGen 3200), P1 option and 5 A CT inputs	Woodward	8440-2050	GCP1, GCP2

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SECTION 26 05 10
BASIC ELECTRICAL MATERIALS AND METHODS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for basic electrical materials and methods.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. ASTM International (ASTM):

1. A 36 – Standard Specification for Carbon Structural Steel
2. A 123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
3. A 153 – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
4. A 240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
5. A 283 – Standard Specification for Low and Intermediate Tensile Strength Carbon Steel Plates
6. A 575 – Standard Specification for Steel Bars, Carbon, Merchant Quality, M-Grades
7. A 576 – Standard Specification for Steel Bars, Carbon, Hot-Wrought, Special Quality
8. A 635 – Standard Specification for Steel, Sheet and Strip, Heavy-Thickness Coils, Hot-Rolled, Alloy, Carbon, Structural, High-Strength Low-Alloy, and High-Strength Low-Alloy with Improved Formability, General Requirements for
9. A 653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
10. A 1011 – Standard Specification for Steel, Sheet and Strip, Hot-Rolled, Carbon, Structural, High-Strength Low-Alloy, High-Strength Low-Alloy with Improved Formability, and Ultra-High Strength
11. B 633 – Standard Specification for Electrodeposited Coatings of Zinc on Iron and Steel
12. D 635 – Standard Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position

B. Federal Specifications (FS):

1. W-C-596 – General Specification for Connector, Electrical, Power
2. W-S-896F – General Specification for Switches, Toggle (Toggle and Lock), Flush Mounted

C. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

1. C57.12.01 – Standard General Requirements for Dry-Type Distribution and Power Transformers
2. C57.12.91 – Standard Test Code for Dry-Type Distribution and Power Transformers
3. C57.96 – Guide for Loading Dry-Type Distribution and Power Transformers
4. C62.11 – Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV)

D. National Electrical Manufacturers Association (NEMA):

1. 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)
2. ICS 2 – Controllers, Contactors and Overload Relays Rated 600 Volts
3. KS 1 – Heavy Duty Enclosed and Dead-Front Switches (600 Volts Maximum)
4. PB 1 – Panelboards
5. WD 1 – General Color Requirements for Wiring Devices

E. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)

F. Underwriters Laboratories, Inc. (UL):

1. 20 – General-Use Snap Switches
2. 67 – Panelboards
3. 98 – Enclosed and Dead-Front Switches
4. 248 – Low Voltage Fuses
5. 489 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
6. 506 – Specialty Transformers
7. 508 – Industrial Control Equipment
8. 943 – Ground-Fault Circuit-Interrupters
9. 1561 – Dry-Type General Purpose and Power Transformers

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. External power and signal connections.
4. Scaled, legible drawings showing exterior dimensions and locations of the electrical and mechanical interfaces.
5. Transformer, including mini power-zone, diagrammatic nameplate data, and percent impedance.
6. Dimensional drawings.

7. Protective devices:
    a. Copies of time-current characteristics.
    b. Protective device trip settings.
8. Current transformer and potential transformer burden calculations.
9. Anchoring instructions and details.
10. One-line diagrams.
11. Three-line drawings.
12. Schematic (elementary) diagrams.
13. Outline diagrams.
14. Interconnection diagrams.
15. Installation details: Include mounting methods, size and detail of supports, channels, and steel; provide weights from which supports, channels, and steel are to carry. Include modifications or further details required.
16. The Equipment Manufacturer shall submit a certified letter stating the materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the Project and site environmental conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating, for ENGINEER approval.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
    a. Provide preliminary and final manuals.
    b. As specified in SECTION 01 78 23.
    c. Shop Drawing Submittal information.
    d. Factory and field certified test reports.
    e. Device O&M manuals for components, electrical devices, and mechanical devices shall include the following:
        1) Operations procedures.
        2) Installation requirements and procedures.
        3) Maintenance requirements and procedures.
        4) Troubleshooting procedures.
        5) Internal schematic and wiring diagrams.
    f. List of spares and expendables required and recommended.
    g. Final As-Built Drawings:
        1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
                (1) On a standard DW provided title block and border.
                (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
                (3) Text: Minimum 0.1 inch, maximum 0.2 inch.
                (4) Titles: 0.2 inch.
    h. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Final Completion date the following extra materials:
1. Fuses, 0 to 600 V: A minimum of six of each type and each current rating installed.
2. Lamps and LEDs for indicating lights: Two of each type and each current rating installed.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the basic electrical materials and methods system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Outlet and Device Boxes:
1. Cast metal:
    a. Appleton, Type FS or FD
    b. Crouse-Hinds, Type FS or FD
2. PVC-coated cast metal:
    a. Ocal, Inc.
    b. Robroy Industries

B. Junctions and Pull Boxes:
  1. Large cast metal box:
    a. Crouse-Hinds, Series W
    b. O.Z./Gedney, Series Y
  2. Large SST box:
    a. Hoffman Engineering Co.
    b. Robroy Industries
  3. Large steel box:
    a. Hoffman Engineering Co.
    b. Robroy Industries

C. Wiring Devices:
  1. Toggle switches:
    a. Hubbell
    b. Leviton
    c. Arrow Hart/Eaton
  2. Receptacle, single and duplex:
    a. Hubbell
    b. Leviton
    c. Arrow Hart/Eaton
  3. Receptacle, ground fault circuit interrupter:
    a. Hubbell
    b. Leviton
    c. Arrow Hart/Eaton

D. Device Plates:
  1. While-in-use weatherproof covers:
    a. Hubbell, WP8M, WP8MH
  2. Weatherproof – for receptacles – gasketed, cast metal, or SST, with an individual cap over each receptacle opening:
    a. Crouse-Hinds, Type WLRD or WLRS
    b. General Electric
    c. Hubbell
    d. Weatherproof – for switches – gasketed, cast metal incorporating external operator for internal switch:
      1) Appleton, FSK-1VTS or FSK-1VS
      2) Crouse-Hinds, DS-181 or DS-185

E. Lighting and Power Distribution Panelboard:
  1. Cutler-Hammer
  2. General Electric
  3. Square D

F. Mini Power-Zone:
  1. Square D Mini Power-Zone

G. Circuit Breaker, Individual, 0 to 600 V:
  1. Cutler-Hammer
  2. General Electric
  3. Square D

H. Separately Mounted Molded Case Switch, Individual, 0 to 600 V:
  1. Cutler-Hammer
  2. General Electric
  3. Square D

I. Disconnect/Safety Switches, Individual, 0 to 600 V:
  1. Cutler-Hammer
  2. General Electric
  3. Square D

J. Fuse, 0 to 600 V:
  1. Motor and transformer circuits, 0 V to 600 V:
    a. Bussmann, Type LPS-RK
    b. Littelfuse, Type LLS-RK
  2. Feeder and service circuits, 0 V to 600 V:
    a. Bussmann, Type LPS-RK
    b. Littelfuse, Type LLS-RK
  3. Feeder and service circuits, 0 V to 600 V:
    a. Bussmann, Type KRP-C
    b. Littelfuse, Type KLPC
  4. Branch circuits and control circuits, 0 V to 600 V:
    a. Bussmann, Type FNQ-R
    b. Littelfuse, Type KLDR or CCMR

K. Push Button, Indicating Light, and Selector Switches:
   1. Allen-Bradley, Bulletin 800T
   2. Eaton, 10250T
   3. General Electric, CR104P
L. Terminal Block, 0 V to 600 V:
   1. General purpose, #8 AWG to #4 AWG:
      a. General Electric, EB series
   2. Terminal block, general purpose:
      a. General Electric, CR151A2
   3. Terminal block, fuse/disconnect plug:
      a. Phoenix Contact, V10K 1, 5-D/TG/D/PE with Type ST
M. Elapsed Time Meter:
   1. General Electric, Type 240, 2 1/2-inch Big Look
N. 24 V Signal/Control Relays:
   1. IDEC Corp series RH
O. Industrial Control Relays:
   1. Potter & Brumfield, KUEP series
P. Magnetic Control, Machine-Tool and Industrial Relays:
   1. General Electric, Type CR120B
Q. Magnetic Contactor:
   1. Allen-Bradley
   2. General Electric, CR 305
R. Alternator Relay:
   1. Time Mark, 261-D-T-120
S. Dry Type Transformer, 0 V to 600 V Primary:
   1. Cutler Hammer
   2. General Electric
   3. Square D
T. Level Switch, Float Type, Water on Floor:
   1. ITT Centripro, A2D Series
U. Support and Framing Channels:
   1. B-Line
   2. Unistrut
V. EUH:
   1. Chromalox, Model LUH

2.2 MATERIALS

A. Outlet and Device Boxes:
   1. Furnish and install as a part of the raceway system the outlet and device boxes required for the proper installation of electrical system components.
   2. Outlet and device boxes:
      a. Exposed, surface and pendant-mounted outlet and device boxes installed in or near wet locations shall be of the PVC-coated cast metal type with threaded hubs.
      b. Exterior-mounted outlet and device boxes not subject to wet location conditions shall be of the cast metal type with threaded hubs.
      c. Recessed drywall outlet boxes serving interior dry locations shall be of the pressed sheet steel, zinc-coated, cadmium-plated type.
      d. Outlet and device boxes shall not be less than 1 1/2 inches deep unless shallower boxes are required by structural conditions and are approved by the ENGINEER.
      e. Ceiling and bracket outlet and device boxes shall not be less than 4 inches octagonal except that smaller boxes may be used where required by the particular fixture to be installed.
   3. Cast metal:
      a. Box: Malleable iron.
      b. Cover: Gasketed, weatherproof, malleable iron, with SST screws.
      c. Hubs: Threaded.
      d. Lugs: Cast mounting.
   4. Box type, steel raceway system:
      a. Outdoor locations – exposed raceways: Cast metal.
      b. Interior dry locations – exposed rigid conduit: Cast metal.
   5. PVC-coated cast metal:
      a. Type: FS or FD with PVC coating.
      b. Coating: Surfaces; 40 mil PVC.
B. Junction and Pull Boxes:
   1. Large sheet steel box:
      a. In accordance with NEMA 250, Type 1.
      b. Box: Code-gauge, galvanized steel.
      c. Cover: Full access, screw type.

d. Machine screws: Corrosion-resistant.
2. Large cast metal box:
    a. In accordance with NEMA 250, Type 4.
    b. Box: Cast malleable iron, with drilled and tapped conduit entrances.
    c. Cover: Hinged with clamps.
    d. Hardware and machine screws: In accordance with ASTM A 240, Type 316 SST.
3. Large SST box:
    a. In accordance with NEMA 250, Type 4X.
    b. Box: 14 gauge, in accordance with ASTM A 240, Type 304 SST, with white enamel painted interior mounting panel.
    c. Cover: Hinged with clamps.
    d. Hardware and machine screws: In accordance with ASTM A 240, Type 304 SST.
4. Large steel box:
    a. In accordance with NEMA 250, Type 4.
    b. Box: 14 gauge steel, with white enamel painted interior and gray primed exterior over phosphated surfaces, with final ANSI 61 gray enamel on exterior surfaces.
    c. Cover: Hinged with clamps.
    d. Hardware and machine screws: In accordance with ASTM A 240, Type 316 SST.
5. Large steel box:
    a. In accordance with NEMA 250, Type 3R.
    b. Box: 14 gauge steel, with ANSI 61 gray enamel on interior and exterior surfaces. Integral drip shield top with seam-free sides, front, and back.
    c. Cover: Hinged with clamps.
    d. Hardware and machine screws: In accordance with ASTM A 240, Type 316 SST.
    e. Options: Padlockable hasp and staple.
6. Mounting hardware: SST.

C. Wiring Devices:
1. Light switches and receptacles shall be labeled to indicate the panelboard and circuit number(s) connected to the device.
2. Toggle switches:
    a. In accordance with NEMA WD 1, UL 20, and FS WS-896E.
    b. Specification grade, totally-enclosed, AC type, with quiet tumbler switches and screw terminals.
    c. Capable of controlling 100% tungsten filament and fluorescent lamp loads. Capable of controlling up to 1 hp motor load at 120 V.
    d. Rating: 20 A, 120/277 V.
    e. Color:
        1) Non-UPS circuits: Brown.
        2) UPS circuits: Orange.
    f. Where two or more switches are shown at one location, they shall be installed under a common wall plate. Switches shall be mounted approximately 4 feet above the finished floor and shall be located on the knob side of doors.
3. Receptacle, single and duplex:
    a. In accordance with NEMA WD 1 and FS W-C-596.
    b. Specification grade, two-pole, three-wire grounding type with screw type wire terminals suitable for #10 AWG.
    c. High-strength, thermoplastic base color.
    d. Color: Brown.
    e. Contact arrangement: Contact to be made on two sides of each inserted blade without detent.
    f. Rating: 125 V, in accordance with NEMA WD 1, configuration 5-20R, 20 A.
    g. Mounting height: 18 inches above the floor.
4. Receptacle, ground fault circuit interrupter:
    a. Duplex, specification grade, tripping at 5 mA:
    b. In accordance with NEMA WD 1 and UL 943.
    c. Specification grade, two-pole, three-wire grounding type with screw type wire terminals suitable for #10 AWG, and provisions for testing.
    d. High-strength, thermoplastic base color.
    e. Color: Brown.
    f. Contact arrangement: Contact to be made on two sides of each inserted blade without detent.
    g. Rating: 125 V, in accordance with NEMA WD 1, configuration 5-20R, 20 A, capable of interrupting 5,000 A without damage.
    h. Mounting height: 18 inches above the floor.

D. Device Plates:
1. General: Sectional type plates not permitted.
2. Metal:
    a. Material: Specification grade, one-piece, 0.040 inch nominal thickness SST.
    b. Finish: In accordance with ASTM A 240, Type 302/304, satin.
    c. Mounting screw: Oval-head, finish matched to plate.

3. Cast metal:
    a. Material: Malleable ferrous metal, with gaskets.
    b. Screw: Oval head SST.
4. Engraved:
    a. Panelboard and circuit number.
    b. Character height: 1/8 inch.
    c. Filler: Red.
5. While-in-use weatherproof covers:
    a. For receptacles: Gasketed, cast metal or SST.
6. Weatherproof:
    a. For receptacles: Gasketed, cast metal or SST, with individual cap over each receptacle opening.
        1) Mounting screw: SST.
        2) Cap spring: SST.
    b. For switches: Gasketed, cast metal incorporating external operator for internal switch.
        1) Mounting screw: SST.
7. Raised sheet metal: 1/2 inch high zinc-plated or cadmium-plated steel designed for one-piece drawn type sheet steel boxes.

E. Panelboard and Distribution Panelboard:
1. In accordance with NEMA PB 1, NFPA 70, and UL 67, including panelboards installed in motor control center when shown on the Drawings.
2. Panelboards and circuit breakers:
    a. Suitable for use with 75°C wire at full NFPA 70, 75°C ampacity.
    b. Rated for 277/480 V or 120/208 V, three-phase, four-wire operation as shown on the Drawings.
3. Short-circuit current equipment rating: Fully rated; series connected unacceptable. Minimum of 22,000 A rms symmetrical. Rating shall apply to the panelboard as a complete unit with short-circuit current rating equal to or greater than the integrated equipment rating shown on the panel schedule or on the plans.
4. Cabinet:
    a. In accordance with NEMA 250, Type 12, industrial use.
    b. Material: Code-gauge, hot-dip galvanized sheet steel, with reinforced steel frame.
    c. Wiring gutter: Minimum 4 inches square; both sides, top, and bottom.
    d. Front: Fastened with adjustable clamps.
        1) Trim size: Same as box.
        2) Finish: Rust inhibitor prime, with the Manufacturer's standard baked enamel or lacquer.
    e. Interior:
        1) Factory assembled, complete with circuit breakers.
        2) Capable of circuit breaker replacement without disturbing adjacent circuit breakers or removing main bus.
        3) Spaces: Cover openings with an easily removable metal cover.
    f. Door hinges: Concealed.
    g. Locking device:
        1) Flush type.
        2) Doors over 30 inches in height: Multipoint.
        3) Identical key locks, with two milled keys for each lock.
    h. Circuit directory: Metal frame with transparent plastic face and enclosed card on the interior of the door. A neatly typed directory properly identifying each circuit shall be provided in the directory holder with the date of installation.
5. Bus bar:
    a. Material: Tin-plated copper full sized throughout length.
    b. Provide for the mounting of future circuit breakers along the full length of bus regardless of the number of units and spaces shown. Machine, drill, and tap as required for current and future positions.
    c. Neutral: Insulated, rated the same as phase bus bars with at least one terminal screw for each branch circuit.
    d. Ground: Copper, installed on the panelboard frame, bonded to the box with at least one terminal screw for each circuit.
    e. Lugs and connection points:
        1) Suitable for either copper or aluminum conductors.
        2) Solderless main lugs for main, neutral, and ground bus bars.
    f. Bolt together and rigidly support bus bars and connection straps on molded insulators.
6. Circuit breakers:
    a. In accordance with UL 489.
    b. Thermal-magnetic, quick-make, quick-break, molded case, of the indicating type showing on/off and tripped positions of operating handle.
    c. Non-interchangeable, in accordance with NFPA 70.
    d. Locking: Provisions for handle padlocking.
    e. Type: Bolt-on circuit breakers in panelboards.
    f. Multi-pole circuit breakers designed to automatically open all poles when an overload occurs on one pole.
    g. Do not substitute single-pole circuit breakers with handle ties for multi-pole breakers.
    h. Do not use tandem or dual circuit breakers in normal single-pole spaces.

i. Ground fault interrupter:
   1) Equip with a conventional thermal-magnetic trip and a ground fault sensor rated to trip in 0.025 second for a 5 mA ground fault in accordance with UL 943, Class A sensitivity.
   2) Sensor with the same rating as the circuit breaker and a push-to-test button.

j. Circuit breakers with trip sizes larger than 100 A rating shall have interchangeable trips.

7. Nameplates:
   a. Indicate equipment disconnecting means remote location.
   b. Indicate complete panelboard rating information and identification tag.

F. Mini Power-Zone:
1. Panelboards and circuit breakers: Suitable for use with 75°C wire at full NFPA 70, 75°C ampacity.
2. Rating: Three-phase, 480 VAC primary, 15 kVA transformer, 120/208 VAC secondary.
3. Integral copper wound transformer, 115ºC rise, and epoxy-resin encapsulated.
4. Provided with two 5% FCBN taps, primary main circuit breaker, and secondary main circuit breakers.
5. Short-circuit current equipment rating: Fully rated; series connected not acceptable. Rating: 22,000 A rms symmetrical.
6. Cabinet:
   a. NEMA 3R with drip shield.
   b. Material: Code-gauge, hot-dip galvanized sheet steel, with reinforced steel frame.
   c. Wiring gutter: Minimum 4 inches square; both sides, top, and bottom.
   d. Front: Fastened with adjustable clamps.
      1) Trim size: Same as the box.
      2) Finish: Rust inhibitor prime, with the Manufacturer's standard baked enamel or lacquer.
   e. Interior:
      1) Factory assembled, complete with circuit breakers.
      2) Capable of circuit breaker replacement without disturbing adjacent circuit breakers or without removing main bus.
      3) Spaces: Cover openings with an easily removable metal cover.
   f. Door hinges: Concealed.
   g. Locking device:
      1) Flush type.
      2) Identical key locks with two milled keys for each lock.
   h. Circuit directory: Metal frame with transparent plastic face and enclosed card on the interior of the door.
7. Bus bar:
   a. Material: Tin-plated copper full sized throughout length.
   b. Provide for the mounting of future circuit breakers along the full length of bus regardless of the number of units and spaces shown. Machine, drill, and tap as required for current and future positions.
   c. Neutral: Insulated, rated the same as phase bus bars with at least one terminal screw for each branch circuit.
   d. Ground: Copper, installed on the panelboard frame, bonded to the box with at least one terminal screw for each circuit.
   e. Lugs and connection points:
      1) Suitable for either copper or aluminum conductors.
      2) Solderless main lugs for main, neutral, and ground bus bars.
   f. Bolt together and rigidly support bus bars and connection straps on molded insulators.
8. Circuit breakers:
   a. In accordance with UL 489.
   b. Thermal-magnetic, quick-make, quick-break, molded case, of the indicating type showing on/off and tripped positions of operating handle.
   c. Non-interchangeable, in accordance with NFPA 70.
   d. Locking: Provisions for handle padlocking.
   e. Type: Bolt-on circuit breakers.
   f. Multi-pole circuit breakers designed to automatically open all poles when an overload occurs on one pole.
   g. Do not substitute single-pole circuit breakers with handle ties for multi-pole breakers.
   h. Do not use tandem or dual circuit breakers in normal single-pole spaces.
   i. Ground fault interrupter:
      1) Equip with a conventional thermal-magnetic trip and a ground fault sensor rated to trip in 0.025 second for a 5 mA ground fault, UL 943, Class A sensitivity.
      2) Sensor with the same rating as the circuit breaker and a push-to-test button.

G. Circuit Breaker, Individual, 0 V to 600 V:
1. UL 489 listed for use at location of installation.
2. Minimum interrupt rating: 65,000 A.
3. Thermal-magnetic, quick-make, quick-break, indicating type, showing on/off and tripped indicating positions of the operating handle.
4. Suitable for use with 75°C wire at full NFPA 70, 75°C ampacity.
5. Locking: Provisions for padlocking the handle.
6. Multi-pole breakers to automatically open all poles when an overload occurs on one-pole.
7. Enclosure: In accordance with NEMA 250, Type 12, industrial use.

8. Interlock: Enclosure and switch shall interlock to prevent opening the cover with the switch in the on position.
9. Do not provide single-pole circuit breakers with handle ties where multi-pole circuit breakers are shown on the Drawings.

H. Separately Mounted Molded Case Switch, Individual, 0 V to 600 V:
1. UL 489 listed for use at location of installation.
2. Minimum interrupt rating: 65,000 A.
3. Discriminator instantaneous trip, quick-make, quick-break, indicating type, showing on/off and tripped indicating positions of the operating handle.
4. Suitable for use with 75°C wire at full NFPA 70, 75°C ampacity.
5. Locking: Provisions for padlocking the handle in the open position.
6. Multi-pole breakers to automatically open all poles when the handle is operated or an overload occurs.
7. Enclosure: NEMA 250, Type 12, industrial use.
8. Interlock: Enclosure and switch shall interlock to prevent opening the cover with the switch in the on position.
9. Do not provide single-pole circuit breakers with handle ties where multi-pole circuit breakers are shown on the Drawings.
10. Nameplates:
    a. Indicate equipment disconnecting means remote location.
    b. Indicate complete rating information and identification tag.

I. Disconnect/Safety Switches, Individual, 0 V to 600 V:
1. Disconnects shall be provided with NEMA 3R secondary enclosed circuit breaker disconnect/safety switches. Circuit breakers shall be provided with adjustable LSIG electronic trip units when shown on the Drawings.
2. In accordance with NEMA KS 1, UL listed and hp rated. Each switch shall be heavy duty, three-pole, 600 V with continuous current rating as shown on the Drawings.
3. Enclosure: In accordance with NEMA 250 and UL 98, the switch enclosure type shall be suitable for use at the location of installation.
4. In accordance with NEMA KS 1 and UL 98 for application to the system with available short-circuit current as shown on the Drawings.
5. Thermal-magnetic, quick-make, quick-break, the on/off positions of the operating handle shall be clearly marked.
6. Locking: Provisions for padlocking the handle in the off position.
7. Switches shall have high conductivity copper, visible blades; non-teasible, positive, quick-make, quick-break mechanisms; and the switch assembly plus the operating handle as an integral part of the enclosure base.
8. Switches shall be fused or non-fused as shown on the Drawings. Switches shall have fuse clips suitable for the required fuse type.
9. Interlock: Enclosure and switch shall interlock to prevent opening the cover with the switch in the on position. Switches shall have defeatable door interlocks.
10. Suitable for use with 75°C wire at full NFPA 70, 75°C ampacity.
11. Fuse mountings shall reject Class H fuses and accept only the current-limiting fuses specified.
12. Nameplates:
    a. Indicate equipment disconnecting means remote location.
    b. Indicate complete rating information and identification tag.

J. Fuse, 0 V to 600 V:
1. Current-limiting, with 200,000 A rms interrupting rating.
2. Provide to fit the mountings specified with the switches and the features to reject Class H fuses.
3. Motor and transformer circuits, 0 V to 600 V:
    a. Amperage: 0 to 600.
    b. In accordance with UL 248, Class RK-1, dual element, with time delay.
4. Feeder and service circuits, 0 V to 600 V:
    a. Amperage: 0 to 600.
    b. In accordance with UL 248, Class RK-1, dual element, with time delay.
5. Feeder and service circuits, 0 V to 600 V:
    a. Amperage: 601 to 6,000.
    b. In accordance with UL 248, Class L, double O-rings, and silver links.
6. Branch circuits and control circuits, 0 V to 600 V:
    a. Amperage: 1/2 to 30.
    b. UL listed, Class CC, rejection type, current limiting, with time delay.
7. Semiconductor type fuses shall be provided for valve actuator protection as recommended by the Actuator Manufacturer.
8. Transformer, motor, and actuator circuits, 0 V to 600 V: Disconnect switch fuses shall be Class-J, current limiting, time delay fuses unless the Equipment Manufacturer indicates otherwise.

K. CTs:
1. CTs shall be selected so that full load secondary currents will lie between 2.5 A and 4.0 A and be coordinated with indicating meters so they read 1/2 to 3/4 scale at full load.
2. CTs shall have the mechanical and electrical ratings to withstand short-circuit current, stresses, and the heating effect imposed by their load. Transformers shall have the polarity identified, shall be capable of carrying rated current continuously, and have ample capacity for connected burden.

3. 15 kV CT rating:
    a. Wound primary, bar type. Vacuum cast in polyurethane resin rated for 15 kV applications.
    b. BIL: 150 kV full wave.
    c. Metering accuracy: ANSI accuracy Class 0.3, B0.1 through B1.8.
4. 5 kV CT rating:
    a. Wound primary, bar type. Vacuum cast in polyurethane resin rated for 5 kV applications.
    b. BIL: 60 kV full wave.
    c. Metering accuracy: ANSI accuracy Class 0.3, B0.1 through B1.8.
5. 600 V CT rating:
    a. Instrument grade, toroid type.
    b. BIL: 10 kV.
    c. Metering accuracy: ANSI accuracy Class 0.3 through B0.9.
6. Provide as a Shop Drawing Submittal, the complete burden calculations for CTs.

L. Potential Transformers:
1. PTs shall be designed and manufactured for metering and protective relay applications. The primary voltage rating shall not be exceeded under normal service by more than 10%, yet capable under emergency conditions to withstand and function successfully at temporary system overvoltages of 1.25 times the primary voltage rating. Primary and secondary current-limiting fuses shall be provided for each PT. Thermal ratings shall be such that, at rated voltage, the burden imposed does not cause the transformer to exceed the allowable temperature rise.
2. 15 kV PT rating:
    a. BIL: 150 kV full wave.
    b. ANSI accuracy class:
        1) 0.3 WXMY, 1.2 Z at 100% rated voltage with 120 V based ANSI burden.
        2) 0.3 WX, 0.6 M, 1.2 Y at 58% rated voltage with 69.3 V based ANSI burden.
    c. The PT insulation class shall be rated 15 kV. The primary fuses shall have a minimum interrupting current rating of 25 kA SYM.
3. 5 kV PT rating:
    a. BIL: 60 kV full wave.
    b. ANSI accuracy class:
        1) 0.3 WXMY, 1.2 Z at 100% rated voltage with 120 V based ANSI burden.
        2) 0.3 WX, 0.6 M, 1.2 Y at 58% rated voltage with 69.3 V based ANSI burden.
    c. The PT insulation class shall be rated 5.5 kV. The primary fuses shall have a minimum interrupting current rating of 45 kA SYM.
4. 600 V PT rating:
    a. BIL: 10 kV.
    b. Metering accuracy: ±1%.
5. Provide as a Shop Drawing Submittal, the complete burden calculations for potential transformers.

M. Push Button, Indicating Light, and Selector Switches:
1. General:
    a. Function: Select, initiate, and display discrete control functions.
    b. Type: Heavy duty, watertight, oil-tight, industrial.
    c. Mounting: 30.5 mm single round hole. Panel thickness 1/16 inch to 1/4 inch.
    d. Legend plate: Large size square style aluminum field and black markings. Minimum letter and number height: 7/64 inch. Markings as shown on the Drawings and as approved by the ENGINEER.
    e. Configuration: Light, push button, or switch as shown on the Drawings.
2. Light features:
    a. Lights: Full voltage 120 VAC and 125 VDC, high-visibility LED, push-to-test type.
    b. Lens color: Color as specified and shown on the Drawings.
3. Push button and switch features:
    a. Guard: Full guard with flush button.
    b. Push button color:
        1) Off, emergency stop, stop, reset: Red.
        2) All others: Black.
    c. Switches shall be maintained or spring-return to center position as required and as approved by the ENGINEER.
    d. Push buttons and selector switches shall be lockable in the off position where shown on the Drawings.
4. Signal interface:
    a. Contact block:
        1) Type: Silver-coated butting.
        2) Rating: 10 A continuous at 125 VDC.
        3) Sequence: Break-before-make.
        4) Arrangement: Normally open or normally closed as indicated and to perform the functions required.
        5) Terminals: Screw with strap clamp.
        6) Switches and push buttons shall have a minimum of one spare contact in addition to the required contacts.
        7) Contact rating: In accordance with NEMA ICS 2, Type A600.

5. NEMA rating: NEMA 4, watertight and dust-tight and NEMA 13, oil-tight.

N. Terminal Junction Box:
   1. Cover: Hinged.
   2. Terminal blocks:
      a. Provide a separate connection point for each conductor entering or leaving box.
      b. Spare terminal points: 25%.
   3. Interior finish: Paint with white enamel or lacquer.

O. Terminal Block (0 V to 600 V):
   1. General:
      a. Accommodate present and spare indicated needs.
      b. One wire per terminal.
      c. Wire spare and unused panel-mounted elements to their panels' terminal block.
      d. Spare terminals: 20% of the connected terminals, but no less than ten per terminal block.
   2. General purpose, #8 AWG to #4 AWG:
      a. Connection type: Washer head blinding screws into molded one-piece terminal boards, conductors and cables terminated with heavy duty ring terminals.
   3. Terminal block, general purpose:
      a. Use for conductor and cable terminations.
      b. Rated voltage: 600 VAC.
      c. Rated current: 30 A.
      d. Wire size: #18 AWG to #10 AWG.
      e. Connection type: Washer head binding screws, conductors and cables terminated with heavy duty ring terminals.
      f. Provide the Manufacturer's mounting kit and marking strip. Marking shall be permanent machine produced.
   4. Terminal block, fuse/disconnect plug:
      a. Use: Provide one for each analog I/O field interface cable.
      b. Rated voltage: 300 VAC.
      c. Rated current: 15 A.
      d. Wire size: #10 AWG to #14 AWG.

P. Elapsed Time Meter:
   1. Drive: Synchronous motor.
   2. Range: 0 hours to 99,999.9 hours, non-reset type.
   3. Mounting: Semi-flush, panel.

Q. 24 V Signal/Control Relays:
   1. Tags: As shown on the Drawings.
   2. Type: Compact general purpose plug-in.
   3. Contact arrangement: As shown on the Drawings, two Form C contacts minimum.
   4. Contact rating: 10 A minimum at 24 VDC and 250 VAC.
   5. Contact material: Silver cadmium oxide alloy.
   6. Coil voltage: 24 VDC.
   7. Coil power: 2.2 VA/1.3 W.
   8. Provided and installed with the Manufacturer recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
   9. Expected mechanical life: 10,000,000 operations minimum.
   10. Expected electrical life at rated load: 100,000 operations.
   11. Indication type: LED indicator lamp.
   12. Lockable push-to-test button.

R. Industrial Control Relays:
   1. 120 VAC and 125 VDC relays.
   2. 24 VAC/VDC relays when contact DC voltage is greater than 30 VDC.
   3. Contact arrangement: As shown on the Drawings, two Form C contacts minimum.
   4. Contact rating: 3 A at 150 VDC load switching.
   5. Contact material: Silver cadmium oxide alloy.
   6. Coil voltage: 110 VDC 120 VAC.
   7. Coil power: 1.8 W.
   8. Provide with indicator lamps.
   9. Expected mechanical life: 100,000 operations minimum.
   10. Expected electrical life at rated load: 100,000 operations minimum.
   11. Provided and installed with the Manufacturer's recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
   12. 110 VDC coil relay bases shall include appropriately rated voltage drop resistors and surge suppression diodes professionally soldered onto the base with leads protected by heat shrink tubing. Voltage drop resistor rating is estimated to be 2,000 ohms, with a minimum rating of 2 W, with at least 5% accuracy. The surge suppression diode shall be a minimum rating of 3 A, 1000 V. Device rating calculations and example fabricated base shall be submitted to ENGINEER for approval.
   13. Provide and install relay hold-down springs.

S. Magnetic Control, Machine-Tool and Industrial Relays:
   1. In accordance with NEMA ICS 2, Class A 600 (600 V, 10 A continuous, 7,200 VA make, 720 VA break), industrial control with a minimum of four field convertible contacts.
   2. Time delay relay attachment:
      a. Solid-state type, timer adjustable range available from 0.1 to 180 seconds as required.
      b. Field convertible from on delay to off delay and vice versa.
   3. Latching attachment: Mechanical latch having unlatching coil and coil clearing contacts.
   4. Magnetic control relays shall be provided and installed with the Manufacturer's recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.

T. Magnetic Contactor:
   1. In accordance with NEMA ICS 2 and UL 508.
   2. Electrically operated, electrically held.
   3. Have UL certification to achieve IEC 947, Type 2 coordination when subjected to 100,000 A short-circuit fault currents.
   4. Main contacts:
      a. Power driven in one direction with gravity dropout.
      b. Silver alloy with wiping action and arc quenchers.
      c. Continuous-duty, rated at a minimum of 20 A, 600 V.
   5. Control: As shown on the Drawings.
   6. Provided and installed with the Manufacturer's recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
   7. One normally open and one normally closed auxiliary contacts rated 10 A at 480 V shall be provided.
   8. Enclosure: In accordance with NEMA 250, Type 12, dust-tight, drip-tight, industrial use, suitable for outdoor installations.

U. Alternator Relay:
   1. Contact arrangement and wired as shown on the Drawings, two Form C contacts minimum.
   2. Contact rating: 10 A minimum at 120 VAC.
   3. Coil voltage: 125 VDC or 120 VAC.
   4. Coil power: 1.2 W.
   5. Expected mechanical life: 10,000,000 operations.
   6. Expected electrical life at rated load: 100,000 operations.
   7. Provided and installed with the Manufacturer's recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.

V. Dry Type Transformer (0 V to 600 V Primary):
   1. Panelboard transformers shall be totally enclosed non-ventilated NEMA 3R type with copper windings. Transformers shall be provided weathershield kits and insulation pads to reduce noise.
   2. In accordance with UL 1561. Transformers shall be UL listed and bear the UL label.
   3. Transformers shall be the low loss type, self-cooled, two-winding with minimum efficiencies when operated at 35% of full load capacity.
   4. Transformers shall be tested in accordance with IEEE C57.12.91, dry type transformers for general applications.
   5. Transformers shall be designed for continuous operation at rated kVA, for 24 hours a day, 365 days a year operation, with normal life expectancy in accordance with IEEE C57.96.
   6. Required performance shall be obtained without exceeding the maximum temperature rise in a 104°F maximum ambient.
   7. Insulation materials shall be flame retardant and shall not support combustion in accordance with ASTM D 635.
   8. Insulation class and temperature rise: 220°C insulation system designed for full load operation at a maximum temperature rise of 115°C above 40°C ambient.
   9. Transformer core shall be constructed with high grade, non-aging, grain-oriented silicon steel with high magnetic permeability and low hysteresis and eddy current losses. Maximum magnetic flux densities shall be substantially below the saturation point. The transformer core volume shall allow efficient transformer operation at 10% above the highest tap voltage. The core laminations shall be tightly clamped and compressed.
   10. Transformer coils shall be wound of electrical grade copper with continuous wound construction.
   11. The core and coil assembly shall be impregnated with non-hydroscopic, thermosetting varnish and cured to reduce hot spots and seal out moisture. The assembly shall be installed on vibration-absorbing pads.
   12. The transformer enclosure shall be made of heavy gauge steel and finished utilizing a continuous process of de-greasing, cleaning, and phosphatizing, followed by electrostatic deposition of a polymer polyester powder coating and baking. The enclosure construction shall be ventilated, NEMA two drip-proof, with lighting holes. Ventilation openings shall be protected against falling dirt and debris. Provide enclosure weathershield(s) where located either outdoors or within the vicinity of a moisture prone area.
   13. Three-phase transformers sized between 15 kVA to 30 kVA shall be provided with and mounted on a wall bracket.
   14. Provide terminal lug kit(s) as needed for a complete installation.
   15. Voltage taps:
      a. Three-phase, 3 kVA to 15 kVA: Four 2 1/2% full capacity; two above and two below normal voltage rating.
      b. Three-phase, 30 kVA and above: Four 2 1/2% full capacity; two above and two below normal voltage rating.
   16. Impedance: 4.5% minimum on units 75 kVA and larger.

17. Sound levels shall be warranted by the Manufacturer.
    a. Maximum sound level:
        1) 40 dB for 0 kVA to 9 kVA.
        2) 45 dB for 10 kVA to 50 kVA.
        3) 50 dB for 51 kVA to 150 kVA.
18. Vibration isolators:
    a. Rated for the transformer's weight.
    b. Isolation efficiency: 99%, at fundamental frequency of sound emitted by transformer.
    c. Less than 30 kVA: Isolate the entire unit from the structure with external vibration isolators.
    d. 30 kVA and above: Isolate the core and the coil assembly from the transformer enclosure with an integral vibration isolator.
19. Nameplates:
    a. Indicate equipment disconnecting means remote location.
    b. Indicate complete transformer nameplate information and identification tag.

W. Encapsulated Transformers (0 V to 600 V Primary):
1. In accordance with UL 1561, UL 506, and IEEE C57.12.01.
2. Transformers shall be tested in accordance with IEEE C57.12.91, dry type transformers for general applications. Transformers shall be UL listed and bear the UL Label.
3. Transformers shall be designed for continuous operation at rated kVA, for 24 hours a day, 365 days a year operation, with normal life expectancy in accordance with IEEE C57.96.
4. Required performance shall be obtained without exceeding the maximum temperature rise in a 104°F maximum ambient.
5. Insulation materials shall be flame retardant and shall not support combustion in accordance with ASTM D 635.
6. Insulation class and temperature rise: 180°C to 185°C insulation system designed for full load operation at a maximum temperature rise of 115°C above 40°C ambient.
7. Transformer core shall be constructed with high grade, non-aging, grain-oriented silicon steel with high magnetic permeability and low hysteresis and eddy current losses. Maximum magnetic flux densities shall be substantially below the saturation point. The transformer core volume shall allow efficient transformer operation at 10% above the highest tap voltage. The core laminations shall be tightly clamped and compressed.
8. Transformer coils shall be wound of electrical grade aluminum with continuous wound construction.
9. The core and coil assembly shall be completely encapsulated in resin with the intent to provide a moisture proof, shock-resistant seal.
10. The transformer enclosure shall be made of heavy gauge steel and finished utilizing a continuous process of de-greasing, cleaning, and phosphatizing, followed by electrostatic deposition of a polymer polyester powder coating and baking. The coating shall be UL recognized for outdoor use.
11. Sound levels shall be warranted by the Manufacturer.
    a. Maximum sound level:
        1) In accordance with IEEE C57.12.01.
        2) 45 dB for 0 kVA to 9 kVA.
        3) 50 dB for 10 kVA to 50 kVA.
12. Vibration isolators:
    a. Rated for the transformer's weight.
    b. Isolation efficiency: 99%, at fundamental frequency of sound emitted by transformer.
    c. Less than or equal to 37.5 kVA: Isolate the entire unit from the structure with external vibration isolators.
13. Nameplates:
    a. Indicate equipment disconnecting means remote location.
    b. Indicate complete transformer nameplate information and identification tag.

X. Low Voltage, Secondary Surge Protective Equipment:
1. In accordance with IEEE C62.11.
2. Surge capacitor:
    a. Impregnated with non-PCB, biodegradable dielectric fluid.
    b. Integral discharge resistor that will drain residual voltage to 50 V crest in less than 1 minute after disconnection from the circuit.
3. Arrestor: High-strength metal oxide valve elements enclosed in high-strength, corrosion-resistant, molded resin housing.
4. Equip the capacitor and the arrestor with a mounting nipple, a flat washer, and a nut suitable for knockout or bracket mounting.

Y. Level Switch, Float Type, Water on Floor:
1. General:
    a. Function: Actuate contact at the preset liquid level.
    b. Type: Float-actuated mounted directly to the wall.
2. Service:
    a. Liquid: Water.
    b. Pressure: Atmospheric.
    c. Temperature: 0°F to 120°F.

3. Performance:
   a. SP: As shown on the Drawings.
   b. Deadband: 1/16 inch maximum.
4. Features:
   a. Entire assembly: Watertight and impact-resistant.
   b. Cable: Length as noted or as necessary per the mounting requirements.
   c. Materials:
      1) Float, stem, and guide connected to a switch enclosure.
      2) Insertion length: As required to achieve the noted SP.
      3) Materials: Stem and float Type 304 SST. Slosh shield lucite.
      4) Float size: 2 inch maximum.
   d. Signal interface:
      1) Switch: SPDT, arrangement.
      2) Contact: Rated 10 A continuous and 85 A starting minimum at 120 VAC.

Z. Support and Framing Channels:
1. Channel members shall be fabricated from structural grade steel in accordance with ASTM A 36, ASTM A 575, ASTM A 576, or ASTM A 635.
2. Fittings shall be fabricated from steel in accordance with ASTM A 36, ASTM A 575, ASTM A 576, or ASTM A 635.
3. Channel:
   a. Cold-formed, manufactured from low carbon strip steel.
      1) Finish:
         a) HDG: 2.6 mil in accordance with ASTM A 123 and ASTM A 153.
         b) Type 304 SST.
         c) Raceway support channel, hardware, and fittings anchored to the floor or equipment pads shall be Type 304 SST.
         d) Exterior cable and raceway support channel, hardware, and fittings shall be Type 304 SST, including vaults, handholes, surge tanks, and switchyard.
4. Nuts and hardware:
   a. Manufactured from mild steel bars, case hardened with positive biting action.
   b. Finish: Electro-galvanized in accordance with ASTM B 633 Type III SC1 or S SST based on location.
5. General fittings:
   a. Manufactured from hot-rolled, pickled, and oiled steel plates, strip or coil, and in accordance with ASTM A 36, ASTM A 575, ASTM A 576, or ASTM A 635.
   b. Finish: HDG in accordance with ASTM A 123 and ASTM A 153 or SST based on location.
6. Concrete inserts:
   a. Cold-formed manufactured from standard 12 gauge in accordance with ASTM A 1011 SST GR33 or ASTM A 653 GR33. Hot-rolled inserts, where indicated shall be manufactured from carbon steel in accordance with ASTM A 283 Grade D.
   b. Finish: HDG in accordance with ASTM A 123 and ASTM A 15 SST based on location.

AA. Nameplates:
1. Material: Laminated plastic.
2. Attachment screws: SST.
3. Color:
   a. General labels: White surface, engraved to a black core, white with black letters.
   b. Special labels: Red surface, engraved to a black core, red with black letters. Letter height shall be 3/8 inch.
4. Engraving:
   a. Push buttons/selector switches: Name of the drive controlled on one, two, or three lines, as required.
   b. Panelboards: Panelboard designation, service voltage, and phases.
   c. Control panels: Control panel designation.
   d. Separately mounted circuit breakers: General label – name of associated equipment.
   e. Terminal junction boxes: Terminal junction boxes shall generally indicate the circuit or circuits installed and the associated voltage level on a general label. Specific wording will be provided by the ENGINEER or the OWNER.
   f. Pull and junction boxes: Pull and junction box general labels shall generally indicate the circuits installed. Specific wording will be provided by the ENGINEER or the OWNER.
5. Letter height:
   a. Push buttons/selector switches: 1/8 inch.
   b. Panelboards: 1/2 inch.
   c. Junction, terminal, and pull boxes: 1/2 inch.
   d. Separately mounted circuit breakers and control panels: 1/2 inch.
   e. Separately mounted safety switches: 1/2 inch.
   f. Remote disconnecting means: 1/2 inch.
6. Where equipment disconnecting means is in a remote location, the disconnecting means shall be lockable and its location shall be field marked.

BB. EUH:
1. Characteristics:
    a. Multiblade propeller fan.
    b. Direct-drive motor.
    c. Heating coil.
    d. Integral thermostat.
    e. Cabinet-mounted.
2. Cabinet:
    a. 16 gauge steel arranged for wall mounting with bracket.
    b. Baked enamel finish of a color selected by the OWNER from the Manufacturer's standard color chart.
3. Electric heating coil:
    a. Low surface temperature type with sheath element inserted in finned-tube coil.
    b. Factory wiring shall include operating and safety controls required by UL and NEC and carry the UL label.
    c. Control wiring shall include 120 V control transformer.
4. Capacity, EUH 5 kW electric coil, arranged for 480 V, three-phase elements.

PART 3 EXECUTION

3.1 GENERAL

A. Refer to the Drawings associated with the Project, prior to the installation or roughing-in of the electrical outlets, conduit, and equipment, to determine the exact location of the outlets.

B. Determine and ensure that electrical equipment shall be accessible, such as junction boxes, pull boxes, panelboards, switches, controls, and such other apparatus as may require maintenance and operation from time to time.

C. After installation, electrical equipment shall be protected to prevent damage during the construction period. Openings in conduits and boxes shall be closed to prevent the entrance of foreign materials.

3.2 PREPARATION

A. Demolition:
1. Demolition work shall be performed by the electrical Subcontractor. Demolished items shall be removed from the premises by the CONTRACTOR.
2. Existing lighting fixtures, devices, switches, wiring, etc. in the renovation shall be demolished. Care shall be taken during demolition work to maintain the integrity of existing raceway systems which may be reused as shown on the Drawings.
3. Care shall be taken to maintain any existing feeder, branch circuit, and auxiliary systems wiring/raceways passing through renovated areas which serves existing equipment or areas to remain in present or future operation.
4. The electrical Subcontractor shall be responsible for verifying the mechanical integrity of any existing raceway system intended to be reused. Where the existing raceway system does not meet the requirements of the Contract Documents, the raceway system shall be repaired or replaced before any new wiring is installed.
5. Existing exposed raceways and raceway components that are not to be reused shall be demolished. Where existing raceways are embedded in building construction, they shall be cut flush with finished surfaces, plugged with a suitable and compatible plate and abandoned in place. Existing wiring shall be removed.
6. Where required, the existing raceway system shall be matched and extended to new outlet/device locations as shown on the Drawings. In general, new raceways in finished areas shall be run concealed in building construction, above hung ceilings, in stud walls, etc. Obtain approval from the OWNER regarding the location and the routing of any exposed raceways prior to installing the same.

3.3 INSTALLATION

A. Testing as specified in SECTION 26 08 00.

B. Outlet and Device Boxes:
1. Install suitable for the conditions encountered at each outlet or device in the wiring or raceway system, sized in accordance with NFPA 70.
2. Locations:
    a. Drawing locations are approximate. The electrical Subcontractor shall study the Project plans in relating to the spaces and equipment surrounding each outlet so that receptacles, switches, or other electrical devices are symmetrically located and mounted in or on the walls, ceiling, and floor.
    b. Outlet and device boxes that interfere with the installation of mechanical equipment, structural, or architectural features or that will be inaccessible due to the work of other trades shall be relocated accordingly as a part of construction conditions encountered during the course of the construction program at no cost to the OWNER. Notify the ENGINEER prior to any relocation.
    c. Light switch: Install on the lock side of doors.
    d. Light fixture: Install in a symmetrical pattern in accordance with the room layout.
3. Mounting height:
    a. General:
        1) Measured to the centerline of the box.
        2) Where specified heights do not suit the building construction or the finish, mount as directed by the ENGINEER.
    b. Devices: 48 inches above floor or match existing.
    c. Thermostat: 54 inches above floor or match existing.
4. Install plumb and level.

5. Flush-mounted:
    a. Install with concealed conduit.
    b. Install proper type extension rings or plaster covers to make the edges of boxes flush with the finished surface.
    c. Holes in the surrounding surface shall be no larger than required to receive the box.
6. Support boxes independently of the conduit by attachment to the building structure or the structural member.
7. Install bar hangers in the frame construction or fasten the boxes directly with wood screws on wood, bolts, and expansion shields on concrete or brick, toggle bolts on hollow masonry units, and machine screws threaded into steelwork.
8. Threaded studs driven in by powder charge and provided with lock washers and nuts shall be acceptable in lieu of expansion shields.
9. Provide plaster rings where necessary.
10. Boxes embedded in concrete or masonry do not need to be additionally supported.
11. Install galvanized mounting hardware in industrial areas.
12. Install separate junction boxes for flush or recessed lighting fixtures where required by fixture terminal temperature.
13. Boxes supporting fixtures: Provide the means of attachment with the adequate strength to support the fixture.
14. Open no more knockouts in sheet steel device boxes than are required; seal unused openings.
15. All locations shall be cast metal.

C. Junction and Pull Boxes:
1. Install where shown on the Drawings and where necessary to terminate, tap-off, or redirect multiple conduit runs.
2. Install pull boxes where necessary in the raceway system to facilitate conductor installation.
3. Install in conduit runs at least every 150 feet or after the equivalent of three right-angle bends.
4. Use outlet boxes as junction and pull boxes wherever possible and allowed by applicable codes.
5. Installed boxes shall be accessible.
6. Do not install on finished surfaces.
7. Install plumb and level.
8. Support boxes independently of the conduit by attachment to the building structure or the structural member.
9. Install bar hangers in the frame construction or fasten the boxes directly with wood screws on wood, bolts, and expansion shields on concrete or brick, toggle bolts on hollow masonry units, and machine screws or welded threaded studs on steelwork.
10. Threaded studs driven in by powder charge and provided with lock washers and nuts shall be acceptable in lieu of expansion shields.
11. Boxes embedded in concrete or masonry do not need to be additionally supported.
12. Mounting hardware:
    a. Noncorrosive areas: Galvanized.
    b. Corrosive areas: PVC-coated steel.
13. Location/type:
    a. Indoor, dry: In accordance with NEMA 250, Type 12.
    b. Indoor and outdoor, wet: In accordance with NEMA 250, Type 4.
    c. Indoor and outdoor, wet and corrosive: In accordance with NEMA 250, Type 4X.
    d. Indoor and outdoor, wet, dust, or oil: In accordance with NEMA 250, Type 13.

D. Wiring Devices:
1. Switches:
    a. Mounting height: As specified in this Section.
    b. Install with the switch operation in vertical position.
    c. Install single-pole, two-way switches such that the toggle is in the up position when the switch is on.
2. Receptacles:
    a. Install with the grounding slot up except where horizontal mounting is shown, in which case install with the neutral slot up.
    b. Ground receptacles to the boxes with grounding wire only.
    c. Weatherproof receptacles:
        1) Install in a cast metal box.
        2) Install such that the hinge for the protective cover is above the receptacle opening.
    d. Ground fault interrupter: Install a feed-through model at locations where ground fault protection is specified for downstream conventional receptacles; use only when approved by the ENGINEER.
    e. Special-purpose receptacles: Install in accordance with the Manufacturer's instructions.

E. Device Plates:
1. Securely fasten to the wiring device; ensure a tight fit to the box.
2. Flush-mounted: Install with the four edges in continuous contact with finished wall surfaces without the use of mats or similar materials. Plaster fillings shall not be acceptable.
3. Surface-mounted: Plate shall not extend beyond the sides of the box unless plates have no sharp corners or edges.
4. Install with an alignment tolerance to the box of 1/16 inch.
5. Engrave with designated titles, when shown on the Drawings.

6. Types:
    a. Outdoor: Weatherproof.
    b. Indoor: Surface-mounted, cast metal boxes.

F. Panelboard and Distribution Panelboard:
1. Install securely, plumb, in-line, and square with walls.
2. Install the top of cabinet 6 feet above the floor.
3. Provide a typewritten circuit directory for each panelboard.

G. Disconnects, Safety Switches, Separately Mounted Circuit Breakers, Molded Case Switches, and Lighting Contactors:
1. Install in accordance with the Manufacturer's instructions and recommendations.
2. Install equipment as shown on the Drawings and in accordance with NFPA 70.
3. Install equipment so that it is readily accessible for inspection, operation, and maintenance.
4. Location/type:
    a. Indoor, dry: In accordance with NEMA 250, Type 12.
    b. Indoor and outdoor, wet: In accordance with NEMA 250, Type 4.
    c. Indoor and outdoor, wet, and corrosive: In accordance with NEMA 250, Type 4X.
    d. Indoor and outdoor, wet, dust, or oil: In accordance with NEMA 250, Type 13.

H. Dry Type Transformer, 0 V to 600 V Primary:
1. Load external vibration isolator such that no direct transformer unit metal is in direct contact with the mounting surface.
2. Provide moisture proof, flexible conduit for electrical connections.
3. Connect voltage taps to achieve (approximately) rated output voltage under normal plant load conditions.
4. Provide wall brackets for single-phase units, 15 kVA to 167 1/2 kVA, and three-phase units, 15 kVA to 112 kVA.
5. Adhere to the Manufacturer's recommended installation clearances with the intent to prevent any unforeseen accidental contact with flammable or combustible materials. Ensure that airflow is not restricted through the bottom of the transformer.
6. Isolation transformer: Ground isolation shields to unit enclosure with conductor of the same material, and the same size minimum, as shield ground lead provided with unit.

I. Control Stations:
1. Heavy duty, watertight, and corrosion-resistant type:
    a. Locations: Nonhazardous, outdoor, or normally wet areas.
    b. Mounting: In accordance with NEMA 250, Type 4X enclosure.
    c. Mounting height: 4 feet above floor or finished grade.
2. Do not install on finished outdoor surfaces.

J. Terminal Junction Box:
1. Install as specified in this Section.
2. Label each block and terminal with a permanently attached, non-destructible tag.
3. Do not install on finished outdoor surfaces.
4. Location:
    a. Indoor, dry: In accordance with NEMA 250, Type 12.
    b. Indoor and outdoor, wet: In accordance with NEMA 250, Type 4.
    c. Indoor and outdoor, wet and corrosive: In accordance with NEMA 250, Type 4X.
    d. Indoor and outdoor, wet, dust, or oil: In accordance with NEMA 250, Type 13.

K. EUH:
1. Install in accordance with the Manufacturer's instructions.
2. Attach securely and permanently to prevent objectionable operating noise.
3. Provide liquid-tight metal flexible conduit for electrical connections.

L. Support and Framing Channel:
1. Furnish zinc-rich primer; paint cut ends prior to installation. Provide caps on the ends from the floor, the walkway, or the pad to 7 feet above. Provide caps on bolts and all-thread on the bottom of the channel.
2. Furnish and install the supplementary steel, channels, and supports required for the proper installation, mounting, and support of the lighting fixtures and electrical equipment to be installed as required.
3. Supplementary steel, channels, and supports shall be furnished, installed and secured with the fittings, support rods, and appurtenances required for a complete support or mounting system.
4. Supplementary steel and channels shall be firmly connected to the building construction in a manner approved by the ENGINEER prior to the installation of the same. Submit to the ENGINEER the locations proposed for using supplementary steel and channels for the support of equipment, fixtures and raceways.
5. The type and size of the supporting channels and steel shall be of sufficient strength and size to allow only a minimum deflection in accordance with the channel and Steel Manufacturer's requirements for loading.
6. Supplementary steel and channels shall be installed in a neat and workmanlike manner parallel to the walls, floor and ceiling construction. Turns shall be made with 90 degree and 45 degree fittings, as required to suit the construction and installation conditions.

3.4 PROTECTION

A. Motor Surge:
1. Ground in accordance with NFPA 70.
2. Low-voltage: Ground terminals to equipment bus.

3.5 CLEANING

A. Upon completion of the installations, thoroughly inspect exposed portions of the electrical installation and completely remove exposed labels, markings, and foreign materials.

B. The interior of boxes and cabinets shall be left clean; exposed surfaces shall be cleaned and plated surfaces polished.

C. Repair damage to finish surfaces resulting from Work under this Section.

END OF SECTION

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SECTION 26 05 13
MEDIUM-VOLTAGE CABLES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for medium-voltage cables.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINENTANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. American National Standards Institute (ANSI):

1. C119.1 – Electric Connectors-Sealed Insulated Underground Connector Systems Rated 600 Volts

B. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):

1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

C. Association of Edison Illuminating Companies (AEIC):

1. CS8 – Specification for Extruded Dielectric, Shielded Power Cables Rated 5 through 46 kV

D. ASTM International (ASTM):

1. B 496 – Standard Specification for Compact Round Concentric-Lay-Stranded Copper Conductors

E. Institute of Electrical and Electronics Engineers (IEEE):

1. 48 – Standard for Test Procedures and Requirements for Alternating-Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV
2. 400 – Guide for Field Testing and Evaluation of the Insulation of Shielded Power Cable Systems Rated 5 kV and Above
3. 400.3 – Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment
4. 404 – Standard for Extruded and Laminated Dielectric Shielded Cable Joints Rated 2.5 kV to 500 kV
5. 1202 – Standard for Flame-Propagation Testing of Wire and Cable - Corrigendum 1

F. Insulated Cable Engineers Association/National Electrical Manufacturers Association (ICEA/NEMA):

1. S-93-639/WC74 – 5-46kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy

G. Underwriters Laboratories (UL):

1. 486A/486B – Standard for Wire Connectors
2. 1072 – Standard for Medium-Voltage Power Cables

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Manufacturer's literature:
   a. Cable descriptive product information.
   b. Cable accessories descriptive product information.
   c. Wiring systems descriptive product information.
   d. Wire systems rating information.
   e. Wire systems dimensional drawings.
   f. Wire systems special fittings.
4. Method and equipment for installing conductors.
5. Cable identification spreadsheet (in XLS/XSLX format) and As-Built Drawings of cable in hardcopy and electronic formats; spreadsheet cell columns shall include:
   a. Conductor/conduit number.
   b. Complete conductor and cable circuit identification.
   c. Source end.
   d. Source terminal (device, terminal, line/phase).
   e. Load end.
   f. Load terminal (device, terminal, line/phase).
6. Conduit/conductor schedule spreadsheet (in XLS/XSLX format) and As-Built Drawings in hardcopy and electronic formats, include approximate lengths.
7. Cable samples with cable marking system identification.
8. Pulling tension calculations and sidewall pressure calculations:
   a. Submit for approval before raceway installation.
   b. Show that maximum tension will not exceed the Manufacturer’s recommendations.
   c. For cables and conductors larger than #2 AWG and pulling lengths longer than 100 feet.
   d. For cables and conductor sizes for pulling lengths longer than 100 feet.

D. Quality Control Submittals:

1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.

b. As specified in SECTION 01 78 23.
c. Shop Drawing Submittal information.
d. Factory and field certified test reports.
e. Final As-Built conduit/conductor schedule spreadsheet (in XLS/XSLX format) and As-Built Drawings in hardcopy and electronic formats, include exact lengths.
f. Final As-Built Drawings:
1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
a) Drawings shall be on a standard DW provided title block and border.
b) As-Builts and Manufacturer's drawings shall be provided:
(1) On a standard DW provided title block and border.
(2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
(3) Text: Minimum 0.1 inches, maximum 0.2 inches.
(4) Titles: 0.2 inches.
g. Warranty documentation.

1.4 QUALITY ASSURANCE

A. The Medium-Voltage Cable Manufacturer shall have a minimum of 10 years of experience in manufacturing medium-voltage cables; cable shall be made in the United States of America.
B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.
C. The Manufacturer shall have available for audit detailed descriptions of the method by which the various manufacturing processes and production test are recorded, thus enabling the traceability of the completed cable. Steps in the manufacturing process, from receipt of raw material to the final tests, shall be included. Where multiple records are used, the method for cross-referencing shall be noted.
D. Terminating shall be performed by electricians having at least 80 hours of formal training and a minimum of 5 years of field experience in the Work of this Section.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Check for reels not completely restrained, reels with interlocking flanges or broken flanges, damaged reel covering, or any other indication of damage. Do not drop reels.
B. Unload reels using a sling and spreader bar. Roll reels in the direction of the arrows shown on the reel and on surfaces free of obstructions that could damage the cable.
C. Store cable on a solid, well-drained location. Unjacketed armored cable shall be stored indoors. Cover cable reels with plastic sheeting or tarpaulin. Do not lay reels flat.
D. Seal cable ends with heat-shrinkable end caps. Do not remove end caps until cables are ready to be terminated.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Warranty for 20 year from the Substantial Completion date for the satisfactory performance and installation of the medium-voltage cables system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS:

A. Cable:
1. General Cable
2. Okonite
3. Southwire
B. Cable Termination Boot and LA Connection Boot:
1. Plastic Dip Moldings, Inc., Insulboot Cable Termination Boot and LA Connection
C. Cable Termination:
1. Interior (5 kV):
a. 3M, Quick Term III, 5620K Series
b. Raychem Corp., HVT-Z Series
2. Exterior:
a. 3M, Quick Term III, 5630K Series
3. 15 kV:
a. 3M, Quick Term III, 5630K Series
D. Pulling Compounds:
1. Cable Grip Co.
2. Ideal Company
3. Polywater, Inc.
E. Cable-To-Bus Bar Connection Kits:
1. Raychem Corp., Type HVBC
F. Cable End Caps – Heat-Shrinkable Polyolefin:
1. 3M, Type EC

G. Electrical Grounding Braid:
   1. 3M
   2. Scotch Brand 25
H. Cable Phase Identification:
   1. 3M
   2. Scotch Brand 35 Tape
I. Cable Ties:
   1. Thomas & Betts, Ty-Rap UV-Resistant Nylon 6.6
J. Electric Arc and Fire Proofing Tape:
   1. Scotch Brand 77 Electric Arc and Fireproofing Tape
   2. Scotch Brand 69 Glass Electrical Tape

2.2 MATERIALS

A. The Manufacturer's name, voltage class, type of insulation, thickness of insulation, conductor size, UL listing, and date of manufacture shall be printed on the jacket.
B. Cables shall be suitable for use in partially submerged wet locations, in nonmetallic or metallic conduits, underground duct systems, and direct-buried installation.
C. Cables shall be able to operate continuously at 105°C conductor temperature, with an emergency rating of 140°C and a short-circuit rating of 250°C. Emergency overloads shall be possible within the lifetime of the cable.
D. Cable shall be UL listed as Type MV-105 and UV-resistant in accordance with UL 1072.
E. Medium-voltage cables shall have the following physical characteristics:
   1. Conductors: Annealed copper, Class B concentric lay, stranded in accordance with ASTM B 496.
   2. EPR insulated cable shall meet or exceed ICEA/NEMA S-93-639/WC 74 and AEIC CS8.
      a. Insulation: Thermosetting EPR compound over an extruded, non-conducting high dielectric stress control layer, with a semi-conducting shield applied directly over the primary insulation. The base elastomer shall have a maximum ethylene content of 72% by weight. The semi-conducting layers and insulation shall be applied using a triple extrusion process.
F. Cable Rating and Type:
   1. 5 kV cable:
      a. Cable type: EPR Single conductor shielded MV-105.
      b. Insulation level: 5 kV – 133%, 8 kV – 100%, 95 kV BIL.
      c. Insulation shield: Thermoset semi-conducting polymeric layer free stripping insulation shield shall consist of a layer of black material extruded directly over the insulation.
      d. Shield: Metallic 5 mil annealed copper tape with a 25% overlap.
      e. Jacket: CPE.
      f. Operating voltage: 4.16 kV, three-phase, 60 Hz, high-resistance grounded distribution system.
   2. 15 kV Cable:
      a. Cable type: EPR Single conductor shielded MV-105.
      b. Insulation level: 15 kV – 133%, 95 kV BIL.
      c. Shield: Metallic 5 mil annealed copper tape with an overlap of 25%.
      d. Jacket: Chlorinated polyethylene, CPE.
      e. Operating voltage: 13.2 kV, three-phase, 60 Hz.
G. Pulling Compound: Non-toxic, nonflammable, noncombustible, and noncorrosive. The material shall be UL listed and compatible with the cable insulation and the jacket.
H. Cable Identification:
   1. Medium-voltage cables in EHH and manholes shall be wrapped in high voltage warning tape.
   2. Identify each medium-voltage cable with a tag at terminations, splices, EHHs, manholes, and pullboxes.
      a. Assign a cable name where the load end shall be the originating location.
         1) Examples:
            a) 52L1-TB3-1A/MPT1-TB-X1 where:
               52L1 = Load end equipment
               TB3 = Device (terminal block) in load end equipment
               1A = Device termination point, usually line/phase
               MPT1 = Source end equipment
               TB = Device (terminal block) in source end equipment, if applicable
               X1 = Device termination point or line/phase
      b. Parallel cables shall be the same length and have the same tag.
I. Cable Termination Boot and LA Connection Boot:
   1. Plastic Dip Moldings, Inc., Insulboot Cable Termination Boot and LA Connection.

2.3 ACCESSORIES

A. Cable:
   1. Material used in terminating and splicing medium-voltage cables shall be as recommended by the Cable Manufacturer. Cables shall be terminated and spliced in accordance with the Kit Supplier's drawings. Cable splices shall be wrapped and shall be in accordance with ANSI C119.1 and IEEE 404. Cable slicing locations, methods, and materials shall be approved by the ENGINEER.
   2. Cable terminations shall be in accordance with IEEE 48, Class I.
   3. Cable accessories shall be by one Manufacturer to assure adequate installer training and application assistance.

4. The Manufacturer shall be able to document a minimum of 5 years successful field experience as well as demonstrating technical life assessment as requested. The Manufacturer shall establish and document a QA program implementing suitable procedures and controls for activities affecting quality. The program shall provide documentation that verifies the quality of production joint kits and traceability back to inspection records, raw material, and the original designs and design proof tested joints.

B. Cable Termination Boot and LA Connection Boot:
   1. Boots shall be capable of insulating bus bars 2 inches to 6 inches wide and for connection of one to four cables. Boots shall electrically insulate and environmentally seal the connection and be easily re-enterable.
   2. Boots shall be rated 15 kV class with a nominal thickness of at least 0.090 inch.

C. Cable Termination:
   1. Interior:
      a. Single conductor shielded cable terminations for indoor applications shall be one-piece, track-resistant EPDM rubber with top seal and ground strap assemblies.
      b. Termination shall have a current rating equal to or greater than the cable ampacity.
      c. Termination shall accommodate any form of cable shielding or construction without the need for special adapters.
      d. Interior 15kv cable shall have minimum two-skirt type stress cones.
   2. Exterior:
      a. Single conductor shielded cable terminations for exterior applications shall be one-piece, track-resistant EPDM rubber with top seal and ground strap assemblies.
      b. Termination shall have a current rating equal to or greater than the cable ampacity.
      c. Termination shall accommodate any form of cable shielding or construction without the need for special adapters.
      d. Exterior stress cones shall be four-skirt type.

D. Lugs and Connectors: Copper lugs and connectors shall be crimped with standard industry tooling. Connections of copper stranded wire in size #6 AWG through 1,000 kcmil shall be made electrically and mechanically secured. The lugs and connectors shall have a current carrying capacity equal to the conductors for which they are rated and be in accordance with UL 486A/486B. Lugs larger than #4/0 AWG shall be two-hole with NEMA spacing. Lugs and connectors shall be rated for operation through 35 kV. Lugs shall be of closed end construction to exclude moisture migration into the cable conductor.

E. Electrical Grounding Braid: Conducting metal braid shall be woven from 240 strands of #30 AWG tinned copper wires and be capable of carrying fault current comparable to that of #6 AWG copper wire.

F. Cable Identification:
   1. A 7 mil, flame retardant, cold- and weather-resistant vinyl plastic electrical tape shall be used for phase identification.
   2. Laser-engraved, two-ply, 1.6 mm microsurfaced impact acrylic tags, secured by PP, plenum rated, UV-resistant cable ties.

PART 3 EXECUTION

3.1 GENERAL

A. Determine the cutting lengths, reel arrangements, and total lengths of cable required. Provide this data to the Cable Manufacturer as soon as possible to assure on-time delivery of the cable.

B. Parallel power conductors shall be of equal length.

C. Make use of the field engineering services available from the Cable Manufacturer.

3.2 INSTALLATION

A. Cable Installation:
   1. When ambient temperature is below 32°F cable shall not be installed. When ambient temperature is below 50°F, cable reels shall be stored at 70°F for at least 1 day before installation.
   2. Do not exceed the Manufacturer’s recommendations for maximum pulling tensions and minimum bending radii.
   3. Pull cables from the direction that requires the least tension.
   4. Feed cables into raceway with zero tension and without cable crossover at raceway entrance.

B. Terminating:
   1. Cables shall be terminated with stress cones.
   2. Cables shall be installed without splices.
   3. The Work area shall be kept warm, dry, and ventilated during cable splicing and terminating.
   4. Prepare cables in accordance with Splice or Termination Kit Manufacturer’s installation details.
   5. Bond cable shield at each terminal location.
   6. Insulate and seal each cable-to-bus termination with heat-shrinkable bus connector kits.
   7. Exterior stress cones shall be four-skirt type.

C. Electric Arc and Fire Proofing: In EHHs, manholes, pullboxes, cable trays, and exposed locations where threat of fire exists or communicated fault can occur, wrap medium-voltage cables with one half-lapped layer of Scotch Brand 77 Electric Arc and Fireproofing Tape. Tape shall be secured with a two-layer band of Scotch Brand 69 Glass Electrical Tape over the last wrap.

D. Marking and Identification:
   1. Medium-voltage feeders in each EHH and manhole shall be wrapped in high voltage warning tape.
   2. Plastic nameplates shall be installed in each EHH, manhole, pullbox, and at splice and terminating points. These nameplates shall show the phase and feeder designations and the date when the cable was installed or when the splice or termination was made.

3.3 QUALITY CONTROL

A. Shop Testing:

1. Perform the Manufacturer's standard production testing and inspection in accordance with ICEA/NEMA S-93-639/ WC74, Section 6. If requested by the ENGINEER, the Manufacturer shall submit certified proof of compliance with ICEA design and test standards.
2. Provide certified test reports indicating that the cable has passed the following tests:
   a. Partial corona discharge test in accordance with AEIC CS8, Section G.
   b. Vertical tray flame test in accordance with IEEE 1202.
3. After completion of the factory tests, individual pulling eyes shall be installed on a single or triplexed conductor length of cable. Pulling eyes shall be suitable for maximum allowable pulling tension on the conductors and shall be sealed against the entrance of water.

B. Field Testing:

1. Visual and mechanical inspection:
   a. Inspect each individual exposed power cable for:
      1) Physical damage.
      2) Proper connections in accordance with single-line diagram.
      3) Cable bends not in conformance with Manufacturer's minimum allowable bending radius, where applicable.
      4) Color coding in accordance with the Contract Documents.
      5) Proper circuit identification.
   b. Inspect mechanical connections for:
      1) Proper lug type for conductor material.
      2) Proper lug installation.
      3) Bolt torque level in accordance with ANSI/NETA ATS, unless otherwise specified by Manufacturer.
   c. Inspect shielded instrumentation cables for:
      1) Proper shield grounding.
      2) Proper terminations.
      3) Proper circuit identification.
2. Equipment testing and inspection shall be performed in accordance with ANSI/NETA ATS and shall include:
   a. Shield continuity test.
   b. Insulation resistance test.
   c. DC Hipot test in accordance with IEEE 400.
   d. Partial Discharge Testing in accordance with IEEE 400.3.
3. Testing as specified in SECTION 26 08 00.
4. Immediately notify the ENGINEER and do not energize the cables if any of the following conditions occur:
   a. Cable damage.
   b. Improper installation and grounding.
   c. Shield discontinuity or high resistance.
   d. Dielectric absorption ratio and PI below 1.5.
   e. Abnormal plot of leakage current versus voltage.
5. Defective and damaged cables:
   a. The ENGINEER shall make the sole determination of the acceptability of the cables based on the submitted test reports. Do not energize cables until the test reports have been reviewed and approved by the ENGINEER.
   b. If, in the opinion of the ENGINEER, the cables or terminations are determined to be damaged or defective, provide the following remedial actions at no additional cost:
      1) Remove terminations and completely retest the cables to determine whether the cables are damaged or defective.
      2) Remove and replace damaged or defective cables as directed by the ENGINEER.
      3) Remake terminations with new kits.
      4) Completely retest cable and terminations.

END OF SECTION

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SECTION 26 05 19
LOW-VOLTAGE CONDUCTORS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for low-voltage conductors.

B. Related Sections:
   1. SECTION 01 78 23 – OPERATION AND MAINENTANCE DATA
   2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
   4. SECTION 27 00 00 – COMMUNICATIONS SYSTEMS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):
   1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

B. ASTM International (ASTM):
   1. B 8 – Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

C. Institute of Electrical and Electronics Engineers (IEEE):
   1. 383 – Standard for Qualifying Electric Cables and Splices for Nuclear Facilities

D. Insulated Cable Engineer's Association and National Electrical Manufacturers' Association (ICEA/NEMA):
   1. S-73-532/WC 57 – Standard for Control, Thermocouple Extension, and Instrument Cables
   2. S-95-658/WC 70 – Power Cables Rated 2000 Volts or Less for the Distribution of Electrical Energy

E. International Organization for Standardization (ISO):
   1. 9001 – Quality Management Systems – Requirements

F. National Electrical Contractors Association (NECA):
   1. 1 – Standard for Good Workmanship in Electrical Construction

G. National Electrical Manufacturers Association (NEMA):
   1. CC 1 – Electric Power Connection for Substations

H. National Fire Protection Association (NFPA):
   1. 70 – National Electrical Code (NEC)

I. Underwriters Laboratories, Inc. (UL):
   1. 13 – Standard for Power-Limited Circuit Cables
   2. 44 – Standard for Thermoset-Insulated Wires and Cables
   3. 62 – Standard for Flexible Cord and Fixture Wire
   4. 486A/486B – Standard for Wire Connectors
   5. 510 – Standard for Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
   6. 854 – Standard for Service-Entrance Cables
   7. 1277 – Standard for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members
   8. 1581 – Reference Standard for Electrical Wires, Cables, and Flexible Cords
   9. 1681 – Standard for Wiring Device Configurations

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
   1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
   2. Catalog, descriptive and specification information for equipment, components, and devices.
   3. Manufacturer's literature:
      a. Wire and cable descriptive product information.
      b. Wire and cable accessories descriptive product information.
      c. Wiring systems descriptive product information.
      d. Wire systems rating information.
      e. Wire systems dimensional drawings.
      f. Wire systems special fittings.
   4. Conductor spreadsheet (in XLS/XSLX format) and drawings of conductor and cable field interconnection in hardcopy and electronic formats. Spreadsheet cell columns shall include:
      a. Conductor/conduit number.
      b. Complete conductor and cable circuit identification.
      c. Source end.
      d. Source terminal (device, terminal, wire number).
      e. Load end.
      f. Load terminal (device, terminal, wire number).
   5. Conduit/conductor schedule spreadsheet (in XLS/XSLX format) and As-Built Drawings in hardcopy and electronic formats, include approximate lengths.
   6. Cable samples with cable marking system identification.
   7. Sample of conductors and cables with identification tags.
   8. Method and equipment for installing conductors.
   9. Connection types and locations.

10. Provide conductor and cable tag and identification labels in field interconnection drawings for systems, cables, and conductors.
11. Pulling tension calculations:
    a. Submit for approval before raceway installation.
    b. Show that the maximum tension will not exceed the Manufacturer's recommendations.
    c. For cables and conductors larger than #2/0 AWG and pulling lengths longer than 100 feet.
    d. For cable and conductor sizes for pulling lengths longer than 200 feet.
    e. Fiber cable pulling calculations for pulling lengths longer than 100 feet.
12. Busway:
    a. Drawings: Complete plan, elevation, and isometric of busway and equipment, busway transitions to equipment, and busway support system.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
    a. Provide preliminary and final manuals.
    b. As specified in SECTION 01 78 23.
    c. Shop Drawing Submittal information.
    d. Factory and field certified test reports.
    e. Conduit/conductor schedule spreadsheet (in XLS/XSLX format) and As-Built Drawings in hardcopy and electronic formats, include exact lengths.
    f. Fiber optic power meter test results.
    g. Fiber optic OTDR test results.
    h. A detailed map showing fiber optic network with numerical and color assignment to each fiber strand and termination panel.
    i. Final As-Built Drawings:
        1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
                (1) On a standard DW provided title block and border.
                (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
                (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
                (4) Titles: 0.2 inches.
    j. Warranty documentation.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. The Manufacturer shall provide a certificate of ISO 9001 compliance.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the low-voltage conductors system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Pulling Compound:
1. Ideal Co.; Yellow 77
2. Polywater, Inc.

B. 600 V Rated Cable:
1. Type 1:
    a. General Cable
    b. Southwire
    c. Okonite Co.
    d. Omni Cable
2. Type 2:
    a. General Cable
    b. Southwire
    c. Okonite Co.
    d. Omni Cable
3. Type 3:
    a. Belden 1118A
    b. General Cable 247620
    c. Lake Cable V162S

4. Type 4:
    a. Belden 1119A
    b. General Cable 261160
    c. Lake Cable V163S
5. Type 5:
    a. Belden 1055A, 1039A, 1041A, 1042A, 1043A, 1044A, 1045A
    b. General Cable 237180, 237160, 235750, 242870, 237130, 277820, 242860
    c. Lake Cable V164SPOS
6. Type 6:
    a. Belden 1093A, 1094A, 1095A, 3066A, 1096A
    b. Lake Cable V1812STOS

C. Conductors 600 V and Below:
1. Tape:
    a. Scotch Brand 77 with Scotch Brand 69 glass cloth tape binder
    b. Plymouth Plyarc 53with Plymouth Plyglas glass cloth tape binder
2. Identification devices for conductors 600 V and below:
    a. Burndy, Insulink
    b. ILSCO
    c. Thomas & Betts, Sta-Kon
3. Nylon, insulated, heavy duty, ring connectors:
    a. Burndy, Insulink
    b. ILSCO, ILSCON
    c. Thomas & Betts, Sta-Kon
4. Cable lugs:
    a. Insulated, locking-fork, compression lugs:
        1) ILSCO, ILSCONS
        2) Thomas & Betts, Sta-Kon
    b. Uninsulated crimp connectors and terminators:
        1) ILSCO
        2) Square D, Versitide
        3) Thomas & Betts, Color-Keyed
    c. Uninsulated, bolted, two-way connectors and terminators:
        1) Burndy, Quiklug
        2) ILSCO
        3) Thomas & Betts, Locktite
5. Cable ties: Nylon, adjustable, self-locking, reusable, and plenum rated:
    a. Thomas & Betts, TY-RAP
6. Heat-shrinkable insulation: Thermally stabilized, cross-linked polyolefin:
    a. Thomas & Betts, SHRINK-KON

D. Communications Cable:
1. CAT-6:
    a. Shielded: Belden 7953A
    b. Unshielded: Belden, 7927
    c. Shielded unless indicated otherwise
2. Data cable (RS-485):
    a. Belden, 3107A

E. Busway:
1. Eaton
2. GE/ABB
3. Square D

F. Tape:
1. General purpose, flame retardant tape:
    a. Scotch Brand Super 33
2. Flame retardant, cold-resistant, and weather-resistant tape:
    a. Scotch Brand Super 88

G. Identification Tag:
1. Thomas & Betts, Ty-Rap UV-Resistant Nylon 6.6

2.2 MATERIALS

A. Pulling Compound:
1. Non-toxic, noncorrosive, noncombustible, nonflammable, wax-based lubricant; UL listed.
2. Suitable for rubber, neoprene, PVC, PE, hypalon, CPE, and lead-covered wire and cable.
3. Suitable for zinc-coated steel, aluminum, PVC, bituminized fiber, and fiberglass raceways.

B. Conductors 600 V and Below:
1. In accordance with ICEA/NEMA S-95-658/WC 70; conductors shall be rated 600 V.
2. Conductor Type:
    a. 120 V and 277 V lighting, #10 AWG and smaller: Solid copper.
    b. 120 V receptacle circuits, #10 AWG and smaller: Solid copper.

c. Other circuits: Stranded copper.
3. Insulation: Type XHHW-2.
4. Flexible cords and cables:
    a. Use only where indicated in the Contract Documents.
    b. Type SOW-A with EPR insulation in accordance with UL 62.
    c. In accordance with ICEA/NEMA S-95-658/WC 70.

C. 600 V Rated Cable:
1. Conductors for general wiring:
    a. Type: TC, in accordance with UL 1277, including vertical tray flame test at 20,000 Btu/hr, and NFPA 70, Article 340, or UL 13 in accordance with NFPA 70, Article 725.
    b. Permanently and legibly marked with the Manufacturer's name, maximum working voltage for which cable was tested, type of cable, and UL listing mark.
    c. Suitable for installation in open air, in cable trays, or conduit.
    d. Minimum temperature rating: 90°C dry locations; 75°C wet locations.
    e. Overall outer jacket: Flame retardant, UV-resistant and oil-resistant.
    f. Color code:
        1) Smaller than #8 AWG: ICEA Method 1, Table E-2.
        2) #8 AWG and larger: ICEA Method 4.
2. Type 1 – XLP/CPE multi-conductor control and power cable:
    a. Conductors:
        1) Class B stranded, tinned, soft copper conforming to Part 2 of ICEA.
        2) Insulation: XLP with CPE jacket.
        3) Insulation thickness: 30 mil.
        4) #14 AWG through #10 AWG, seven-strand.
        5) UL 1277 listed as Type XHHW-2 rated VW-1, wet or dry locations, 90ºC.
        6) Flame resistance rated UL 1581, VW-1.
        7) Conductor group bound with spiral wrap of barrier tape.
    b. Individual conductors and complete cables shall be tested in accordance with UL requirements for TC power and control tray cables having XHHW-2, VW-1 insulated conductors, and ICEA/NEMA S-73-532/WC 57.
    c. Cable: Passes the ribbon burner cable tray flame test requirements in accordance with UL and IEEE 383.
3. Type 2 – FREP/CPE multi-conductor power cable:
    a. Conductors:
        1) In accordance with ICEA/NEMA S-73-532/WC 57.
        2) Class B stranded, tinned, soft copper in accordance with Part 2 of ICEA/NEMA S-95-658/WC 70.
        3) Insulation: Flame retardant EPR, with CPE jacket.
        4) Insulation thickness: 30 mil.
        5) #14 AWG through #10 AWG, seven-strand.
        6) UL 1277 listed as Type XHHW-2 rated VW-1, wet or dry locations 90ºC.
        7) Conductor group bound with spiral wrap of barrier tape.
    b. Individual conductors and complete cables shall be tested in accordance with UL requirements for TC power and control tray cables having XHHW-2, VW-1 insulated conductors, and ICEA/NEMA S-95-658/WC 70.
    c. Cable assembly is UL 1581/ UL 1681 VF flame resistance rated.
4. Type 3 – #16 AWG, twisted, shielded pair, instrumentation cable: Single pair, designed for noise rejection for process control, computer, or data log applications in accordance with ICEA/NEMA S-73-532/WC 57.
    a. Outer jacket: 45 mil nominal thickness.
    b. Individual pair shield: 1.35 mil, double-faced aluminum/synthetic polymer overlapped to provide 100% coverage.
    c. Dimension: 0.3 inch nominal OD.
    d. Conductors:
        1) Bare, soft, annealed copper, Class B, seven-strand concentric, in accordance with ASTM B 8.
        2) #18 AWG, seven-strand tinned copper drain wire.
        3) Insulation: 15 mil nominal PVC.
        4) Jacket: 4 mil nominal nylon.
        5) Color code: Pair conductors black and red.
5. Type 4 – #16 AWG, twisted, shielded triad instrumentation cable: Single triad, designed for noise rejection for process control, computer, or data log applications in accordance with ICEA/NEMA S-73-532/WC 57.
    a. Outer jacket: 45 mil.
    b. Individual pair shield: 1.35 mil, double-faced aluminum/synthetic polymer, overlapped to provide 100% coverage.
    c. Dimension: 0.32 inch nominal OD.
    d. Cable assembly is UL 1581/UL 1681 VF flame resistance rated.
    e. Conductors:
        1) Bare, soft, annealed copper, Class B, seven-strand concentric, in accordance with ASTM B 8.
        2) #18 AWG, seven-strand, tinned copper drain wire.
        3) Insulation: 15 mil nominal PVC.
        4) Jacket: 4 mil nylon.
        5) Color code: ICEA Method 1, Table E-2, triad conductors black, red, and blue.

6. Type 5 – #16 AWG, multi-twisted, shielded pairs with a common, overall shield instrumentation cable: Designed for use as instrumentation, process control, and computer cable, in accordance with ICEA/NEMA S-73-532/WC 57:
   a. Cable assembly is 1581/UL 1681 flame resistance rated.
   b. Conductors:
      1) Bare, soft, annealed copper, Class B, seven-strand concentric, in accordance with ASTM B 8.
      2) Tinned copper drain wires.
      3) Pair drain wire size #18 AWG; group drain wire size #16 AWG.
      4) Insulation: 15 mil PVC.
      5) Jacket: 4 mil nylon.
      6) Color code: ICEA Method 1, Table E-1, pair conductors black and white with conductors numerically printed for group identification.
      7) Individual pair shield: 1.35 mil, double-faced aluminum/synthetic polymer.
      8) 600 V, 90°C rating.
   c. Cable shield: 2.35 mil, double-faced aluminum/synthetic polymer, overlapped for 100% coverage.
   d. Cable sizes:

No. of Pairs	Maximum Outside Diameter (inches)	Nominal Jacket Thickness (mils)
2	0.584	45
4	0.600	60
8	0.760	60
12	0.935	60
16	1.07	80
20	1.175	80
24	1.350	80

7. Type 6 – #18 AWG, multi-twisted, shielded triads with a common, overall shield instrumentation cable: Designed for use as instrumentation, process control, and computer cable, in accordance with ICEA/NEMA S-73-532/WC 57:
   a. Conductors:
      1) Bare, soft, annealed copper, Class B, seven-strand concentric, in accordance with ASTM B 8.
      2) Tinned copper drain wires.
      3) Pair drain wire size #20 AWG, group drain wire size #18 AWG.
      4) Insulation: PVC/nylon.
      5) Jacket: PVC.
      6) Color code: ICEA Method 1, Table E-1, pair conductors black, white, and red with conductors numerically printed for group identification.
      7) Individual pair shield: 100% coverage, aluminum foil-polyester tape.
      8) 600 V rating.
   b. Cable shield: 100% coverage, aluminum foil-polyester tape.
   c. Cable sizes:

No. of Triads	Estimated Maximum Outside Diameter (inches)	Estimated Nominal Jacket Thickness (mils)
2	0.493	48
4	0.577	63
8	0.745	63
12	0.944	84
16	1.046	84
24	1.284	84

D. Grounding Conductors:
   1. Equipment: Stranded copper with green, Type XHHW-2, insulation.
   2. Direct-buried: Bare, stranded copper, hand-drawn, minimum #4/0 AWG.
E. Communications Cable:
   1. CAT-6:
      a. Telephone and data cable shall be industrial Ethernet cable with the following features:
         1) 4 twisted pairs shielded, #23 AWG solid bare, annealed copper conductors.
         2) Insulation: Polyolefin.
         3) Outer jacket: Industrial grade PVC.
         4) Suitable applications: Industrial Ethernet cable, harsh environments, 100 MHz CAT-6, RJ-45 compatible, noisy environments, 100BaseTX.
         5) Each cable shall be labeled in visible locations at both ends using the materials and nomenclature specified.

2. Data cable (RS-485):
    a. Data cable shall have the following features:
        1) Two twisted pairs, overall 100% shielded, #22 AWG stranded, tinned copper conductors.
        2) Each cable shall be labeled in visible locations at both ends using the materials and nomenclature specified.

F. Busway:
1. Provide a totally enclosed low impedance busway system with necessary fittings, power takeoffs, hanging devices, and accessories. The busway shall have dead-front hinged cover type plug outlets positioned for feeders to the electrical equipment.
2. Rated 3,000 A continuous, three-phase, four-wire, 600 V, internal ground. The minimum available short-circuit current at the input end shall be 65,000 A rms symmetrical.
3. Components:
    a. Busway housing shall be extruded aluminum for maximum protection against corrosion from water and other contaminants normally encountered during construction. Housing shall be totally enclosed for protection against mechanical damage and dust accumulation. Hardware shall be plated to prevent corrosion.
    b. Bus bar insulation material shall be epoxy NEMA Class B, 130°C. Insulation shall be UL rated as self-extinguishing and shall be impervious to acids, alkalis, acetones, machine oils and lubricants commonly found in industrial environments. The Manufacturer shall provide test data documenting the insulation's impact resistance, chemical resistance, and expected life of 50 years.
    c. Busway shall be rated as in accordance with the Contract Documents.
    d. Bus bars shall be copper:
        1) Copper bus bars shall be tin-plated.
        2) Temperature rise at any point in the busway shall not exceed 55°C above ambient when operating at rated load current.
4. Hanger system: Horizontal busway runs shall be UL listed to hang on 10 foot centers in any position. Horizontal busway runs shall have support hangers a maximum of 5 feet apart. Vertical busway riser runs shall be supported with spring hangers as shown on the Drawings and as recommended by the Manufacturer.
5. Joints shall have ±1/2 inch adjustability and be the one-bolt removable type. Joints shall be able to be made from one side when the busway is installed against a wall or ceiling. Plug-in and feeder shall use identical parts. Multi-stacks shall be phase collected.
6. Plug-in busway shall be identical to feeder construction and performance except it shall have dead-front hinged cover type plug outlets positioned for feeders to the electrical equipment. Outlets shall be usable simultaneously.
7. Plug-in unit safety device:
    a. Busway plugs shall be of the types and rating listed in the Contract Documents. Switching devices shall be completely enclosed in a sheet steel housing.
    b. Shields shall protect stabs and ground plug body before stabs make contact. A grounding terminal shall be inside plug body and shielding to prevent access to live parts when the cover is open. A ground stab shall engage the ground tab on the busway and internal ground bus shall be provided when required.
    c. The cover and operating handle shall have provision to padlock in the off position. The operating handle shall be easily moved from end to side or vice versa.
    d. A releasable cover interlock shall prevent the opening of the cover except when the switch is off.
    e. Operating switch type plugs shall have a positive quick-make, quick-break interrupter. Circuit breaker plugs shall have true rms electronic sensing and an interrupting rating of at least 65,000 A rms, with interchangeable rating plugs.
8. Testing: Each busway item shall pass a dielectric withstand test of 5,000 VDC for 5 seconds.
9. Finish: ANSI 61 gray enamel.

2.3 ACCESSORIES

A. Conductors 600 V and Below:
1. Tape:
    a. General purpose, flame retardant: 7 mil, vinyl plastic, rated for 90°C minimum, in accordance with UL 510.
    b. Flame retardant, cold-resistant, and weather-resistant: 8.5 mil, vinyl plastic.
    c. Arc and fireproofing: 30 mil, elastomer.
2. Identification devices:
    a. Sleeve: White identification heat-shrink sleeves with legible, machine printed, permanent black ink letters and numbers; figures shall be a minimum of 1/8 inch high.
    b. Tag: Round phenolic white surface with black core engraved tags matching conduit tags dimensions secured by PPE, plenum rated, UV-resistant, cable ties, Thomas & Betts Ty-Rap UV-Resistant Nylon 6.6.
    c. Grounding conductor: Permanent green heat-shrink sleeve, 2 inches minimum.
3. Connectors and terminations: Nylon, insulated, heavy duty, ring connectors. Current transformer circuits shall be ring type connectors.
4. Cable lugs:
    a. In accordance with NEMA CC 1.
    b. Rated 600 V of the same material as the conductor metal.

B. Busway:
1. Furnish nameplates for each device as shown on the Drawings. Color schemes shall be as shown on the Drawings.

2. Thermal expansion fittings for:
    a. Runs longer than 150 feet when busway is not free to move at ends of run.
    b. When busway run crosses building expansion joint.
    c. Reducer cubicles and special adapter cubicles as shown on the Drawings.

PART 3 EXECUTION

3.1 GENERAL

A. Conductor installation shall be in accordance with NECA 1.
B. Conductor and cable sizing shown on the Drawings is based on copper conductors.
C. Do not exceed the Cable Manufacturer's recommendations for maximum pulling tensions and minimum bending radii.
D. Parallel power conductors shall be of equal length.
E. Tighten screws and terminal bolts in accordance with UL 486A/486B for copper conductors.
F. Provide cable lugs with the correct number of holes, bolt size, and center-to-center spacing as required by equipment terminals.
G. Bundling: Where single conductors and cables in equipment, panels, terminal boxes, wireways, and other locations are not wrapped together by some other means, bundle conductors from each conduit throughout their exposed length with cable ties placed at intervals not exceeding 12 inches o.c.
H. Ream, remove burrs, and clear the interior of installed conduit before pulling wires or cables.
I. Concrete-Encased Raceway Installation: Prior to the installation of conductors, pull a mandrel approximately 1/4 inch smaller than the inside diameter of the raceway through each raceway.
J. Communications as specified in SECTION 27 00 00.

3.2 PREPARATION

A. Busway:
    1. Verify that busways are ready to install.
    2. Verify field measurements are as shown on the Drawings and as instructed by the Manufacturer.
    3. Verify that required utilities are available, in proper location, and ready for use.
    4. Beginning of installation means the installer accepts conditions.

3.3 INSTALLATION

A. Power Conductor Color Coding:
    1. #6 AWG and larger: Apply general purpose, flame retardant tape at each end, and at accessible locations wrapped at least six full overlapping turns, covering an area 1 1/2 inches to 2 inches wide.
    2. #8 AWG and smaller: Provide colored conductors.
    3. Colors:

System	**Conductor**	**Color**
All Systems	Equipment Grounding	Green
240/120 V Single-Phase, Three-Wire	Grounded Neutral One Hot Leg Other Hot Leg	White Black Red
208Y/120 V Three-Phase, Four-Wire	Grounded Neutral Phase A Phase B Phase C	White Black Red Blue
480Y/277 V Three-Phase, Four-Wire	Grounded Neutral Phase A Phase B Phase C	Gray Brown Orange Yellow
125 VDC	Positive Negative	Purple Purple with white tracer
24 VDC	Positive Negative	Blue Blue with white tracer
Note: Phase A, B, C implies direction of positive phase rotation		

    4. Tracer: Outer covering of white with an identifiable colored strip other than green in accordance with NFPA 70.

B. Circuit Identification:
    1. Identify power, instrumentation, control, communications, security, SCADA and fire alarm, cables, and conductors at each termination, splice, EHH, and manhole.
        a. Assign a circuit name where the load end shall be originating location.
            1) Examples:
                a) 52-2-TB-48-21/GCP-NGT-XXX where:
                    52-2 = Load end equipment
                    TB = Device (terminal block) in load end equipment
                    48-21 = Device terminal (normally the same as wire number)
                    GCP = Source end equipment
                    NGT = Device (terminal block) in source end equipment
                    XXX = Device terminal, if different than wire number

b. Conductors and cables that are in parallel or in series between equipment shall have the same circuit name. Terminal/conductor numbers shall be the same as the terminal to which it connects.

2. Method:
   a. Conductors #3 AWG and smaller cables with small conductors: Identification sleeves shall be sized to fit the conductor insulation and shrunk to fit the conductor with hot air.
   b. Cables, and conductors #2 AWG and larger fiber optic cables: Each cable and conductor identification tag shall be secured by cable ties.
   c. Taped-on markers or tags relying on adhesives are not permitted.
   d. Provide conductor and cable tag and identification labels in field interconnection drawings for systems, cables, and conductors.

C. Conductors 600 V and Below:
1. Do not splice incoming service conductors and branch power distribution conductors #8 AWG and larger unless shown on the Drawings or approved by the ENGINEER.
2. Connections and terminations:
   a. Install wire nuts only on solid conductors of 120 V and 277 V lighting and 120 V receptacle circuits only.
   b. Install nylon self-insulated crimp connectors and terminators for instrumentation, control, and power circuit conductors #6 AWG and smaller.
   c. Install uninsulated crimp connectors and terminators for instrumentation, control, and power circuit conductors #4 AWG through #2/0 AWG.
   d. Install uninsulated, bolted, two-way connectors and terminators for power circuit conductors #4/0 AWG and larger.
   e. Install uninsulated, bolted, two-way connectors for motor circuit conductors No. 12 and larger.
   f. Tape insulate uninsulated connections.
   g. Place no more than one conductor in any single-barrel pressure connection.
   h. Install crimp connectors with tools approved by the Connector Manufacturer.
   i. Install terminals and connectors acceptable for the type of material used.
   j. Compression lugs:
      1) Attach compression lugs with a tool specifically designed for that purpose.
      2) The tool shall provide complete, controlled crimp and shall not release until crimp is complete.
      3) Do not use plier type crimpers.
3. Do not use soldered mechanical joints.
4. Splices and terminations:
   a. Indoors: Use general purpose, flame retardant tape.
   b. Outdoors: Use flame retardant, cold-resistant, and weather-resistant tape.
5. Cap spare conductors and cables with UL listed end caps.
6. Cabinets, panels, and MCCs:
   a. Remove surplus wire; bridle and secure.
   b. Where conductors pass through openings or over edges in sheet metal, remove burrs, chamfer edges, and install bushings and protective strips of insulating material to protect the conductors.
7. Control and instrumentation wiring:
   a. Where terminals provided will accept such lugs, terminate control and instrumentation wiring, except solid thermocouple leads, with insulated, locking-fork compression lugs.
   b. Terminate with methods consistent with the terminals provided, and in accordance with the Terminal Manufacturer's instructions.
   c. Locate splices in readily accessible cabinets or junction boxes using terminal strips.
   d. Cable protection:
      1) Install individual wires, pairs, or triads into bundles at least 1/2 inch in diameter.
      2) Maintain integrity of shielding of instrumentation cables.
      3) Ensure grounds do not occur because of damage to jacket over the shield.
8. Extra conductor length: For conductors to be connected by others, install a minimum of 6 feet of extra conductor in freestanding panels and a minimum of 2 feet in other assemblies.
9. Busway:
   a. Install in accordance with the Manufacturer's instructions.
   b. Install required safety labels.

3.4 CLEANING:

A. Busway:
1. Clean the interiors of switchboards, panels, and separate enclosures to remove construction debris, dirt, and shipping materials.
2. Repaint scratched or marred exterior surfaces to match the original finish.

3.5 ADJUSTING:

A. Busway:
1. Adjust circuit breakers, switches, access doors, and operating handles for free mechanical and electrical operation as described in Manufacturer's instructions.
2. Adjust circuit breaker trip and time delay settings to the values specified by the coordination study.

3.6 QUALITY CONTROL

A. Conductors 600 V and Below: Test in accordance with UL 44 and UL 854.

B. Visual and Mechanical Inspection:
   1. Inspect each individual exposed power cable for:
      a. Physical damage.
      b. Proper connections in accordance with the single-line diagram.
      c. Cable bends not in conformance with Manufacturer's minimum allowable bending radius, where applicable.
      d. Color coding conformance with specifications.
      e. Proper circuit identification.
   2. Inspect mechanical connections for:
      a. Proper lug type for conductor material.
      b. Proper lug installation.
      c. Bolt torque level in accordance with ANSI/NETA ATS.
   3. Inspect shielded instrumentation cables for:
      a. Proper shield grounding.
      b. Proper terminations.
      c. Proper circuit identification.
   4. Inspect Control cables for:
      a. Proper termination.
      b. Proper circuit identification.
   5. Cables terminated through window type CTs: Verify that neutrals and grounds are terminated for correct operation of protective devices.

C. Electrical Tests for Conductors No. 6 and Larger:
   1. Insulation resistance tests:
      a. Utilize 1,000 VDC megohmmeter for 600 V insulated conductors.
      b. Test each conductor with respect to ground and to adjacent conductors in accordance with ANSI/NEMA ATS procedures for 1 minute.
      c. Evaluate ohmic values by comparison with conductors of same length and type.
      d. Investigate values less than 50 megohms.
   2. Continuity test by ohmmeter method to ensure proper cable connections.

D. Busway:
   1. Inspect installed busways for anchoring, alignment, grounding, and physical damage.
   2. Check the tightness of accessible mechanical and electrical connections with a calibrated torque wrench. The minimum acceptable values are specified in the Manufacturer's instructions.
   3. Megger busways using 2,500 VDC Megger. Check phase to phase, phase to ground. Individual lengths shall be at least 3 megohms. Entire run shall be at least 1 megohm. Divide runs over 100 feet long.

E. Testing as specified in SECTION 26 08 00.

END OF SECTION

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SECTION 26 05 26
GROUNDING AND BONDING

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for grounding and bonding.
- B. Related Sections:
  1. SECTION 01 78 23 – OPERATION AND MAINENTANCE DATA
  2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
  3. SECTION 26 05 19 – LOW VOLTAGE CONDUCTORS
  4. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES
- A. Institute of Electrical and Electronics Engineers (IEEE):
  1. C2 – National Electrical Safety Code
  2. 81 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System
- B. National Fire Protection Association (NFPA):
  1. 70 – National Electrical Code (NEC)
- C. Underwriters Laboratories (UL):
  1. 467 – Grounding and Bonding Equipment

1.3 SUBMITTALS
- A. As specified in SECTION 26 05 00.
- B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.
- C. Shop Drawings:
  1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
  2. Catalog, descriptive and specification information for equipment, components, and devices.
  3. Exothermic weld connectors:
     - a. Installation manual for the exothermic process used.
     - b. A copy of training certifications for installers.
  4. Compression connectors: Compression tools including die details.
  5. Ground grid and ground system layout drawings shall include:
     - a. Dimensioned locations and depths.
     - b. Connection types and locations.
     - c. Ground Enhancement Materials Manufacturer’s literature and installation instructions.
- D. Quality Control Submittals:
  1. O&M manuals:
     - a. Provide preliminary and final manuals.
     - b. As specified in SECTION 01 78 23.
     - c. Shop Drawing Submittal information.
     - d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration.
     - e. Factory and field certified test reports.
     - f. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
     - g. Final As-Built Drawings:
       - 1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW’s current CAD Standards and shall include, but not be limited to, the Standards located online in DW’s CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         - a) Drawings shall be on a standard DW provided title block and border.
         - b) As-Builts and Manufacturer’s drawings shall be provided:
           - (1) On a standard DW provided title block and border.
           - (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
           - (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
           - (4) Titles: 0.2 inches.
     - h. Warranty documentation.

1.4 QUALITY ASSURANCE
- A. Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
- B. UL Compliance: Materials manufactured within scope of UL shall conform to UL standards and have an applied UL listing mark.

1.5 SITE CONDITIONS
- A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY
- A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the grounding and bonding system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS:

A. Connectors – Exothermic Weld Type:
   1. Cadweld
   2. Cadweld Exolon
   3. Erico Products, Inc.

B. Connectors – Compression Type:
   1. Burndy Corp.

C. Connectors – Mechanical Type:
   1. Burndy Corp.
   2. Thomas and Betts Co.

D. Ground Enhancing Materials:
   1. Erico Products, Inc.

E. Ground Rods:
   1. Erico Products, Inc.

2.2 MATERIALS

A. Ground Rod:
   1. Material: Copper-clad steel.
   2. Diameter: Minimum 3/4 inch.
   3. Length: 10 feet.

B. Ground Conductors: As specified in SECTION 26 05 19.

C. Connectors:
   1. Exothermic weld type:
      a. Outdoor weld: Suitable for exposure to elements or direct burial.
      b. Indoor weld: Utilize low-smoke, low-emission process.
      c. Current carrying capacity greater than or equal to that of the conductor.
      d. Permanent molecular bond that will not loosen, corrode, or deteriorate.
   2. Compression type:
      a. Compress-deforming type; wrought copper extrusion material.
      b. Manufactured of high copper alloy specifically for the particular grounding application.
      c. Suitable for direct burial in earth and concrete.
      d. Identifying compression die number inscription shall be impressed on compression fitting.
      e. Single indentation for conductors #6 AWG and smaller.
      f. Double indentation with extended barrel for conductors #4 AWG and larger.
      g. Barrels pre-filled with oxide-inhibiting and anti-seizing compound and sealed.
   3. Mechanical type:
      a. Split-bolt, saddle, or cone screw type only when approved by the ENGINEER.
      b. Copper alloy material.
   4. Ground enhancing materials:
      a. Ground enhancement material in its set form shall have a resistivity of not more than 2 ohm-cm.
      b. Ground enhancement material shall be permanent and maintenance-free, no recharging with salts or chemicals which may be corrosive, and maintain its earth resistance with time. It shall set up firmly and not dissolve, decompose, or otherwise pollute the soil or the local water table.
      c. The ground enhancement material shall be suitable for installation in a dry or slurry form.
      d. The ground enhancement material shall not depend on the continuous presence of water to maintain its conductivity.

PART 3 EXECUTION

3.1 GENERAL

A. The main ground electrode system resistance to ground shall be no greater than 5 ohms. Install additional ground cable and ground rod electrodes to achieve specified resistance to ground.

B. Grounding shall be in accordance with NFPA 70 and IEEE C2.

C. Provide and extend existing grounding grid as shown on the Drawings. Provide individual ground pigtails for equipment and bonding as shown on the Drawings.

D. Ground cable shall have a minimum cover of 30 inches below finished grade.

E. Ground cable near the base of a structure shall be installed no closer than 24 inches to the structure.

F. Ground cable through exterior walls shall be prepared with a waterstop that shall include filling the space between the strands with solder and soldering a 12-inch copper disc over the cable.

G. Exposed ground cables shall be securely fastened every 36 inches at a minimum, utilizing fasteners with corrosion resistance equal to that of the conductor.

H. Ground electrical service neutral at service entrance equipment to the existing ground grid.

I. Ground each separately derived system neutral to ground grid.

J. Bond together system neutrals, service equipment enclosures, exposed noncurrent-carrying metal parts of electrical equipment, metal raceways, ground conductor in raceways and cables, receptacle ground connections, and metal piping systems.

K. Connections between dissimilar metals shall be made with tinned copper or tinned bronze equipment.

L. Provide a separate, green insulated, grounding conductor in each raceway independent of raceway material:
   1. Multi-conductor power and control cables shall include an integral green insulated grounding conductor.
   2. Provide a separate grounding conductor in each individual raceway for parallel feeders.
M. Ductbanks:
   1. Provide a bare copper grounding conductor the entire length of each ductbank, embedded in the concrete of the ductbank.
   2. Bond ductbank ground conductors together in each EHH or where ductbanks join, merge, intersect, or split.
N. Shielded Instrumentation Cables:
   1. Ground shield to ground bus at power supply for analog signal.
   2. Expose shield a minimum of 1 inch at termination to field instrument and apply heat-shrink tube.
   3. Do not ground instrumentation cable shield at more than one point. The grounding point shall be at the control panel or at the power source end of the signal carried by the cable.

3.2 INSTALLATION

A. Wire Connections:
   1. Install ground conductors in conduit containing power conductors and control circuits.
   2. Connect ground conductors to raceway grounding bushings.
   3. Extend and connect ground conductors to ground bus in equipment containing a ground bus.
   4. Connect the enclosure of equipment containing ground bus to that bus.
   5. Bolt connections to equipment ground bus. Cable connections to bus bar shall be made with compression one-hole or two-hole lugs.
   6. Bond grounding conductors to metallic enclosures at each end and to intermediate metallic enclosures.
   7. Furnish junction box materials and connect to the equipment grounding system.
   8. Ground conductors on equipment shall be formed to the contour of the equipment and firmly supported.
   9. Ground connection hardware, bolts, and nuts shall be in accordance with UL 467, high-strength, high-conductivity copper alloy.
B. Motor Grounding: Extend equipment ground bus by grounding conductor installed in motor feeder raceway; connect to motor frame.
C. Ground Rods:
   1. Install full length with conductor connection at upper end.
   2. Install with connection point below finished grade.
   3. Conductor connection shall be exothermic weld.
D. Connections:
   1. General:
      a. Above grade connections: Exothermic weld type or compression type where approved by the ENGINEER.
      b. Below grade connections, splices, and joints: Exothermic weld type.
      c. Connections, splices, and joints that will be inaccessible upon completion of construction: Exothermic weld type.
      d. Remove paint, dirt, moisture, or other surface coverings at connection points to allow good metal-to-metal contact.
      e. Notify the ENGINEER prior to concealing or covering ground connections. Do not conceal or cover ground connections until the ENGINEER or the authorized Representative has approved the ground connections.
   2. Exothermic weld type:
      a. Wire brush or file the contact point to bare metal surface.
      b. Use welding cartridges and molds in accordance with the Manufacturer's recommendations.
      c. Avoid using badly worn molds.
      d. Molds shall be completely filled with metal when making welds.
      e. After completed welds have cooled, remove slag from the weld area and thoroughly clean the joint.
   3. Compression type:
      a. Install in accordance with the Connector Manufacturer's recommendations.
      b. Install connectors of proper size for grounding conductors specified.
      c. Install using the Connector Manufacturer's compression tool having properly sized dies.
   4. Mechanical type:
      a. Apply a homogeneous blend of colloidal copper and rust and corrosion inhibitor before making the connection.
      b. Install in accordance with the Connector Manufacturer's recommendations.
      c. Mechanical connections shall not be concealed.
      d. Use only when approved by the ENGINEER.
E. Metal Structure Grounding:
   1. Bond electrical and I&C equipment supported by metal platforms to the platforms. Bond metal platforms or steps to the grounding grid.
   2. Provide electrical contact between metal frames and railings supporting push button stations, receptacles, instruments, control panels, and raceways carrying circuits to these devices.
   3. The following shall be permanently and effectively bonded to the ground grid with a #6 AWG copper conductor: Equipment, enclosures, metallic structures, metal sheathing, exposed metal vertical structures, stairs, railings, hand rails, fences, fence/wall poles, gates, door frames, window frames, tanks, vessels, skids, etc.

F. EHH, Manhole, and Vault Grounding:
   1. Make connections of grounding conductors fully visible and accessible, with exothermic weld.
   2. Connect noncurrent-carrying metal parts, hatches, stairs, and any metallic raceway grounding bushings with #6 AWG copper conductor.

G. Transformer Grounding:
   1. Bond neutrals of transformers within buildings to the system ground network and to any additional grounding electrodes shown on the Drawings.
   2. Bond neutrals of pad-mounted transformers to ground grid. If there is not a ground grid, bond to four locally driven ground rods and buried ground wire encircling transformer and system ground network.

H. Surge Protection Equipment Grounding: Connect surge arrestor ground terminals to equipment ground bus.

3.3 QUALITY CONTROL

A. Visual and Mechanical Inspection:
   1. Inspect equipment and circuit grounds in switchgear, MCCs, and panelboards assemblies for proper connection and tightness.
   2. Inspect ground bus connections in switchgear, MCCs, and panelboards assemblies for proper termination and tightness.
   3. Ensure effective transformer core and equipment grounding.

B. Electrical Tests:
   1. Fall-of-potential test:
      a. Measurement of main ground system resistance: In accordance with IEEE 81.
      b. Main ground electrode system resistance to ground shall be no greater than 5 ohms.
   2. Two-point direct method test:
      a. Measurement of ground resistance between main ground system, equipment frames, and system neutral and derived neutral points: In accordance with IEEE 81.
      b. Equipment ground resistance shall not exceed main ground system resistance by 0.50 ohm.
   3. Verify and measure high resistance system ground connection to the ground grid.
   4. Testing as specified in SECTION 26 08 00.

END OF SECTION

SECTION 26 05 33
RACEWAYS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for raceways.

B. Related Sections:
1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 31 23 33 – TRENCH BACKFILL

1.2 REFERENCES

A. American National Standards Institute (ANSI):
1. C80.1 – American National Standard for Electric Rigid Steel Conduit (ERSC)

B. ASTM International (ASTM):
1. F 2160 – Standard Specification for Solid Wall High Density Polyethylene (HDPE) Conduit Based on Controlled Outside Diameter (OD)

C. International Organization for Standardization (ISO):
1. 9001 – Quality Management Systems – Requirements

D. National Electrical Manufacturers Association (NEMA):
1. RN 1 – Polyvinyl Chloride (PVC) Externally Coated Galvanized Rigid Steel Conduit and Intermediate Metal Conduit
2. TC 2 – Electrical Polyvinyl Chloride (PVC) Tubing and Conduit
3. TC 3 – Polyvinyl Chloride (PVC) Fittings for Use with Rigid PVC Conduit and Tubing

E. National Fire Protection Association (NFPA):
1. 70 – National Electrical Code (NEC)

F. Underwriters Laboratories, Inc. (UL):
1. 6 – Electrical Rigid Metal Conduit – Steel
2. 360 – Liquid-Tight Flexible Metal Conduit
3. 514B – Conduit, Tubing and Cable Fittings
4. 651 – Schedule 40, 80, Type EB and A Rigid PVC Conduit and Fittings
5. 870 – Wireways, Auxiliary Gutters, and Associated Fittings

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Conduit and ductbank layout:
   a. Dimensioned plans and sections, showing arrangement, routing, depths, locations, penetrations, tags and labels of raceways, conduits, equipment, pull boxes, condulets, supports, expansion/deflection fittings, etc.
   b. Layout drawings shall be provided in hardcopy and electronic media.
4. Equipment and machinery proposed for bending, threading, and handling metal conduit.
5. Method for bending PVC conduit less than 30 degrees.
6. PVC-coated RGS Manufacturer’s certificate of completion from the Manufacturer’s conduit training course for personnel installing PVC-coated conduit.
7. Method and equipment for cleaning existing conduits.
8. EHHs, including complete dimensioned drawings, calculations, concrete mix design, component cut-sheets and information.
9. Concrete encased, steel reinforced ductbank, including complete dimensioned drawings, steel data and configuration, concrete mix design, component cut sheets and information.
10. Conduit/conductor schedule spreadsheet (in XLS/XSLX format) and As-Built Drawings of cable in hardcopy and electronic formats, include approximate cable lengths.
11. Means and methods for repairing PVC-coated RGS conduit.
12. Raceway supporting methods and calculations including, but not limited to, dimensioned drawing, calculated weight per foot, conduit attachment, support anchoring, materials and methods. Calculations shall be provided to demonstrate that the raceway support systems are capable of handling at least twice the installed loading.

D. Quality Control Submittals:
1. Testing related Submittals: For each existing conduit, provide information including:
   a. Condition of removed conductors or cables.
   b. Materials removed from existing conduit when cleaned.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. As-Built Drawings, schedules, lists, and photographs in hardcopy and electronic media.

e. Final As-Built conduit/conductor schedule with exact lengths in hardcopy and electronic media (XLSX).
    1) Power conductor lengths shall be in Electrical Systems Analysis.
f. Final As-Built Drawings:
    1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
        a) Drawings shall be on a standard DW provided title block and border.
        b) As-Builts and Manufacturer's drawings shall be provided:
            (1) On a standard DW provided title block and border.
            (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
            (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
            (4) Titles: 0.2 inches.
g. Warranty documentation.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer's Qualifications:
    1. A minimum of 10 years of documented experience in the Work of this Section.
    2. Approved by the Manufacturer.
B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 18 months from the Substantial Completion date for the satisfactory performance and installation of the raceway system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Conduit and Tubing:
    1. Allied
    2. Republic
    3. Wheatland
B. PVC-Coated RGS Conduit:
    1. Ocal
    2. Robroy
    3. Atkore/Calbond
C. Polyolefin Polymer-Coated RGS Conduit:
    1. Gafco Green
D. PVC Schedule 40 and Schedule 80 Conduit:
    1. Arnco
    2. Cantex
    3. Carlon
    4. Colby
E. Bushing:
    1. Thomas & Betts
    2. O.Z./Gedney, Type HB
F. Grounding Bushing:
    1. Appleton, Series GIB
    2. O.Z./Gedney, Type HBLG
G. Conduit Hub:
    1. Crouse-Hinds, Type Myers SCRU-TITE
H. Conduit Bodies (For Normal Conditions):
    1. Appleton, Form 35 threaded unilets
    2. Crouse-Hinds, eight threaded condulets
I. Conduit Sealing Fitting:
    1. Appleton, Type EYF, EYM, or ESU
    2. Crouse-Hinds, Type EYS or EZS
    3. Killark, Type EY or EYS
J. Drain Seal:
    1. Appleton, Type SF
    2. Crouse-Hinds, Type EYD or EZD
K. Drain/Breather Fitting:
    1. Appleton, Type ECDB
    2. Crouse-Hinds, ECD
L. Expansion Fitting:
    1. Deflection/expansion movement:
        a. Appleton, Type DX

b. Crouse-Hinds, Type XD
c. Gafco Green, AF Series
2. Expansion movement only:
a. Appleton, Type XJ
b. Crouse-Hinds, Type XJ
c. Gafco Green, AF Series

M. Cable Sealing Fittings:
1. Appleton, CG-S
2. Crouse-Hinds, CGBS

N. PVC-Coated RGS Conduit:
1. Ocal Type STG
2. Robroy, Type STG

O. Flexible Metal, Liquid-Tight Conduit:
1. Appleton, Series STB
2. Crouse-Hinds, Series LTB
3. Thomas & Betts, Series 5300

P. HDPE Ribbed Conduit:
1. Couplings:
a. Arnco, Shur-lock coupler

Q. Watertight Entrance Seal Device:
1. New construction:
a. O.Z./Gedney, Type FSK or WSK
2. Cored-hole application:
a. Link Seal, type LS
b. O.Z./Gedney, Series CSM

R. Wireways:
1. B-Line Systems, Inc.
2. Hoffman
3. Square D

S. Aluminum EHH Frames and Covers:
1. BILCO, J-AL-H20

T. Electrical Handholes:
1. Oldcastle Precast, AMCOR or Utility Vault Co.
2. Vaughn Concrete Products, Inc.

U. Conduit Support Stands:
1. Unistrut, Type P2072A SQ

V. Duct Bank Spacers:
1. Carlon, Type SNAP-LOC, Snap-N-Stac
2. Underground Devices, Inc., Type WUNPEECE

W. Corrosion Inhibiting Compound:
1. Thomas & Betts, Kopr-Shield

X. Knockout/Cap-Off Seals:
1. Crouse-Hinds, Style STC

Y. Fire-Stops and Seals:
1. 3M, Fire Barrier Composite Sheets CS195
2. Dow Corning, Fire-Stop Series 2000

Z. Identification Devices:
1. Warning tape:
a. Brady, Catalog #91601
2. Fiber optic warning tape:
a. Ideal Industries, #42-104
3. Wraparound duct band:
a. Raychem, Type TWDB
4. Tracer wire:
a. Copperhead Industries, LLC

AA. Floor Support Along Conduits:
1. Unistrut, SST floor stands

BB. Metallic Conduit Enclosure Terminations:
1. Interior hubs:
a. Crouse-Hinds Myers, Scru-Tite
2. Exterior hubs:
a. Crouse-Hinds Myers, Scru-Tite

CC. CP Warning Tape:
1. Brady Catalog #91601

DD. Raceway Sealant:
1. Polywater AFT Foam Sealant
2. Polywater FST Foam Sealant when indicated

2.2 MATERIALS

A. Precast EHHs:

1. Sump:
   a. Slope floors toward drain points, leaving no pockets or other non-draining areas.
   b. Provide sump at low point of floor constructed with a heavy, CI, slotted or perforated hinged cover.
2. Raceway entrances: For raceways to be installed under this Contract, provide knockout panels or precast individual raceway openings.
3. Embedded pulling iron:
   a. Material: 3/4 inch diameter stock, fastened to overall steel reinforcement before concrete is placed.
   b. Location: Wall opposite each raceway entrance.
4. Cable racks:
   a. Arms and insulation: Adjustable, of sufficient number to accommodate cables for each raceway entering or leaving manhole, including spares.
      1) Wall attachment:
         a) Adjustable inserts in concrete walls. Bolts or embedded studs are not permitted.
         b) Insert spacing: Maximum 3 foot o.c. on the entire inside perimeter.
         c) Arrange so that the spare raceway ends are clear for future cable installation.
5. EHH frames and covers:
   a. Material: Aluminum.
      1) Cover type: Solid, lockable, hinged, of diamond plate pattern design.
      2) Vault and lid design loading: AASHTO H-20-44, with impact.
      3) Cover lock assembly: Recessed lock assembly with a flush, gasketed, removable brass screw plug machine engraved with the EHH's Drawing designation, e.g., EHH1. The cover and lock assembly shall be provided with a Best Lock Core matching the cores and keys of each EHH. Keys shall be provided to the OWNER at Final Completion.
      4) Cover lifting assist: The cover shall include provisions so that its weight is not borne by the lock assembly when opening or closing the cover.
      5) SST hardware.
6. Hardware: Steel, hot-dip galvanized.

B. Granular Fill for Direct Buried Raceways: Squeegee bedding as specified in SECTION 31 23 33.

2.3 COMPONENTS

A. Conduit and Tubing:

1. RGS conduit:
   a. In accordance with ANSI C80.1 and UL 6.
   b. Material: Hot-dip galvanized, inside and outside.
2. PVC-coated RGS conduit:
   a. In accordance with NEMA RN 1.
   b. UL listed.
   c. Factory-cut threads shall be protected with hot-dip and a clear urethane coating.
   d. Install in accordance with the Manufacturer's instructions. For PVC-coated RGS conduits, provide and install with a sufficient amount of the Manufacturer's touch-up compound to the end of the conduit in the area normally covered by the sleeve, just prior to assembling joints to create a seal between the sleeve and the conduit coating to keep moisture out.
   e. Provide the Manufacturer's touch-up material as needed to ensure a fully complete, sealed, undamaged conduit system.
   f. PVC-coated RGS conduit shall be resistant to UV damage and shall not deteriorate when exposed outdoors.
   g. PVC-coated conduit, fittings, and accessories shall be supplied by the same Manufacturer.
   h. Couplings and fittings shall be provided with PVC sleeves and seals.
   i. Material:
      1) Conduit: In accordance with ANSI C80.1 and UL 6.
      2) PVC Coating:
         a) Minimum 40 mils nominal thickness, exterior coating bonded to metal.
         b) Minimum 2 mils nominal thickness, interior coating bonded to metal.
   j. Conduit cutting, threading, and installation/joining tools: Only tools approved by the Manufacturer and the ENGINEER.
3. Polyolefin polymer-coated RGS conduit:
   a. Conduit shall be hot-dipped galvanized inside and out with hot-dipped galvanized factory-cut threads.
   b. The zinc coating shall be intact, uncoated, and shall not impede electrical ground conductivity.
   c. Provide the necessary Manufacturer material as may be needed to endure a fully complete, continuously sealed, undamaged conduit system.
   d. Provide additional polymer and repair any abrasions to polymer coating.
   e. Polymer-coated RGS conduit shall be resistant to UV damage and deterioration when exposed outdoors.
   f. Polyolefin polymer-coated conduit, fittings, and accessories shall be supplied by the same Manufacturer.
   g. Couplings and fittings shall be provided with polyolefin polymer-coated sleeves and seals.

h. Material:
    1) Conduit: In accordance with ANSI C80.1 and UL 6.
    2) Polyolefin polymer coating:
        a) Minimum 40 mils nominal thickness, exterior coating bonded to metal.
        b) Minimum 2 mils nominal thickness, interior coating bonded to metal.

4. PVC Schedule 80 conduit:
    a. In accordance with NEMA TC 2 and UL 651.
    b. UL listed for concrete encasement, underground direct burial, concealed, or direct sunlight exposure, and 90°C insulated conductors.
5. PVC Schedule 40 conduit for CP systems only:
    a. In accordance with NEMA TC 2 and UL 651.
    b. UL listed for concrete encasement, underground direct burial, concealed, or direct sunlight exposure, and 90°C insulated conductors.
6. Flexible metal, liquid-tight conduit:
    a. UL 360 listed for 105°C for dry locations.
    b. Material: Galvanized steel, with an extruded PVC jacket.
7. HDPE-ribbed conduit:
    a. Smooth exterior.
    b. Manufactured in accordance with ASTM F 2160.
    c. UL listed for direct burial applications.
    d. Diameter: 2 inches.
    e. Wall thickness: Schedule 80, 0.218 inch.
    f. Color: Orange.

B. Wireways:
    1. In accordance with UL 870.
    2. Type: Steel or SST, with removable, hinged cover.
    3. Rating: NEMA 3R or NEMA 4X.
    4. Finish:
        a. NEMA 3R: Gray, baked enamel.
        b. NEMA 4X: None.

C. Fittings:
    1. RGS:
        a. General:
            1) In accordance with UL 514B.
            2) Type:
                a) Threaded, galvanized.
                b) Set screw fittings not permitted.
        b. Bushing:
            1) Material: Malleable iron with integral insulated throat, rated for 150°C.
        c. Grounding bushing:
            1) Material: Malleable iron with integral insulated throat rated for 150°C, with solderless lugs.
        d. Conduit hub:
            1) Material: Zinc or SST with lexan insulated throat and integral grounding lug on the locknut.
        e. Conduit bodies:
            1) Material: Malleable iron, sized in accordance with NFPA 70.
            2) Threaded holes in condulet body type only.
            3) Pulling elbows not permitted.
        f. Couplings: As supplied by the Conduit Manufacturer.
        g. Cable sealing fittings:
            1) To form watertight, non-slip cord or cable connection to conduit.
            2) For conductors with OD of 1/2 inch or less: Neoprene bushing at connector entry.
    2. PVC-coated RGS conduit:
        a. In accordance with UL 514B.
        b. General: Set screw fittings are not permitted.
        c. Type: RGS, PVC-coated by the Conduit Manufacturer to the same coating specifications as the conduit.
        d. Overlapping pressure sealing sleeves.
        e. Conduit hangers, attachments, and accessories: PVC-coated.
        f. PVC-coated RGS conduit shall be installed using the PVC Coating Manufacturer's recommended fittings, hangers, attachments, and accessories.
        g. Male threads on elbows and nipples, and female threads on fitting or conduit couplings shall be protected by a urethane coating.
        h. Conduit hub:
            1) Material: PVC-coated malleable iron with insulated throat and integral grounding lug on the locknut.
    3. PVC conduit and tubing:
        a. In accordance with NEMA TC 3.
        b. Type: PVC, slip-on.

4. Flexible metal, liquid-tight conduit:
   a. Metal insulated throat connectors with integral nylon or plastic bushing rated for 105°C.
   b. Insulated throat and sealing O-rings.
   c. Long design type extending outside of box or other device at least 2 inches.
   d. When connecting to PVC-coated RGS, use the Conduit Manufacturer’s coated fitting.
5. Watertight entrance seal device:
   a. New construction:
      1) Material: Oversized sleeve, malleable iron body with sealing ring, pressure ring, grommet seal, and pressure clamp.
   b. Cored-hole application:
      1) Material: Assembled dual pressure disks, neoprene sealing ring, and membrane clamp.

2.4 ACCESSORIES

A. Conduit Support Stands:
   1. Material: SST.
   2. Shape: Square.
B. Duct Bank Spacers:
   1. Type: Nonmetallic, interlocking, for multiple conduit sizes.
   2. Suitable for all types of conduit.
C. Corrosion inhibiting compound: Homogenized blend of polished colloidal copper.
D. Knockout/Cap-Off Seals:
   1. Zinc finish with threaded hub and sealing O-ring.
   2. For use to seal abandoned conduit penetrations in sheet metal cabinets and boxes.
E. Fire-Stops and Seals:
   1. Apply in accordance with the Manufacturer’s recommendations.
   2. Products which are affected by water are not acceptable.
F. Identification Devices:
   1. Raceway tags:
      a. Material: SST.
      b. Shape: 1 1/2 inch diameter round.
      c. Raceway designation: Laser engraved.
      d. Three rows of text centered on tag:
         1) 0.188 inch header: Conduit #.
         2) 0.11 inch text:
            a) Source.
            b) Destination.
      e. Affix to conduits with 48-mil SST wire and zinc clamps.
      f. Identify in accordance with the conduit/conductor schedule.
   2. Warning tape:
      a. Material: Detectable polyester.
      b. Color: Red.
      c. Width: Minimum 2 inches.
      d. Designation: Warning on tape shall read: Caution: Buried Electrical Lines.
   3. Fiber optic warning tape:
      a. Material: PE, 4 mil gauge.
      b. Color: Orange.
      c. Width: Minimum 3 inches.
      d. Designation: Warning on tape shall read: Fiber optic line is located below tape.
   4. CP warning tape:
      a. Material: Detectable polyester; color: red.
      b. Width: Minimum 2 inches.
      c. Designation: Warning on tape shall read: Caution: Buried CP Electrical Lines.
   5. Wraparound duct band:
      a. Material: Heat-shrinkable, cross-linked polyolefin, pre-coated with hot-melt adhesive.
   6. Pull string:
      a. 1/4 inch diameter braided or twisted nylon cordage.
      b. Minimum tensile strength: 1,000 lbs.
      c. Provide with distance markings.
   7. Tracer wire:
      a. #12 AWG.
      b. Copper-clad steel wire with HDPE coating.
      c. UL listed for direct burial.

PART 3 EXECUTION

3.1 GENERAL

A. Crushed or deformed raceways are not permitted.
B. Conduit and tubing sizes shown are based on the use of copper conductors.
C. Raceways 1 1/4 inch and larger shall use conduit bodies and condulets at least one size larger than the raceway and shall be sized in accordance with NFPA 70 at a minimum.

D. Each conduit run shall be identified on each end, at pull points, wall penetration, floor penetrations, and grade penetrations by a SST tag corresponding to the identification listed in the conduit and conductor schedule. Request additional conduit and conductor schedule numbers from ENGINEER.
E. Group raceways installed in same area.
F. Follow structural surface contours when installing exposed raceways.
G. Two or more conduits in the same general routing shall be parallel with symmetrical bends. Run exposed raceways parallel or perpendicular to walls, structural members, or intersections of vertical planes.
H. Avoid passageway and access obstructions. Conduits installed horizontally shall allow headroom of at least 7 feet except in areas where headroom cannot be maintained because of other considerations, as determined by the ENGINEER.
I. Install concealed, embedded, and buried raceways so that they emerge at right angles to surface and have no curved portion exposed.
J. Conduits shown on the Drawings shall be provided and installed at a minimum. Conductors and cables shall not be consolidated into conduits unless shown on the Drawings or approved by the ENGINEER.
K. Metal conduits shall be reamed, burrs removed, the thread degreased, cleaned, and dried before installation.
L. Paint threads, after removing cutting oil, and before assembling RGS conduit, with corrosion inhibiting compound.
M. Conduits shall be installed in such a manner as to keep exposed threads to an absolute minimum and in no case shall more than three threads be left exposed.
N. Maintain raceway entirely free of obstructions and moisture.
O. Immediately after installation, plug or cap raceway ends with watertight and dust-tight seals until time for pulling in conductors.
P. Spare conduits shall be plugged with metal threaded plugs or capped with steel threaded caps.
Q. Sealing Fittings: Provide drain seal in raceways where condensate may collect above sealing fitting.
R. Avoid moisture traps where possible. When unavoidable in exposed conduit runs, provide junction box and drain fitting at conduit low point.
S. Seal raceways in exterior devices, EHHs, condulets, pull boxes, and enclosures with raceway sealant to prevent the entrance of gases or liquids from one area to another. Conduit terminations at sheet steel boxes shall be sealed by forcing a non-hardening sealing compound into the conduit for a distance at least equal to the conduit diameter.
   1. Seal raceways at the first access point where they enter structures with raceway sealant.
   2. Seal raceways into interior chemical process areas with raceway sealant.
   3. Seal raceways subject to temperature variations to avoid condensation forming in raceway with raceway sealant.
   4. Seal exterior raceways entering equipment and devices, including but not limited to, switchgear, switchgear walk-in enclosures, transformers, panelboards, generators, generator enclosures, control panels, boxes, condulets, instrumentation, metering pedestals, enclosures, security equipment, and antennas.
T. Do not install raceways in concrete equipment pads, foundations, or beams.
U. Horizontal raceways installed under slabs shall lay a minimum of 6 inches below the slab, with no part embedded within slab.
V. Proximity to Heated Piping: Install raceways a minimum of 12 inches from parallel runs.
W. Block Walls: Do not install raceways in the same horizontal course with reinforcing steel.
X. Exterior raceways that enter a below grade structure and terminate in a below grade panel, cabinet, or enclosure shall enter the panel, cabinet, or enclosure in the bottom third of the panel, cabinet, or enclosure.

3.2 INSTALLATION
A. Application:
   1. Conduit:
      a. Diameter: Minimum 3/4 inch and minimum 1 inch for underground conduits, unless indicated otherwise.
      b. Conduit applications apply.
      c. Exterior, exposed: PVC-coated RGS.
      d. Interior, exposed:
         1) RGS in dry, non-corrosive areas.
         2) PVC-coated RGS in below grade vaults, handholes, wet, or corrosive areas.
      e. Interior, concealed, not embedded in concrete: PVC-coated RGS or RGS.
      f. Above ground, embedded in concrete walls, masonry walls, ceilings, or floors: PVC-coated RGS or RGS.
      g. Direct earth burial: PVC-coated RGS.
      h. Concrete-encased raceways, except in underground ductbanks: PVC-coated RGS or RGS with approved concrete coverage.
      i. Under slabs-below-grade: PVC-coated RGS.
      j. Concrete-encased, steel reinforced ductbanks, PVC Schedule 80, RGS or PVC-coated RGS.
B. In Cast-In-Place Concrete:
   1. Minimum cover 1 inch.
   2. Provide support during placement of concrete to ensure raceways remain in position.
   3. RGS conduits embedded in duct banks, concrete encasement and concrete floor, wall and ceiling slabs shall be coated with a factory-installed PVC coating, when required by governmental agency having jurisdiction over the Work or to meet code compliance.
   4. Floor slabs:
      a. Outside diameter of conduit not to exceed 1/3 of the slab thickness.
      b. Separate conduit by minimum four times conduit outside diameter, except at crossings.

C. Connections:
1. For motors, fans, unit heaters, dry type transformers, electrically operated valves, instrumentation, and other equipment, with rotating or moving parts where flexible connection is required to minimize vibration:
   a. Conduit size 4 inches or less: Flexible metal, liquid-tight conduit.
   b. Conduit size over 4 inches: Nonflexible.
   c. Length: 18 inches minimum, 24 inches maximum, of sufficient length to allow movement or adjustment of equipment.
2. Outdoor areas, process areas exposed to moisture, and areas required to be oil-tight and dust-tight: Flexible metal, liquid-tight conduit.
3. Transition from concrete-embedded to exposed:
   a. PVC-coated rigid steel conduit.
   b. PVC-coated conduit shall extend at least 6 inches above and below the floor.
4. Transition from underground to exposed:
   a. PVC-coated RGS conduit.
   b. PVC conduit shall extend at least 6 inches above and below the floor.
5. Under equipment mounting pads: PVC-coated RGS conduit.
6. In exterior light pole foundations: PVC-coated RGS conduit.

D. Penetrations:
1. Make at right angles.
2. Notching or penetration of structural members, including footings and beams, not permitted.
3. Fire-rated walls, floors, or ceilings: Fire-stop openings around penetrations to maintain fire-resistance rating. PVC-coated RGS conduit protruding through concrete floor slabs to a point 12 inches above and 12 inches below concrete surface.
4. Above ground concrete walls, floors, or ceilings: Provide non-shrink grout dry-pack when approved by the ENGINEER, or use watertight seal device.
5. Entering structures:
   a. Below grade conduits entering structures shall be provided with C-condulets 1 foot to 3 feet inside the wall or LB-condulets. The C-condulet covers shall be faced down and the conduit shall be identified at the condulet.
   b. Watertight entrance seal devices are required at structure entrances.
   c. Seal raceways at first condulet, box, or outlet with raceway sealant.
   d. Concrete roof or membrane waterproofed wall or floor:
      1) Provide a watertight seal.
      2) Securely anchor malleable iron body of watertight entrance seal device into construction with one or more integral flanges.
      3) Secure membrane waterproofing to watertight entrance seal device in a permanent, watertight manner.
      4) Seal penetration with silicone type sealant.
   e. HVAC equipment:
      1) Penetrate equipment in the area established by the Manufacturer.
      2) Terminate conduit with flexible metal liquid-tight conduit at the junction box or the condulet attached to exterior surface of equipment prior to penetrating equipment.
      3) Seal penetration with expandable plastic compound.
      4) Seal raceways in exterior equipment with raceway sealant.
   f. Corrosive-sensitive areas:
      1) Seal conduits passing through room walls or floors.
      2) Seal penetration expandable plastic compound.
      3) Seal raceways at first condulet, box, or outlet with raceway sealant.
   g. Underground penetrations: Core drill wall and install a watertight entrance seal device.
   h. Manholes and handholes:
      1) Metallic raceways: Provide insulated grounding bushings.
      2) Nonmetallic raceways: Provide bell ends flush with wall.
      3) HDPE conduit: Install such that raceways enter at nearly right angles and as near as possible to one end of wall.
6. Concrete equipment pads: Provide non-shrink grout dry-pack in blockout areas and around conduits.
7. Core-drilled penetrations:
   a. The extents of core-drilled holes in concrete slabs or walls shall:
      1) Not exceed 10 inches in diameter.
      2) Not be located within 6 inches from any edge of slab or wall.
      3) Not be located within a beam or column cross section.
      4) When placed in groups shall be placed with at least one hole diameter clear between them. The largest adjacent hole in the group will not control the spacing. At a minimum, adjacent holes shall not be spaced with less than 3 inches clear between them.
   b. Prior to core-drilling, locate slab and wall reinforcement by an approved non-destructive method (X-ray, GPR, etc.). No reinforcement may be cut without written approval from the ENGINEER.
   c. Prior to core-drilling, submit dimensioned plans and elevations of core-drilled hole sizes and layout relative to walls, columns, and slab edges to the ENGINEER for review and approval.
   d. Avoid interference found. Repair existing damaged conduits, structures, and utilities.

e. Coordinate additional requirements for wall and floor slab penetrations in accordance with the Contract Documents.

E. Support:
   1. Provide floor support along conduits at 5 foot intervals using SST Unistrut floor stands. Conduits shall be a minimum of 12 inches off the finished floor. Support from structural members only, at intervals not exceeding NFPA 70 requirements, and in any case not exceeding 10 feet. Do not support from piping, pipe supports, or other raceways. No drilling into roof decking without written approval from the ENGINEER.
   2. Multiple adjacent raceways: Provide ceiling trapeze. For trapeze-supported conduit, allow 30% extra space for future conduit.
   3. Provide and attach wall brackets, strap hangers, or ceiling trapeze as specified in the Contract Documents and as approved by the ENGINEER. Typical methods:
      a. Hollow masonry units: Toggle bolts or hollow set drop-in expansive anchors.
      b. Concrete or brick: Expansion shields, or threaded studs driven in by powder charge, with lock washers and nuts.
      c. Wood: Wood screws.
      d. Steelwork: Machine screws.
   4. Nails or wooden plugs inserted in concrete or masonry for attaching raceway are not permitted. Do not weld raceways or pipe straps to steel structures. Do not use wire in lieu of straps or hangers.

F. Bends:
   1. Install concealed raceways with a minimum of bends in the shortest practical distance. Bends shall not exceed 270 degrees between pulling points. Pull boxes shall be provided for straight runs not to exceed 200 feet.
   2. Make bends and offsets of the longest practical radius.
   3. Install with symmetrical bends or cast metal fittings.
   4. Avoid field-made bends and offsets, but where necessary, make with acceptable hickey or bending machine. Do not heat metal raceways to facilitate bending.
   5. Make bends in parallel or banked runs from same center or centerline with the same radius so that bends are parallel.
   6. Factory elbows may be installed in parallel or banked raceways if there is change in plane of run, and raceways are same size.
   7. PVC conduit:
      a. 30 degree bends: Provide factory-made.
      b. Bends larger than 30 degrees: Provide PVC-coated rigid steel.
      c. 90 degree bends: Provide the Manufacturer’s PVC-coated rigid steel elbows.
      d. Use the Manufacturer's recommended method for forming smaller bends.
   8. Flexible conduit: Do not make bends that exceed allowable conductor bending radius of cable to be installed or that significantly restricts conduit flexibility.
   9. PVC-coated RGS conduit field bends shall only be made with the Conduit Manufacturer’s recommended bending equipment to prevent damage to the PVC coating.

G. Expansion/Deflection Fittings:
   1. Provide on raceways at structural expansion joints, in long tangential runs.
   2. Provide expansion/deflection joints for 50°F maximum temperature variation.
   3. Install in accordance with the Manufacturer's instructions.

H. PVC-Coated Rigid Steel Conduit:
   1. Install in accordance with the Manufacturer's instructions. For PVC-coated RGS conduits, provide and install with a sufficient amount of the Manufacturer’s touch-up compound to the end of the conduit in the area normally covered by the sleeve, just prior to assembling joints to create a seal between the sleeve and the conduit coating to keep moisture out.
   2. Provide PVC boot to cover exposed threading.

I. PVC Conduit:
   1. Solvent welding:
      a. Provide the Manufacturer’s recommended solvent; apply to joints.
      b. Install such that joint is watertight.
      c. Follow the Manufacturer’s recommendations for making solvent welds.
   2. Adapters:
      a. PVC to metallic fittings: PVC terminal type.
      b. PVC to rigid metal conduit: PVC female adapter.
   3. Belled-end conduit: Bevel the unbelled end of the joint prior to joining.

J. Wireways:
   1. Install in accordance with the Manufacturer's instructions.
   2. Locate with cover on accessible vertical face of wireway.

K. Termination at Enclosures:
   1. Cast metal enclosure: Provide the Manufacturer's pre-molded insulating sleeve inside metallic conduit terminating in threaded hubs.
   2. Enclosure terminations:
      a. Metallic conduit:
         1) Interior: Provide zinc hub, for RGS conduit, and PVC-coated hub, for PVC-coated RGS conduit. Provide with and bond grounding screw.

2) Exterior: Provide SST hub, for RGS conduit, and PVC-coated hub, for PVC-coated RGS conduit. Provide with and bond grounding screw.
3) Grounding bushings and hub grounding screws shall be installed with a bonding jumper from the bushing or screw to the equipment ground bus, ground terminal, or ground pad.
4) Install plastic bushing on ends of conduit where grounding is not required only when approved by the ENGINEER.
5) Provide insulated throat when conduit terminates in sheet metal boxes having threaded hubs.

b. Flexible metal conduit: Provide two screw type, insulated, malleable iron connectors.
c. PVC Schedule 40 conduit: Provide PVC terminal adapter with lock nut and plastic bushing.

3. New and existing conduits: Terminate new and existing conduits entering enclosures and equipment (new and existing) with a grounding bushing; provide a grounding jumper, bonding, ground bushings and extending to equipment ground bus, ground terminal, or grounding pad.
4. Install knockout seals as specified in existing or abandoned penetrations in sheet-metal structures, enclosures, pull/junction boxes, etc. Install threaded zinc-coated plugs in abandoned cast metal structures, enclosures, or junction/pull boxes.

L. Underground Raceways:

1. Grade: Maintain minimum grade of 4 inches in 100 feet, either from one manhole, handhole, or pull box to the next, or from a high point between them, depending on surface contour.
2. Cover: Maintain minimum 2 foot cover above conduit and concrete encasement.
3. Make routing changes as necessary to avoid obstructions or conflicts.
4. Couplings: In multiple conduit runs, stagger so that couplings in adjacent runs are not in the same transverse line.
5. Union type fittings, Erickson couplings, and split couplings are not permitted.
6. Spacers:
   a. Provide preformed, nonmetallic spacers, designed for such purpose, to secure and separate parallel conduit runs in a trench or concrete encasement.
   b. Install at intervals no greater than that specified in NFPA 70 for support of the type conduit used, but in no case greater than 10 feet.
7. Support conduit to prevent bending or displacement during backfilling or concrete placement.
8. Installation with other piping systems:
   a. Crossings: Maintain minimum 12 inches vertical separation.
   b. Parallel runs: Maintain minimum 12 inches separation.
   c. Installation over valves or couplings is not permitted.
9. Metallic raceway coating: Apply wraparound duct band with one-half tape width overlap to obtain two complete layers.
10. Concrete encasement: Class A concrete as specified in SECTION 03 30 00; contain 3 lbs of red oxide per 94 lb sack of cementitious material.
11. Concrete placement and overflow outside of the approved ductbank section dimensions shall be minimized. Excessive concrete placement and overflow shall be removed.
12. No underground conduit shall be smaller than 1 inch.
13. Concrete-encased conduit shall have minimum concrete thicknesses of 2 inches between conduits, 1 inch between conduit and reinforcing, and 3 inches over reinforcing.
14. Concrete encasement on exposed outdoor conduit risers shall continue to 4 inches above grade, with top crowned and edges chamfered.
15. Underground conduits shall be sloped to drain from buildings to the manholes or handholes.
16. Backfill: Do not backfill until inspected by the ENGINEER or the ENGINEER's Representative.

M. Empty Raceways:

1. Provide permanent, removable RGS cap or plug over each end.
2. HDPE conduit: Provide PVC plug with pull tab for underground raceways.
3. Provide two nylon pull cords in each.
4. Identify, as specified in this Section, with waterproof tags attached to pull cord at each end, and at intermediate pull point.

N. Identification Devices:

1. Raceway tags: Tags relying on adhesives or taped-on markers are not permitted.
2. Install at each terminus including, but not limited to, EHHs, equipment, enclosures, pull boxes, gutters, condulets, penetrations, wall penetrations, floor penetrations, grade penetrations, etc. Install warning tape approximately 12 inches above underground or concrete-encased raceways. Align parallel to, and within 12 inches of, centerline of runs.

3.3 PROTECTION

A. Protect products from the effects of moisture, corrosion, and physical damage during construction.
B. Provide and maintain manufactured watertight and dust-tight seals over conduit openings during construction.
C. Touch up painted conduit threads after assembly to cover nicks or scars.
D. Touch up damage to coating on PVC-coated conduit with patching compound approved by the Manufacturer.

END OF SECTION

SECTION 26 05 70
ELECTRICAL SYSTEMS ANALYSIS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for electrical systems analysis (ESA).

B. Related Sections:

1. SECTION 01 31 00 – PROJECT MANAGEMENT AND COORDINATION
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. American National Standards Institute (ANSI):

1. Z535 – Safety Alerting Standards

B. Institute of Electrical and Electronics Engineers, Inc. (IEEE):

1. 242 – Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
2. 399 – Recommended Practice for Industrial and Commercial Power Systems Analysis
3. 1584 – Guide for Performing Arc Flash Hazard Calculations

C. National Fire Protection Association (NFPA):

1. 70E – Standard for Electrical Safety in the Workplace

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 45 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Provide hardcopies and an electronic copy of the ESA in ESA EasyPower version 10 or newer. Provide one read-only copy and one read/writable copy to the OWNER via the DW approved dropbox.
   a. Model and studies shall be submitted with EasyPower DEZ and subsystem template SEZ files. Include: Schedules, panelboards schedules, MCC schedules, switchgear lineups.
2. Resume(s) for Colorado licensed professional electrical engineer(s) preparing the ESA.
3. The ESA shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.
4. One-line drawing with complete system information.
5. Impedance drawing with complete system impedances, resistances, reactances, and sequence impedances.
6. Submit two copies of the ESA, short-circuit study, protective device coordination study, arc flash hazard study, and load flow and voltage drop study to the electric utility for approval.
7. Short-circuit study: An initial study shall be submitted as specified in SECTION 01 31 00 for Milestones, but no later than 30 days prior to energizing, startup, or commissioning of equipment. Coordinate with the electric utility to ensure equipment AIC ratings are adequate.
8. Protective device coordination study: An initial study shall be submitted as specified in SECTION 01 31 00 for Milestones, but no later than 30 days prior to energizing, startup, or commissioning of equipment. Time-current curves on the same plot shall each be a different color.
9. Arc flash hazard study: An initial study shall be submitted as specified in SECTION 01 31 00 for Milestones, but no later than 30 days prior to energizing, startup, or commissioning of equipment.
10. Provide temporary arc flash labels for electrical equipment within the scope of the study on energized equipment, in ENGINEER-approved locations. Temporary arc flash labels shall remain on equipment until permanent labels are installed.
11. Load flow and voltage drop study: An initial study shall be submitted as specified in SECTION 01 31 00 for Milestones, but no later than 30 days prior to energizing, startup, or commissioning of equipment. Load flow study shall include Excel load study spreadsheet for power distribution equipment.
12. PF correction study: An initial study shall be submitted as specified in SECTION 01 31 00 for Milestones, but no later than 30 days prior to energizing, startup, or commissioning of equipment.
13. Picture files of equipment, nameplates, and schedules shall be named for easy identification and provided with the ESA study.

D. Quality Control Submittals:

1. The ESA shall be updated, As-Built, and submitted prior to the Substantial Completion date. Utilize characteristics of as-installed equipment and materials. Shop Drawing information shall be updated and included.
2. Hardcopy and electronic version of installed programs, settings, complete model numbers, equipment and material characteristics.
3. Install arc flash labels for electrical distribution and utilization equipment. Installation of arc flash labels shall be coordinated and performed with the ENGINEER and the OWNER.
4. Provide a complete As-Built ESA in hardcopy media and in electronic format.
   a. Hardcopy media: Provide four copies of the study in a hard cover, tabbed divider, three-ring binders.
   b. Electronic format:
      1) Complete ESA in ESA EasyPower version 10.0 or newer. Provide one read-only copy and one read/writable copy of the completed EasyPower ESA to the OWNER via the DW approved dropbox. Any software library revisions which deviate from standard and are used for the creation or modification of the EasyPower ESA shall be identified through written correspondence to the OWNER. Any revised library files shall be copied and provided via the DW approved dropbox.

2) Introductory section, description, summary, discussion, recommendations, etc. shall be submitted in DOCX format.
3) Tabulated data, equipment and material data and characteristics, settings, etc. shall be submitted in XLSX format.
4) Complete ESA shall be submitted in Adobe Acrobat PDF.
5) The electronic format shall contain the as-constructed schedules created by using the EasyPower standard templates. Schedules shall contain the following at a minimum:
   a) Equipment specific fields filled out including, but not limited to: Equipment names, ratings, installation locations, upstream equipment designations, Manufacturer and catalog information, connected and demand loading of circuits, load types, harmonics, scaling factors, respective arc flash information included for the bus including and excluding the main breaker, trip times, bussing, motors, capacitors, variable frequency/speed AC and DC drives, protective devices and starters, short-circuit, power flow, raceways, conductors, comments, and hyperlinks.
   b) Overcurrent sizes, settings, and circuit location within the respective schedule.
   c) Load size and descriptive information.
6) DEZ one-line diagrams shall contain text/note boxes detailing the following information:
   a) Utility system information with dates collected and utility contact information.
   b) Name and respective contact information of the firm and the engineer who prepared the study.
   c) Study or latest revision date and the OWNER's contract number for which the study was prepared.
7) Picture files provided shall be named appropriately for easy identification and included with the study.

1.4 QUALITY ASSURANCE

A. General:
1. If available, an existing ESA model in EasyPower (DEZ file) will be provided to the CONTRACTOR to develop the modified ESA model and provide the ESA required for this Project. Verify existing model information (including model data) that influences the project ESA and update the existing model with field-collected data. The CONTRACTOR shall be responsible for new model information and updating the existing model to reflect modifications and changes. The ESA required by the Contract Documents shall include complete studies from the utility source through feeders and branch circuits in new equipment.
2. The ESA and EasyPower model shall include, but not be limited to:
   a. Studies shall be performed in ESA EasyPower version 10 or newer.
   b. The EasyPower model shall include the complete power distribution system including, but not limited to: Utility system interface, switchgear, transformers, generators, protective relays, overcurrent protective devices, MCCs, MCC individual buckets/units, switchboards, main distribution panels, panelboards, disconnects, motors, single-phase transformers, single-phase panelboards, HVAC equipment, conductors, conduits, feeders, branch circuits, raceways, etc.
   c. Notify the ENGINEER in writing of any inadequacies and provide recommendations for corrections as soon as they are identified.
   d. Equipment and component titles used in the studies shall be identical to the equipment and component titles shown on the Drawings or as provided by the ENGINEER.
   e. Perform complete fault calculations for each proposed and ultimate source combination.
   f. The ESA shall be at site conditions.
   g. Source combination may include present and future circuits, large motors, or generators.
   h. Acquire and provide tabulation for the actual, existing, and proposed equipment, device and material information, and data for the studies, in a timely manner to allow the studies to be completed. Information and data shall be provided for equipment, electrical system, conductors, cables, conduits, overcurrent protection devices, generators, motors, protective relays, and other component and system information when available.
   i. Verify study information obtained from the Contract Documents and provided by the ENGINEER.
   j. Coordinate with the utility throughout the Project to obtain and verify the latest utility system data and information is accurate and up-to-date.
   k. Existing equipment data.
   l. Device coordination time-current curves.
   m. Conduits, conductors, and cables characteristics in the final ESA shall match the final As-Built conduit/conductor schedules.
   n. Equipment information and data in the final ESA shall match the final equipment As-Built Drawings and O&M manual information and data.
   o. Study scenarios:
      1) The studies shall include all possible electrical system configurations including, but not limited to:
         a) Operation on normal (utility) source.
         b) Operation on generator source.
         c) Parallel operation on normal and generator sources.
         d) Main-breakers closed, tie-breaker open.
         e) Either main-breaker open, tie-breaker closed.

B. The ESA shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado, and in accordance with IEEE 242 and IEEE 399.

C. Tabulations:
1. Include complete:
   a. Manufacturer, model number, and tag numbers.

b. Equipment data.
c. Overcurrent protection information, adjustable range, and settings.
d. Protective relay information, adjustable range, and settings.
e. Conduit, conductor, and cable material data: Include conductor lengths, number of conductors per phase, conductor impedance, (resistance and reactance) values, insulation types, conduit size and type.
f. Bus data: Materials, plating, ratings, and size.
g. Transformer data, nameplate information, impedances, X/R ratios, cooling information, etc.
h. Generator and motor data, nameplate information, reactances, resistances, etc.
i. Utility data:
    1) Utility personnel that provided data: Name, title, and phone number.
    2) Utility source data: three-phase short-circuit MVA, three-phase short-circuit X/R, single-phase short-circuit MVA, single-phase short-circuit Xo/Ro, SCAmps, kV.
    3) Utility transformer data: kVA, Secondary kV, %Z, X/R, %R.
    4) System impedance:
        a) Symmetrical fault currents.
        b) Asymmetrical fault currents.
    5) Reclosure information.
    6) Utility line data: Conductor size, neutral size, configuration, distance, positive sequence impedance per distance, positive sequence impedance P.U. in ohms, zero sequence impedance per distance, zero impedance P.U. in ohms.

D. Study Analyses:
1. Written summary:
    a. Scope of studies performed.
    b. Identify the line of demarcation between the utility company and the OWNER's equipment. Provide same identification on As-Built Drawings.
    c. Explanation of bus and branch numbering system.
    d. Prevailing conditions.
    e. Selected equipment deficiencies.
    f. Results of studies.
    g. Comments or suggestions.
    h. Suggest changes and additions to the equipment rating and/or characteristics.

E. Short-Circuit Study:
1. Motor short-circuit contributions shall be included.
2. Tabulation shall be included which lists the calculated short-circuit currents, X/R ratios, asymmetry factors, motor contributions, equipment short-circuit interrupting or withstand current ratings, and notes regarding the adequacy or inadequacy of the equipment.
3. Symmetrical and asymmetrical fault currents. Include the maximum available short-circuit current in rms symmetrical amperes and the X/R ratio of the fault current for each bus/branch calculation.
4. The system one-line drawing shall clearly identify individual equipment buses, bus numbers used in the short-circuit analysis, cable and bus connections between the equipment, calculated maximum short-circuit current at each bus location, and other information pertinent to the study.
5. A comprehensive discussion section evaluating the adequacy or inadequacy of the equipment shall be provided and include recommendations as appropriate for improvements to the system.
6. Provide:
    a. Calculation methods and assumptions.
    b. Selected base per unit quantities.
    c. One-line diagrams.
    d. Source impedance data, including electric utility system and motor fault contribution characteristics.
    e. Impedance diagrams.
    f. As part of determining the equipment duty adequacy, evaluate equipment X/R rating, as tested, compared to the X/R rating of the subjected fault. Identify any adjusted symmetrical values.
    g. Tabulations of calculated quantities.
    h. Results, conclusions, and recommendations.
7. Calculate short-circuit interrupting and momentary (when applicable) duties for an assumed three-phase bolted fault at each:
    a. Bus.
    b. Electric utility supply termination point: Switchgear.
    c. Transformer primary and secondary.
    d. Generator.
    e. Switchgear.
    f. MCC.
    g. Switchboard.
    h. Motor controller.
    i. Panelboard.
    j. Three-phase disconnect.
    k. Automatic transfer switch.
    l. Three-phase motor.

m. Motor 0.5 hp and larger.
n. Significant location throughout the system.

8. Provide a bolted line-to-ground fault current study for areas as defined for three-phase bolted fault short-circuit study.
9. Provide a bolted line-to-line fault current study for areas as defined for three-phase bolted fault short-circuit study.
10. Verify:
    a. Equipment and protective devices are applied within their ratings.
    b. Adequacy of switchgear, MCC, panelboards, motor controller bus bars to withstand short-circuit stresses.
    c. Adequacy of transformer windings to withstand short-circuit stresses.
    d. Conductor and cable sizes for ability to withstand short-circuit heating, besides normal load currents.
    e. Use EasyPower recommended workaround for single-phase systems.

F. Protective Device Coordination Study:
1. Where necessary and approved by the ENGINEER, an appropriate compromise shall be made between system protection and service continuity with system protection and service continuity considered to be of equal importance.
2. The study shall include a separate tabulation containing all**,** including existing, recommended, and actual device ratings, sizes, settings, locations, numbers, tags, type, Manufacturer, model number, tap range, time range, trip sequence, alarms, annunciation, input and output devices, etc., corresponding to the system one-line diagram. The tabulation shall include, but not be limited to, fuses, breakers, protective devices, protective relays, etc.
3. Provide calculations to determine settings.
4. System one-line diagram shall be provided that clearly identifies individual equipment buses, bus numbers, device identification numbers, and the maximum available short-circuit current at each bus.
5. Provide a discussion section which evaluates the degree of system protection and service continuity with overcurrent devices, along with recommendations as required for addressing system protection or device coordination deficiencies.
6. Provide CT and PT information: Model number, ratio, rating factor, relay class, ANSI metering accuracy, BIL, excitation curves, VA, etc. Provide complete burden calculations including devices and conductors. Indicate the linear region of operation on the excitation curves. Provide discussion and recommendations for correcting saturation.
7. Provide a complete coordination study of relays, fuses, circuit breakers, and other protective devices. The coordination study shall include the entire system including electric utility protective devices.
8. Protective devices shall be adjusted, tested, set, and calibrated in the field, prior to energizing the equipment, in accordance with the settings in the study, the study shall be resubmitted with all field changes. The Work shall be done by a qualified Factory Service Representative prior to final acceptance. Protective device settings and sizes shall be approved by the ENGINEER and the electric utility when applicable.
9. Proposed protective device coordination time-current curves, graphically displayed on conventional log-log curve sheets.
10. Each curve sheet shall have a title and a one-line diagram with identification that applies to the specific portion of the system associated with time-current curves on that sheet.
11. Terminate device characteristic curves at a point reflecting the maximum symmetrical or asymmetrical fault current to which the device is exposed.
12. Identify the device associated with each curve by the Manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.
13. Plot characteristics on curve sheets, at a minimum:
    a. Electric utility's equipment, fuses, reclosers, cables, including the Manufacturer's minimum melt, total clearing, tolerance, and damage bands.
    b. Protective relays.
    c. Generator decrement curve.
    d. Motor curves, including reduced voltage starting if applicable.
    e. Overcurrent devices, fuses, and circuit breakers.
    f. Low-voltage fuses including the Manufacturer's minimum melt, total clearing, tolerance, and damage bands.
    g. Low-voltage equipment circuit breaker trip devices, including the Manufacturer’s tolerance bands.
    h. Conductor and cable damage curves.
    i. Pertinent transformer full-load currents at 100% and 600%.
    j. Transformer magnetizing inrush currents.
    k. Transformer damage curves.
    l. ANSI transformer withstand parameters.
    m. Significant symmetrical and asymmetrical fault currents.
    n. Arc flash currents.
    o. Ground fault protective device settings.
    p. Protective devices for the largest branch circuit and the feeder circuit breaker in each panelboard.

G. Arc Flash Hazard Analysis:
1. Results of the analysis shall include all case scenarios submitted in tabular form, electronic form in XLSX format, and shall include, at a minimum, arc flash boundary, incident energy, working distance, shock hazard, shock hazard approach boundaries, equipment name and arc flash label number, equipment or bus fed by, and the date the analysis was performed.

2. The analysis shall be performed under worst case arc flash conditions, and the final report shall describe, when applicable, how the conditions differ from worst case bolted fault conditions.
3. The arc flash hazard analysis shall be in accordance with IEEE 1584 and NFPA 70E.
4. The arc flash hazard analysis shall include recommendations for reducing incident energy levels and enhancing worker safety.
5. Install arc flash labels for electrical distribution and utilization equipment:
   a. In accordance with ANSI Z535.
   b. Indicating worst case conditions.
   c. EasyPower produced information, meeting DW's latest labeling standard and information. Label examples in accordance with DW CPCS Standard Details 26900 through 26903.
   d. The ENGINEER will provide individual sequential AF####s to be used in labels.
   e. AF####s shall be included in the model as part of the bus data ID name in the format: Equipment name, two spaces, AF####.
   f. Labels shall be provided for electrical distribution equipment and energized electrical conductors or circuit parts capable of being inadvertently touched or approached nearer than a safe distance by a person. Labels shall also be provided for electrical conductors or circuit parts that are not suitably guarded, isolated, or insulated.
   g. Labels shall be provided for each vertical section of equipment with multiple sections including switchgears, switchboards, MCCs, etc.
   h. A separate label and bus within the EasyPower model shall be provided between overcurrent protection devices in separate locations, enclosures, and vertical sections. A separate label and bus within the EasyPower model shall be provided for the equipment main protection section based on the line side of the protective device. Separate labels and a bus within the EasyPower model shall be provided for load side sections of equipment with multiple sections based on the load side of the main protection device.
   i. The following label sizes shall be provided:
      1) Large labels (10 inches by 7 inches): Interior and exterior electrical distribution and utilization equipment, doors, removable panels (front and back), and removable covers for equipment including, but not limited to, switchgear, switchboards, transformers, generators, motors, motor controllers, motor starters, MCCs, metering cabinets, HRG systems, bus transition sections, power supplies uninterruptible power supplies, variable frequency drives, disconnects, panelboards, distribution panels, wireways/gutters/pull boxes/EHHs with splices or distribution bus/blocks, mini-power zones, transfer switches, ATSs, LCPs, ECPs, lighting control cabinets, control panels, etc.
      2) Small labels (6 inches by 4 inches): Equipment approved by the ENGINEER that a large label will not fit.
   j. After the ESA is As-Built by the CONTRACTOR and approved by the ENGINEER; provide the ENGINEER with the worst case scenario comparison report, containing only worst case scenario data. The worst case scenario comparison report shall be exported from EasyPower, saved, and provided to the ENGINEER as an Excel (XLSX) file. Within 30 days of receipt, the ENGINEER will provide the CONTRACTOR an Excel file for use in defining and ordering arc flash labels.
   k. Follow the instructions embedded within the arc flash label fields spreadsheet, providing additional data required for the labels, and order the arc flash labels, as specified in the CPCS details 26700 through 26703, from the following third-party vendor:
      1) Clarion Safety Systems, LLC, Merrily Hansen, mhansen@clarionsafety.com, phone: (800) 748-0241, fax: (800) 748-0536.
   l. Install arc flash labels on the equipment with guidance from the ESA Subcontractor and the ENGINEER.
6. Load study, load flow, and voltage drop analysis:
   a. The load study, load flow, and voltage drop analysis shall include calculations of power flow in branch and feeder circuits, calculated voltages at each bus, and voltage drops of each feeder.
   b. The analysis shall provide the calculated maximum values of kVA, kW, kVAR, PF, and amperes for each power circuit.
   c. The calculated power losses in each branch and total system losses shall be provided.
   d. The analysis shall include a one-line diagram clearly identifying individual equipment buses, bus numbers, cable and bus connections, power flow throughout the system, and other information related to the analysis.
   e. A discussion section evaluating the loading and voltage levels for the system shall be provided and recommendations included as appropriate to improve system operation.
7. PF correction study:
   a. A PF correction study shall be performed to determine the appropriate level of compensation needed to achieve the desired PF.
   b. Impacts on harmonic and transient concerns shall be evaluated to determine the optimum size and configuration of the equipment.
   c. The study shall make appropriate recommendations to provide proper operation of the electrical system.
   d. The study shall be based on data acquired by the CONTRACTOR.
   e. System loading tables shall be provided that include PF data and estimated levels of PF compensation provided.
   f. Evaluation of system operation using the estimated levels of compensation shall be provided with consideration to harmonic and transient concerns.
   g. Final levels of compensation shall be determined and used as the base case condition for the harmonic and transient studies.

h. Conclusions, recommendations, and equipment specifications as a result of the PF correction study shall be summarized in the final report.
i. PF measurements shall be performed to verify the study result. The measurements shall be conducted over a 7-day period.

8. Harmonic analysis study:
   a. A harmonic analysis study shall be made to determine the levels of harmonic voltages and currents in the system.
   b. The type and level of compensation needed to achieve the desired PF and acceptable levels of harmonics shall be considered.
   c. Transient concerns shall be evaluated to determine the optimum equipment size, location in the system, and configuration.
   d. The study shall make appropriate recommendations to provide proper protection and operation of the electrical system.
   e. The harmonic analysis study and system model shall be based on complete equipment, device, conductor, and materials data acquired by the CONTRACTOR. Harmonic measurements shall be performed to provide nonlinear load characteristics, distortion levels, and model verification. The measurements shall be conducted over a 7-day period.
   f. Frequency scan cases, impedance versus frequency, shall be completed to determine the system frequency response characteristic for various system conditions.
   g. Analysis shall be performed to determine the system harmonic voltage and current levels and voltage distortion levels, and compared with measured values to determine the effect of various system conditions. The study shall include individual order harmonics, THD and TDD values.
9. Switching transient analysis study:
   a. Switching transient analysis study shall be made to determine the transient overvoltages for various switching conditions and their effect on the operation of the electrical system.
   b. Various system conditions, consistent with previously gathered data from the PF correction study and harmonic analysis study, shall be evaluated so that the proper overvoltage protection specifications may be developed.
   c. Transient simulations shall be performed using a digital computer to determine transient voltage levels at the low voltage buses within the electrical system.
   d. The electrical system parameters shall be varied to determine their effect on the transient voltages.
   e. Various solutions to remove excessive transient voltage levels shall be proposed and considered and additional computer simulations made to determine their validity.
   f. The evaluation shall consider solutions to PF and harmonic concerns with respect to transient overvoltage levels.
   g. Nuisance tripping of electronic power equipment (e.g., adjustable speed drives) shall be evaluated and corrective or preventive techniques suggested.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Carollo Engineers – Engineering Services
B. E2 Power Systems, Inc. Electrical Engineering Services
C. Eaton Cutler – Hammer Engineering Services
D. Schneider Electric, Square D Engineering Services

PART 3 EXECUTION

3.1 GENERAL

A. Adjust relay and protective device settings in accordance with the values established by protective device coordination study.
B. Make modifications to equipment as required to achieve conformance with the approved ESA studies.
C. Provide ENGINEER-approved arc flash labels for electrical equipment within the scope of the study. Install ENGINEER-approved arc flash labels for electrical equipment in the presence of the ENGINEER and the OWNER.
D. Notify the ENGINEER in writing of any inadequacies and provide recommendations for corrections as soon as they are identified.
E. Field testing and settings coordination as specified in SECTION 26 08 00.

END OF SECTION

SECTION 26 08 00
COMMISSIONING OF ELECTRICAL SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for commissioning of electrical systems.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):

1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

B. American National Standards Institute/National Electrical Manufacturers Association (ANSI/NEMA):

1. AB 4 – Guidelines for Inspection and Preventive Maintenance of Molded-Case Circuit Breakers Used in Commercial and Industrial Applications

C. ASTM International (ASTM):

1. D 877 – Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using Disk Electrodes
2. D 923 – Standard Practices for Sampling Electrical Insulating Liquids
3. D 924 – Standard Test Method for Dissipation Factor (or Power Factor) and Relative Permittivity (Dielectric Constant) of Electrical Insulating Liquids
4. D 971 – Standard Test Method for Interfacial Tension of Insulating Liquids Against Water by the Ring Method
5. D 974 – Standard Test Method for Acid and Base Number by Color-Indicator Titration
6. D 1298 – Standard Test Method for Density, Relative Density, or API Gravity of Crude Petroleum and Liquid Petroleum Products by Hydrometer Method
7. D 1500 – Standard Test Method for ASTM Color of Petroleum Products (ASTM Color Scale)
8. D 1524 – Standard Test Method for Visual Examination of Used Electrical Insulating Liquids in the Field
9. D 1816 – Standard Test Method for Dielectric Breakdown Voltage of Insulating Liquids Using VDE Electrodes
10. D 3612 – Standard Test Method for Analysis of Gases Dissolved in Electrical Insulating Oil by Gas Chromatography

D. Institute of Electrical and Electronics Engineers (IEEE):

1. 43 – Recommended Practice for Testing Insulation Resistance of Electric Machinery
2. 81 – Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Grounding System
3. 400.3 – Guide for Partial Discharge Testing of Shielded Power Cable Systems in a Field Environment
4. C2 – National Electrical Safety Code (NESC)
5. C57.13.1 – Guide for Field Testing of Relaying Current Transformers
6. C57.104 – Guide for the Interpretation of Gases Generated in Oil-Immersed Transformers

E. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)
2. 70E – Standard for Electrical Safety in the Workplace

1.3 SEQUENCING AND SCHEDULING

A. Perform inspection and electrical tests after equipment has been reworked, reused, reconnected, reinstalled, or installed.

B. Perform tests with apparatus de-energized whenever feasible.

C. Inspection and electrical tests on energized equipment shall be:

1. Scheduled with the ENGINEER prior to de-energization.
2. Minimized to avoid an extended period of interruption to the operating plant equipment.

D. Notify the ENGINEER at least 1 day prior to performing tests on energized electrical equipment.

1.4 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 business days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings and Administrative Submittals:

1. Submittals shall be approved prior to performing inspections or tests.
2. Testing technician resume(s) and NICET or NETA certification documentation.
3. Schedule for performing inspection and tests.
4. A list of references and procedures to be used for each test.
5. A sample copy of equipment and materials inspection form(s).
6. A sample copy of individual device test form.
7. A sample copy of individual system test form.
8. Calibration certificates for test equipment and torque wrenches.

D. Quality Control Submittals:

1. A signed draft copy of the certificate of proper installation shall be submitted prior to energizing electrical equipment as specified in individual Specification Sections. Final testing and inspection reports and certificates for each electrical item tested shall be submitted and approved with O&M data prior to the Substantial Completion date.

2. Hardcopy and electronic version of installed programs, settings, complete model numbers, equipment, and material characteristics.
3. O&M data:
   a. Provide preliminary and final manuals.
   b. As specified in Section 01 78 23.
   c. Shop Drawing Submittal information.
   d. Provide complete final commissioning manual and provide individual testing reports in each applicable O&M manual.
   e. After test or inspection reports and certificates have been reviewed by the ENGINEER and returned, insert a copy of each in applicable O&M manuals.

1.5 QUALITY ASSURANCE

A. Testing Agency Qualifications:
   1. Corporately and financially independent agency functioning as an unbiased testing authority.
   2. Professionally independent of Manufacturers, Suppliers, and installers of electrical equipment and systems being tested.
   3. An employer of engineers and technicians regularly engaged in the testing and inspecting of electrical equipment, installations, and systems.
   4. A supervising engineer accredited as a Certified Electrical Test Technologist by NICET, or NETA, and having a minimum of 5 years of testing experience on similar projects.
   5. Technicians certified by NICET or NETA (Level 3).
   6. Assistants and apprentices assigned to the Project at a ratio that shall not exceed two certified to one noncertified assistant or apprentice.
   7. Professional Engineer registered in the State of Colorado to provide comprehensive project report outlining services performed, results of such services, recommendations, actions taken, and opinions.
   8. In compliance with OSHA Title 29 criteria for accreditation of testing laboratories or a full member company of the International Electrical Testing Association.

B. Test equipment shall have an operating accuracy in accordance with ANSI/NETA ATS.

C. Test instrument calibration shall be in accordance with ANSI/NETA ATS with a calibration sticker on the test instrument.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Vertiv

B. Electric Power Systems

C. Magna IV

PART 3 EXECUTION

3.1 GENERAL

A. Testing and inspection shall be performed on new equipment and modified existing equipment.

B. Tests and inspection shall establish the following:
   1. Electrical equipment is operational within industry and Manufacturer's tolerances.
   2. Installation allows for proper equipment operation.
   3. Equipment is suitable for energization.
   4. Installation shall be in accordance with the Contract Documents, NFPA 70, NFPA 70E, and IEEE C2.
   5. Installation shall be in accordance with ANSI/NETA ATS where referenced hereinafter. Conformity shall include the following sections from the ANSI/NETA ATS: 3, 3.1, 3.2, 4, 4.1, 4.2, 5, 5.1, 5.2, 5.3, and 5.4. The ancillary sections shall be considered congruent requirements with any references to Sections 7 and any other NETA reference.

C. Perform inspection and testing in accordance with ANSI/NETA ATS, industry standards, and the Manufacturer's recommendations.

D. Set, test, and calibrate protective relays, circuit breakers, fuses, and other applicable devices in accordance with the values established by the ENGINEER.

E. Adjust mechanisms and moving parts for free mechanical movement.

F. Adjust adjustable relays and sensors to correspond to operating conditions, or as recommended by the Manufacturer.

G. Verify nameplate data in accordance with the Contract Documents. Where any deviations are found, provide written documentation of findings to the ENGINEER.

H. Realign and level equipment not properly aligned and level.

I. Properly anchor electrical equipment found to be inadequately anchored.

J. Tighten accessible bolted connections, including wiring connections, with a calibrated torque wrench to the Manufacturer's recommendations.

K. Clean contaminated surfaces with cleaning solvents as recommended by the Manufacturer.

L. Provide proper lubrication of applicable moving parts.

M. Verify and inform the ENGINEER of working clearances and spaces about electrical equipment that are not in accordance with NFPA 70.

N. Investigate and Repair or Replace:
   1. Electrical items that fail tests.
   2. Active components not operating in accordance with the Manufacturer's instructions.
   3. Damaged electrical equipment.

O. Electrical Enclosures:
   1. Remove foreign material and moisture from enclosure interior.
   2. Vacuum and wipe clean enclosure interior.
   3. Remove corrosion found on metal surfaces.
   4. Repair or replace, as determined by the ENGINEER, door and panel sections having dented surfaces.
   5. Repair or replace, as determined by the ENGINEER, poor fitting doors and panel sections.
   6. Repair or replace improperly operating latching, locking, or interlocking devices.
   7. Replace missing or damaged hardware.
   8. Finish:
      a. Provide matching paint and touch up scratches and mars.
      b. If required due to extensive damage, refinish the entire assembly.

P. Replace fuses and circuit breakers that are not in accordance with the Contract Documents.

Q. Perform thermographic survey in accordance with ANSI/NETA ATS.

R. Field testing and settings coordination as specified in SECTION 26 05 70.

3.2 QUALITY CONTROL

A. Cables, Medium-Voltage and High-Voltage:
   1. Visual and mechanical inspection:
      a. Compare cable data with the Contract Documents.
      b. Inspect exposed sections of cables for physical damage.
      c. Inspect bolted electrical connections for high resistance using the following methods:
         1) Use of a low-resistance ohmmeter in accordance with ANSI/NETA ATS.
         2) Verify the tightness of accessible bolted electrical connections by calibrated torque wrench method in accordance with the Manufacturer’s published data or ANSI/NETA ATS.
         3) Perform a thermographic survey in accordance with ANSI/NETA ATS.
      d. Inspect compression-applied connectors for correct cable match and indentation.
      e. Inspect shield grounding, cable supports, and terminations.
      f. Verify that visible cable bends do not exceed the Manufacturer’s maximum published bending radius.
      g. If cables are terminated through window type CTs, inspect to verify that neutral and ground conductors are correctly placed and that shields are correctly terminated for the operation of protective devices.
      h. Inspect for correct identification and arrangements.
      i. Inspect cable jacket and insulation condition.
      j. Use a calibrated torque wrench to tighten to the Manufacturer’s recommendations
   2. Electrical tests:
      a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with ANSI/NETA ATS.
      b. Perform an insulation resistance test individually on each conductor with all other conductors and shields grounded. Apply voltage in accordance with the Manufacturer’s published data. In the absence of the Manufacturer’s published data, use ANSI/NETA ATS.
      c. Perform a shield-continuity test on each power cable.
      d. Provide the following tests:
         1) Dielectric withstand:
            a) DC dielectric withstand voltage.
            b) VLF dielectric withstand voltage.
            c) Power frequency: 50/60 Hz, dielectric withstand voltage.
         2) Baseline diagnostic tests:
            a) PF/dissipation factor, tan delta.
            b) Power frequency: 50/60 Hz.
            c) VLF.
         3) DC insulation-resistance.
         4) Partial discharge test:
            a) Power frequency: 50/60 Hz.
            b) VLF.
   3. Tests shall be performed in accordance with IEEE 400.3:
      a. Compare bolted connection resistance values to the values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50% of the lowest value. Bolt-torque levels shall be in accordance with the Manufacturer’s published data. In the absence of the Manufacturer’s published data, use ANSI/NETA ATS.
      b. Results of the thermographic survey shall be in accordance with ANSI/NETA ATS.
      c. The minimum bend radius that insulated cables may be bent for permanent training shall be in accordance with ANSI/NETA ATS.
      d. Insulation resistance values shall be in accordance with the Manufacturer’s published data. In the absence of the Manufacturer’s published data, use ANSI/NETA ATS. Values of insulation resistance less than ANSI/NETA ATS or the Manufacturer’s recommendations shall be investigated.
      e. Shielding shall exhibit continuity. Investigate resistance values in excess of 10 ohms per 1,000 feet of cable.
      f. If no evidence of distress or insulation failure is observed by the end of the total time of voltage application during the dielectric withstand test, the test specimen is considered to have passed the test.

g. Based on the test methodology chosen, refer to applicable standards or the Manufacturer's literature for acceptable values.

B. Low-Voltage Cables, 600 V Maximum:
1. Visual and mechanical inspection:
a. Inspect each individual exposed power cable for:
1) Physical damage.
2) Proper connections in accordance with the one-line diagram.
3) Cable bends not in conformance with the Manufacturer's minimum allowable bending radius where applicable.
4) Color coding shall be in accordance with the Contract Documents.
5) Proper circuit identification.
b. Inspect mechanical connections for:
1) Proper lug type for conductor material.
2) Proper lug installation.
3) Bolt- torque level in accordance with ANSI/NETA ATS.
c. Inspect shielded instrumentation cables for:
1) Proper shield grounding.
2) Proper terminations.
3) Proper circuit identification.
d. Inspect control cables for:
1) Proper termination.
2) Proper circuit identification.
e. Cables terminated through window type CT: Verify that neutrals and grounds are terminated for correct operation of protective devices.
2. Electrical tests for conductors, No. 6 and larger:
a. Insulation resistance tests:
1) Utilize 1,000 VDC megohmmeter for 600 V insulated conductors.
2) Test each conductor with respect to ground and to adjacent conductors in accordance with ANSI/NETA ATS for 1 minute.
3) Evaluate ohmic values by comparison with conductors of the same length and type.
4) Investigate values less than 100 megohms.
b. Continuity test by ohmmeter method to ensure proper cable connections.

C. Safety Switches, 600 V Maximum:
1. Visual and mechanical inspection:
a. Proper blade pressure and alignment.
b. Proper operation of switch operating handle.
c. Adequate mechanical support for each fuse.
d. Proper contact-to-contact tightness between fuse clip and fuse.
e. Cable connection bolt-torque level in accordance with ANSI/NETA ATS.
f. Proper phase barrier material and installation.
g. Verify that fuse sizes and types correspond to the one-line diagram.
h. Perform mechanical operational test and verify electrical and mechanical interlocking system operation and sequencing.
2. Electrical tests:
a. Insulation resistance tests:
1) Applied megohmmeter DC voltage in accordance with ANSI/NETA ATS.
2) Phase-to-phase and phase-to-ground for 1 minute on each pole.
3) Insulation resistance values equal to, or greater than, the ohmic values established by the Manufacturer.
b. Contact resistance tests:
1) Contact resistance in microhms across each switch blade and fuse holder.
2) Investigate deviation of 50% or more from adjacent poles or similar switches.

D. Busways:
1. Visual and mechanical inspection:
a. Compare the equipment nameplate data with drawings and specifications.
b. Inspect busway for physical damage and correct connection in accordance with the one-line diagram.
c. Inspect for appropriate bracing, suspension, alignment, and enclosure ground.
d. Inspect bolted electrical connections for high resistance using one of the following methods:
1) Use of low-resistance ohmmeter in accordance with this Section.
2) Verify the tightness of accessible bolted electrical connections by calibrated torque wrench method in accordance with the Manufacturer's published data or ANSI/NETA ATS.
3) Perform a thermographic survey in accordance with ANSI/NETA ATS.
4) Confirm physical orientation in accordance with the Manufacturer's labels to ensure adequate cooling.
e. Examine outdoor busway for removal of weep-hole plugs, if applicable, and the correct installation of joint shield.

2. Electrical tests:
    a. Measure the insulation resistance of each busway, phase-to-phase and phase-to-ground for 1 minute, in accordance with ANSI/NETA ATS.
    b. Perform an overpotential test on each busway, phase-to-ground with phases not under test grounded, in accordance with the Manufacturer's published data. If the Manufacturer has no recommendation for the test, it shall be in accordance with ANSI/NETA ATS. Where no DC test value is shown in ANSI/NETA ATS, AC value shall be used. The test voltage shall be applied for 1 minute.
    c. Perform contact-resistance test on each connection point of non-insulated busway. On insulated busway, measure resistance of assembled busway sections and compare values with adjacent phases.
    d. Perform phasing test on each busway tie section energized by separate sources. Tests shall be performed from their permanent sources.
3. Test values:
    a. Compare bolted connection resistances and bus joint resistances to the values of similar connections.
    b. Bus bolt-torque levels shall be in accordance with ANSI/NETA ATS.
    c. Microhm or millivolt drop values shall not exceed the high levels of the normal range as indicated in the Manufacturer's published data. If the Manufacturer's data is not available, investigate any values that deviate from similar connections by more than 50% of the lowest value.
    d. Insulation resistance test voltages and resistance values shall be in accordance with the Manufacturer's published data or ANSI/NETA ATS. Minimum resistance values are for a nominal 1,000-foot busway run. Use the following formula to convert the measured resistance value to the 1,000 foot nominal value:
        1) R_{1000ft} = Measured Resistance x (Run Length/1000).
    e. Converted values of insulation-resistance less than those in ANSI/NETA ATS or the Manufacturer's minimum shall be investigated. Overpotential tests shall not proceed until insulation resistance levels are raised above minimum values.
    f. The insulation shall withstand the overpotential test voltage applied.

E. Motors:
1. General: Inspection and testing limited to motors rated 1/2 hp and larger. Visual and mechanical inspection:
    a. Proper electrical and grounding connections.
    b. Shaft alignment.
    c. Blockage of ventilating air passageways.
    d. Operate the motor and check for:
        1) Excessive mechanical and electrical noise.
        2) Overheating.
        3) Correct rotation.
        4) Check vibration detectors, RTDs, or motor inherent protectors for functionality and proper operation.
        5) Excessive vibration.
    e. Check the operation of space heaters.
2. Electrical tests:
    a. Insulation-resistance tests:
        1) In accordance with IEEE 43 at test voltages established by ANSI/NETA ATS for: Motors 200 hp and less for 1 minute duration with resistances tabulated at 30 seconds and 60 seconds.
        2) Insulation-resistance values equal to, or greater than, the ohmic values established by the Manufacturer.
    b. Insulation-resistance test on insulated bearings in accordance with the Manufacturer's instructions.
    c. Measure running current and voltage, and evaluate relative to load conditions and nameplate FLAs.

F. Engine Driven Generator:
1. Visual and mechanical inspection:
    a. Proper grounding.
    b. Blockage of ventilating passageways.
    c. Proper operation of jack water heaters.
    d. Integrity of engine cooling and gas supply systems.
    e. Excessive mechanical and electrical noise.
    f. Overheating of engine or generator.
    g. Proper installation of vibration isolators.
    h. Proper cooling liquid type and level.
    i. Operate the engine driven generator and check for:
        1) Excessive mechanical and electrical noise.
        2) Overheating.
        3) Correct rotation.
        4) Check RTDs or generator inherent.
        5) Excessive vibration.
    j. Verify that voltage regulator and governor operation will cause the unit speed and output voltage to stabilize at proper values within a reasonable length of time.
    k. Proper operation of meters and instruments.
    l. Compare the generator nameplate rating and connection with the one-line diagram.

2. Electrical and mechanical tests:
    a. Cold start test by interrupting normal power source with a test load consisting of the connected building load to verify:
        1) Transfer switch operation.
        2) Automatic starting operation.
        3) Operating ability of engine-generator.
        4) Overcurrent devices capability to withstand inrush currents.
    b. Phase rotation tests.
    c. Test engine protective shutdown features for:
        1) Low oil pressure.
        2) Overtemperature.
        3) Overspeed.
    d. Load bank test with reactors and resistors adjusted to 80% PF for each load step. Record voltage, frequency, load current, oil pressure, and engine coolant temperature at 15 minute intervals.
        1) 25% applied load for 30 minutes.
        2) 50% applied load for 30 minutes.
        3) 75% applied load for 30 minutes.
        4) 100% applied load for 3 hours.
        5) Load test results to demonstrate the ability of the unit to deliver rated load for the test period.

G. Molded and Insulated Case Circuit Breakers:
1. General: Inspection and testing limited to circuit breakers rated 100 A and larger and to motor circuit protector breakers rated 50 A and larger.
2. Visual and mechanical inspection:
    a. Proper mounting.
    b. Proper conductor size.
    c. Feeder designation in accordance with the nameplate and the one-line diagram.
    d. Cracked casings.
    e. Connection bolt-torque level in accordance with ANSI/NETA ATS.
    f. Operate the breaker to verify smooth operation.
    g. Compare the frame size and the trip setting with the circuit breaker schedules or the one-line diagram.
    h. Verify that terminals are suitable for 75°C rated insulated conductors.
3. Electrical tests:
    a. Insulation-resistance tests:
        1) Utilize 1,000 VDC megohmmeter for 480 V and 600 V circuit breakers and 500 VDC megohmmeter for 240 V circuit breakers.
        2) Pole-to-pole and pole-to-ground with breaker contacts opened for 1 minute.
        3) Pole-to-pole and pole-to-ground with breaker contacts closed for 1 minute.
        4) Test values shall be in accordance with ANSI/NETA ATS.
    b. Contact resistance tests:
        1) Contact resistance in microhms across each pole.
        2) Investigate a deviation of 50% or more from adjacent poles and similar breakers.
    c. Primary current injection test to verify:
        1) Long-time minimum pickup and delay.
        2) Short-time pickup and delay.
        3) Ground fault pickup and delay.
        4) Instantaneous pickup by run-up or pulse method.
        5) Trip characteristics of adjustable trip breakers shall be within the Manufacturer's published time-current characteristic tolerance band, including adjustment factors.
        6) Trip times shall be in accordance with ANSI/NEMA AB 4.
        7) Instantaneous pickup value shall be in accordance with ANSI/NEMA AB 4.

H. Grounding Systems:
1. Visual and mechanical inspection:
    a. Equipment and circuit grounds in equipment for proper connection and tightness.
    b. Ground bus connections in equipment for proper termination and tightness.
    c. Effective transformer core and equipment grounding.
    d. Accessible connections to grounding electrodes for proper fit and tightness.
    e. Accessible exothermic-weld grounding connections to verify that molds were fully filled and proper bonding was obtained.
2. Electrical tests:
    a. Fall-of-potential test:
        1) Measurement of the main ground system's resistance shall be in accordance with IEEE 81.
        2) The main ground electrode system’s resistance to ground shall be no greater than 1 ohm.
    b. Two-point direct method test:
        1) Measurement of ground resistance between the main ground system, equipment frames, and system neutral and derived neutral points shall be in accordance with IEEE 81.
        2) Equipment ground resistance shall not exceed main ground system resistance by 0.50 ohm.

I. Low-Voltage Motor Control:
   1. Visual and mechanical inspection:
      a. Proper barrier and shutter installation and operation.
      b. Proper operation of indicating and monitoring devices.
      c. Proper overload protection for each motor.
      d. Blockage of air cooling passages.
      e. Proper operation of drawout elements.
      f. Integrity and contamination of bus insulation system.
      g. Check door and device interlocking system by:
         1) Closure attempt of device when door is in the open position.
         2) Opening attempt of door when device is in the on position.
      h. Check nameplates for proper identification of:
         1) Equipment title and tag number with the latest one-line diagram.
         2) Push buttons.
         3) Control switches.
         4) Pilot lights.
         5) Control relays.
         6) Circuit breakers.
         7) Indicating meters.
      i. Verify that fuse and circuit breaker sizes and types are in accordance with the Contract Documents.
      j. Verify that CT and PT ratios are in accordance with the Contract Documents.
      k. Check bus connections for high resistance by thermographic survey and low resistance ohmmeter and calibrated torque wrench applied to bolted joints:
         1) Ohmic value to be zero.
         2) Bolt-torque level in accordance with ANSI/NETA ATS.
      l. Check operation and sequencing of electrical and mechanical interlock systems by:
         1) Closure attempt for locked open devices.
         2) Opening attempt for locked closed devices.
         3) Key exchange to operate devices in positions.
      m. Verify the performance of each control device and feature furnished as part of the MCC.
      n. Control Wiring:
         1) Compare wiring to local and remote control, and protective devices with elementary diagrams.
         2) Check for proper conductor lacing and bundling.
         3) Check for proper conductor identification.
         4) Check for proper conductor lugs and connections.
      o. Exercise active components.
      p. Inspect contactors for:
         1) Correct mechanical operations.
         2) Correct contact gap, wipe, alignment, and pressure.
         3) Correct torque of connections.
      q. Compare solid-state overload setting with full-load current for proper size and setting.
      r. Compare overload heater rating with full-load current for proper size.
      s. Compare motor protector and circuit breaker with motor characteristics for proper size.
      t. Perform phasing check on double-ended MCCs to ensure proper bus phasing from each source.
   2. Electrical tests:
      a. Insulation-resistance tests:
         1) Applied megohmmeter DC voltage in accordance with ANSI/NETA ATS.
         2) Bus section phase-to-phase and phase-to-ground for 1 minute on each phase.
         3) Contactor phase-to-ground and across open contacts for 1 minute on each phase.
         4) Starter section phase-to-phase and phase-to-ground on each phase with the starter contacts closed and the protective devices open.
         5) Test values shall be in accordance with ANSI/NETA ATS.
      b. Overpotential tests:
         1) Maximum applied AC or DC voltage in accordance with ANSI/IEEE.
         2) Phase-to-phase and phase-to-ground for 1 minute for each phase of each bus section.
         3) Test results evaluated on a pass/fail basis.
      c. Current injection through overload unit at 300% of motor full-load current and monitor trip time:
         1) Trip time in accordance with the Manufacturer's published data.
         2) Investigate values in excess of 120 seconds.
      d. Control wiring tests:
         1) Apply secondary voltage to control power and potential circuits.
         2) Check voltage levels at each point on terminal boards and each device terminal.
         3) Insulation-resistance test at 1,000 VDC on control wiring except that connected to solid-state components. Insulation-resistance shall be 1 megohm at a minimum.
      e. Operational test by initiating control devices to affect proper operation.

J. Instrumentation and Communication Circuits:
   1. Instrumentation and communication conductors shall be tested for continuity, polarity, and complete loop checks.
   2. Conductors shall be disconnected from instruments and control boards while being tested.

K. Medium-Voltage, Switchgear:
   1. Visual and mechanical inspection:
      a. Compare the equipment nameplate data with the Contract Documents.
      b. Inspect physical and mechanical condition.
      c. Confirm correct application of the Manufacturer's recommended lubricants.
      d. Verify appropriate anchorage and required area clearances.
      e. Verify appropriate equipment grounding.
      f. Verify correct blade alignment, blade penetration, travel stops, and mechanical operation.
      g. Verify that fuse sizes and types are in accordance with drawings and short-circuit and coordination studies.
      h. Verify that expulsion-limiting devices are in place on holders having expulsion type elements.
      i. Verify that each fuse holder has adequate mechanical support.
      j. Inspect bolted electrical connections for high resistance using the following methods:
         1) Use of low-resistance ohmmeter in accordance with this Section.
         2) Verify the tightness of accessible bolted electrical connections by calibrated torque wrench method in accordance with the Manufacturer's published data or ANSI/NETA ATS.
      k. Perform a thermographic survey in accordance with ANSI/NETA ATS.
      l. Test interlocking systems for correct operation and sequencing.
      m. Verify correct phase-barrier materials and installation.
      n. Compare switchblade clearances with the industry standards.
      o. Inspect indicating and control devices for correct operation.
   2. Electrical tests:
      a. Perform insulation resistance tests on each pole, phase-to-phase and phase-to-ground with the switch closed and across each open pole for 1 minute. Test voltage shall be in accordance with the Manufacturer's published data or ANSI/NETA ATS.
      b. Perform an overpotential test on each pole with switch closed. Test each pole-to-ground with all other poles grounded. Test voltage shall be in accordance with the Manufacturer's published data or ANSI/NETA ATS.
      c. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with this Section.
      d. Measure contact resistance across each switchblade and fuse holder.
      e. Measure fuse resistance.
      f. Verify heater operation.
   3. Test values:
      a. Compare bolted connection resistances to the values of similar connections.
      b. Bolt-torque levels shall be in accordance with ANSI/NETA ATS.
      c. Microhm or millivolt drop values shall not exceed the high levels of the normal range in accordance with the Manufacturer's published data. If the Manufacturer's data is not available, investigate any values that deviate from similar connections by more than 50% of the lowest value.
      d. The insulation shall withstand the overpotential test voltage applied.
      e. Minimum insulation-resistance shall be in accordance with the Manufacturer's published data or ANSI/NETA ATS.
      f. Investigate fuse resistance values that deviate from each other by more than 15%.

L. Low-Voltage Switchgear and Switchboard Assemblies:
   1. Visual and mechanical inspection:
      a. Compare the equipment nameplate data with the Contract Documents.
      b. Inspect physical and mechanical condition.
      c. Verify appropriate anchorage, required area clearances, physical damage, and correct alignment.
      d. Inspect doors, panels, and sections for corrosion, dents, scratches, fit, and missing hardware.
      e. Verify that fuse and circuit breaker sizes and types correspond to drawings and the coordination study, and to the circuit breakers address for microprocessor-communication packages.
      f. Inspect bolted electrical connections for high resistance using the following methods:
         1) Use of low-resistance ohmmeter as specified in this Section.
         2) Verify the tightness of accessible bolted electrical connections by calibrated torque wrench method in accordance with the Manufacturer's published data or ANSI/NETA ATS.
      g. Compare switchblade clearances with the industry standards.
      h. Inspect indicating and control devices for correct operation.
      i. Perform a thermographic survey in accordance with ANSI/NETA ATS.
      j. Verify that CT and PT ratios correspond to the Drawings.
      k. Compare the equipment nameplate data with the latest one-line diagram when available.
      l. Confirm correct operation and sequencing of electrical and mechanical interlock systems.
      m. Attempt closure on locked-open devices. Attempt to open locked-closed devices.
      n. Make key exchange with devices operated in off-normal positions.
      o. Thoroughly clean switchgear prior to testing.

p. Lubrication:
    1) Verify appropriate contact lubricant on moving current-carrying parts.
    2) Verify appropriate lubrication on moving and sliding surfaces.

q. Inspect insulators for evidence of physical damage or contaminated surfaces.
r. Verify correct barrier and shutter installation and operation.
s. Exercise active components.
t. Inspect mechanical indicating devices for correct operation.
u. Verify that filters are in place and/or vents are clear.
v. Perform visual and mechanical inspection on instrument transformers.
w. Inspect control power transformers.
x. Inspect physical damage, cracked insulation, broken leads, tightness of connections, defective wiring, and overall general condition.
y. Verify that primary and secondary fuse ratings or circuit breakers are as shown on the Drawings.
z. Verify correct functioning of drawout disconnecting and grounding contacts and interlocks.
aa. Verify tie-breaker control power ATS operation.

2. Electrical tests:
    a. Perform tests on instrument transformers.
    b. Perform ground-resistance tests.
    c. Perform resistance tests through bus joints with a low-resistance ohmmeter, if applicable, in accordance with this Section.
    d. Perform insulation resistance tests on each bus section, phase-to-phase and phase-to-ground, for 1 minute in accordance with ANSI/NETA ATS.
    e. Perform an overpotential test on each bus section, each phase-to-ground with phases not under test grounded, in accordance with the Manufacturer's published data. If the Manufacturer has no recommendation for this test, it shall be in accordance with ANSI/NETA ATS, Table 100.2. The test voltage shall be applied for 1 minute.
    f. Perform insulation resistance tests at 1,000 VDC on control wiring. For units with solid-state components, follow the Manufacturer's recommendations.
    g. Perform control wiring performance test.
    h. Perform current injection tests on the entire current circuit in each section of switchgear.
    i. Perform current tests by primary injection, where possible, with magnitudes such that a minimum of 1.0 A flows in the secondary circuit.
    j. Where primary injection is impractical, utilize secondary injection with a minimum current of 1.0 A.
    k. Test the current at each device.
    l. Determine the accuracy of meters and calibrate watt-hour meters. Verify multipliers.
    m. Perform a phasing check on double-ended switchgear to ensure correct bus phasing from each source.

3. Control power transformers:
    a. Perform insulation resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with ANSI/NETA ATS unless otherwise specified by the Manufacturer.
    b. Perform a secondary wiring integrity test. Disconnect the transformer at secondary terminals and connect secondary wiring to correct secondary voltage. Confirm potential at all devices.
    c. Verify correct secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.
    d. Verify the correct function of control transfer relays located in switchgear with multiple power sources.

4. Voltage transformers:
    a. Perform insulation resistance tests. Perform measurements from winding-to-winding and each winding-to-ground. Test voltages shall be in accordance with ANSI/NETA ATS.
    b. Perform secondary wiring integrity test. Confirm correct potential at all devices.
    c. Verify secondary voltages.
    d. Verify operation of switchgear/switchboard heaters.

5. Test values:
    a. Compare bus connection resistances to the values of similar connections.
    b. Bolt-torque levels shall be in accordance with ANSI/NETA ATS.
    c. Microhm or millivolt drop values shall not exceed the high levels of the normal range in accordance with the Manufacturer's published data. If the Manufacturer's data is not available, investigate any values that deviate from similar bus by more than 50% of the lowest value.
    d. Insulation resistance values for bus, control wiring, and control power transformers shall be in accordance with the Manufacturer's published data. In the absence of the Manufacturer's published data, use Table 100.1. Values of insulation-resistance less than the table or the Manufacturer's minimum shall be investigated. Overpotential tests shall not proceed until insulation resistance levels are raised above minimum values.
    e. The insulation shall withstand the overpotential test voltage applied.

M. Medium-Voltage Lighting Arrestors and Surge Capacitors:

1. Visual inspection:
    a. Ground connections to the ground bus.
    b. Shortest practical jumper connections to the line.

2. Electrical tests:
    a. Grounding electrode resistance test in accordance with IEEE 81, using three-point fall-of-potential method.
    b. Insulation PF.
    c. Insulation-resistance.
    d. RF noise test using Stoddard Noise Test set with applied voltage of 1.18 times the maximum continuous operating voltage.
    e. Insulation PF leakage current, watts, loss, and insulation-resistance tests in accordance with the Manufacturer’s test values. RIV value shall not exceed 10 microvolts above background noise.
    f. Leakage current and watts loss tests.

N. Panelboards:
1. Provide a thermographic survey of panelboards after equipment has been operational at the maximum load for a minimum duration of 1 hour. Identify heating abnormalities and correct problematic connections and constructions.
2. Verify torque and correct deficient connections with the intent to meet the Manufacturer’s Specifications.
3. Measure the average load balance between phase conductors through a 1 day period with unloaded and loaded conditions. Where imbalance is found to exceed 4%, adjust the loads to correct the imbalance.
4. Verify circuit breakers installed match the Contract Documents.
5. Verify panel directories match the Contract Documents.

O. Transformers, Liquid-Filled:
1. Visual and mechanical inspection:
    a. Compare the equipment nameplate data with the Contract Documents.
    b. Inspect physical and mechanical condition.
    c. Inspect impact recorder prior to unloading.
    d. Test dew point of tank gases, if applicable.
    e. Inspect anchorage, alignment, and grounding.
    f. Verify the presence of PCB content labeling.
    g. Verify the removal of any shipping bracing after placement.
    h. Verify the bushings are clean.
    i. Verify that alarm, control, and trip settings on temperature and level indicators are as specified.
    j. Verify the operation of alarm, control, and trip circuits from temperature and level indicators, pressure relief device, gas accumulator, and fault pressure relay, if applicable.
    k. Inspect bolted electrical connections for high resistance using the following methods.
        1) Use of a low-resistance ohmmeter in accordance with ANSI/NETA ATS.
        2) Verify the tightness of accessible bolted electrical connections by calibrated torque wrench method in accordance with the Manufacturer’s published data or ANSI/NETA ATS.
        3) Perform a thermographic survey in accordance with ANSI/NETA ATS.
    l. Verify the correct liquid level in tanks and bushings.
    m. Verify that positive pressure is maintained on gas-blanketed transformers.
    n. Perform inspections and mechanical tests as recommended by the Manufacturer.
    o. Test load tap-changer in accordance with ANSI/NETA ATS.
    p. Verify the presence of transformer surge arresters.
    q. Verify the de-energized tap-changer position is left as specified.
2. Electrical tests:
    a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter, if applicable, in accordance with ANSI/NETA ATS.
    b. Perform insulation resistance tests, winding-to-winding and each winding-to-ground. Apply in accordance with the Manufacturer’s published data. In the absence of the Manufacturer’s published data, use ANSI/NETA ATS. Calculate the polarization index.
    c. Perform turns-ratio tests at tap positions.
    d. Perform insulation PF or dissipation factor tests on windings in accordance with the Test Equipment Manufacturer’s published data.
    e. Perform PF or dissipation factor tests on each bushing equipped with a PF/capacitance tap. In the absence of a PF/capacitance tap, perform hot-collar tests. Tests shall be in accordance with the Test Equipment Manufacturer’s published data.
    f. Perform excitation-current tests in accordance with the Test Equipment Manufacturer’s published data.
    g. Measure the resistance of each high-voltage winding in each no-load tap-changer position. Measure the resistance of each low-voltage winding in each load tap-changer position, if applicable.
    h. If the core ground strap is accessible, remove and measure the core insulation-resistance at 500 VDC.
    i. Measure the percentage of oxygen in the gas blanket, if applicable.
    j. Remove a sample of insulating liquid in accordance with ASTM D 923. The sample shall be tested for the following:
        1) Dielectric breakdown voltage in accordance with ASTM D 877 or ASTM D 1816.
        2) Acid neutralization number in accordance with ASTM D 974.
        3) Specific gravity in accordance with ASTM D 1298.
        4) Interfacial tension in accordance with ASTM D 971.
        5) Color in accordance with ASTM D 1500.
        6) Visual condition in accordance with ASTM D 1524.

7) PF or dissipation factor in accordance with ASTM D 924.
k. Remove a sample of insulating liquid and perform dissolved-gas analysis in accordance with IEEE C57.104 or ASTM D 3612.
l. Test instrument transformers in accordance with ANSI/NETA ATS.
m. Test surge arresters in accordance with ANSI/NETA ATS, if applicable.
n. Test transformer neutral grounding impedance device, if applicable.

3. Test values:
a. Alarm, control, and trip circuits from temperature and level indicators, and the pressure relief device and the fault pressure relay shall operate within the Manufacturer's recommendations for their specified settings.
b. Compare bolted connection resistance values to the values of similar connections. Investigate values that deviate from those of similar bolted connections by more than 50% of the lowest value.
c. Bolt-torque levels shall be in accordance with the Manufacturer's published data. In the absence of the Manufacturer's published data, use ANSI/NETA ATS.
d. Results of the thermographic survey shall be in accordance with ANSI/NETA ATS.
e. Liquid levels in the transformer tanks and bushings shall be within indicated tolerances.
f. Positive pressure shall be indicated on the pressure gauge for gas-blanketed transformers.
g. Minimum insulation resistance values of transformer insulation shall be in accordance with the Manufacturer's published data. In the absence of the Manufacturer's published data, use ANSI/NETA ATS. Values of insulation-resistance less than the table or the Manufacturer's recommendations shall be investigated. The polarization index shall be compared to previously obtained results and shall not be less than 1.0.
h. Turns-ratio test results shall not deviate by more than 1/2% from either the adjacent coils or the calculated ratio.
i. Maximum winding insulation PF/dissipation factor values of liquid-filled transformers shall be in accordance with the Manufacturer's published data. In the absence of the Manufacturer's published data use ANSI/NETA ATS.
j. Investigate bushing PF and capacitance values that vary from nameplate values by more than 10%. Hot-collar tests are evaluated on a mA loss basis, and the results shall be compared to values of similar bushings.
k. Typical excitation-current test data pattern for a three-legged core transformer is two similar current readings and one lower current reading.
l. Temperature corrected winding-resistance values shall compare within 1% of previously obtained results.
m. Core insulation values shall be comparable to previously obtained results but not less than 1 megohm at 500 VDC.
n. Investigate the presence of oxygen in the nitrogen gas blanket.
o. Insulating liquid values shall be in accordance with ANSI/NETA ATS.
p. Evaluate results of dissolved-gas analysis in accordance with IEEE C57.104.
q. Results of electrical tests on instrument transformers shall be in accordance with ANSI/NETA ATS.
r. Results of surge arrester tests shall be in accordance with ANSI/NETA ATS.
s. Compare grounding impedance device values to the Manufacturer's published data.

P. Dry Type Transformers:
1. Visual and mechanical inspection:
a. Physical and insulator damage.
b. Proper winding connections.
c. Bolt-torque level in accordance with ANSI/NETA ATS.
d. Defective wiring.
e. Proper operation of fans, indicators, and auxiliary devices.
f. Removal of shipping brackets, fixtures, or bracing.
g. Free and properly installed resilient mounts.
h. Cleanliness and improper blockage of ventilation passages.
i. Verify the tap-changer is set at the correct ratio for rated output voltage under normal operating conditions.
j. Verify proper secondary voltage phase-to-phase and phase-to-ground after energization and prior to loading.

2. Electrical tests:
a. Insulation-resistance tests:
1) Applied megohmmeter DC voltage in accordance with ANSI/NETA ATS for each:
a) Winding-to-winding.
b) Winding-to-ground.
2) 10 minute test duration with resistances tabulated at 30 seconds, 1 minute, and 10 minutes.
3) Results temperature corrected in accordance with ANSI/NETA ATS.
4) Temperature corrected insulation-resistance values equal to, or greater than, the ohmic values established by the Manufacturer.
5) Insulation-resistance test results shall compare within 1% of adjacent windings.
b. Perform tests and adjustments for fans, controls, and alarm functions as recommended by the Manufacturer.

Q. Instrument Transformers:
1. Visual and mechanical inspection:
a. Visually check current, potential, and control transformers for:
1) Cracked insulation.
2) Broken leads or defective wiring.

3) Proper connections.
4) Adequate clearances between primary and secondary circuit wiring.

b. Verify mechanically:
1) Grounding and shorting connections have good contact.
2) Withdrawal mechanism and grounding operation, when applicable, operate properly.

c. Verify proper primary and secondary fuse sizes for PTs.

2. Electrical tests:
a. PT tests:
1) Insulation-resistance test of transformer and wiring-to-ground at 1,000 VDC for 30 seconds.
2) Polarity test.

b. PT tests:
1) Insulation-resistance test at test voltages in accordance with the Manufacturer's recommendations or ANSI/NETA ATS, for 1 minute on:
a) Winding-to-winding.
b) Winding-to-ground.
2) Polarity test to verify polarity marks or H1-X1 relationship as applicable.

c. Insulation-resistance measurement on instrument transformer shall not be less than that recommended by the Manufacturer or shown in ANSI/NETA ATS.

R. Demonstration of Protective Devices:
1. General:
a. Demonstrate the correct operation of protective relays and protective device, shutdowns, trips, and alarms to the electric utility and the ENGINEER.
b. Only qualified electricians and technicians shall perform the demonstrations.
c. The demonstration shall be divided into the following:
1) Calibration.
2) Trip checks.
3) Online tests.

2. Calibration:
a. Proper testing and verification of CTs, PTs, and the settings of the relays shall be demonstrated to the electric utility and the ENGINEER.
b. Testing and calibration of CTs, PTs, and relays shall be performed with test equipment calibrated to the Manufacturer's specifications. Provide certified documentation of test equipment calibration.
c. CT verification:
1) Perform checks in accordance with IEEE C57.13.1.
2) Ratio check.
3) Polarity check.
4) Excitation (saturation) test reports from the Manufacturer.
5) Insulation-resistance (megger) test.

d. PT verification:
1) Perform checks in accordance with IEEE C57.13.1.
2) Ratio check.
3) Polarity check.

e. Relays:
1) Test in accordance with the Manufacturer's, the electric utility's, and the ENGINEER's acceptance.
2) Tests on nominal recommended settings for:
a) Pickup parameters on each operating element.
b) Timing at three points on time-current curve.
c) Pickup target and seal-in units.
d) Special tests as required to check the operation of restraint, directional, and other elements in accordance with the Manufacturer's instruction manual.
3) Phase angle and magnitude contribution tests on differential and directional relays after energization to vectorially verify proper polarity and connections.
4) Current injection tests:
a) For entire current circuit in each section.
b) Secondary injection for current flow of 1 A.
c) Test current at each device.

3. Trip checks:
a. Relays shall be functionally operated to demonstrate proper motor controller and breaker operation.
b. Verify that motor controllers and breakers cannot be manually or automatically closed with the trip relay in the latched or the tripped position.
c. Demonstrate that interlocks between motor controllers and breakers operate properly.

4. Online tests: Test relays online.

5. Miscellaneous control circuits:
a. Control circuits shall be tested for point-to-point continuity.
b. Terminations shall be inspected for proper connections and labels.
c. Proper tests shall be performed to ensure that no unintentional grounds or shorts exist in the circuitry.

d. Verify the proper operation of auxiliary relays.
e. Time-delay relays shall be checked for correct time settings and time delay response in accordance with data furnished by the OWNER.

END OF SECTION

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SECTION 26 09 00
CONTROL AND PROTECTION EQUIPMENT

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for control and protection equipment.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
7. SECTION 48 70 00 – GENERATION STARTUP AND COMMISSIONING

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):

1. C37.90.1 – Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
2. C37.90.2 – Standard for Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers

B. National Electrical Manufacturers Association (NEMA):

1. ICS 2.3 – Instructions for the Handling, Installation, Operation and Maintenance of Motor Control Centers Rated Not More than 600 V

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
4. Dimensional drawings.
5. Calculations including: Load study, CT and PT burden calculations and neutral grounding system calculations.
6. Protective devices:
   a. Copies of time-current characteristics.
   b. Protective device trip settings.
7. Anchoring instructions and details.
8. One-line diagrams.
9. Outline diagrams.
10. Schematic/interconnect diagrams with wiring number identification and wiring list.
11. Internal layout drawing.
12. Power requirements and heat dissipation: Maximum heat dissipations Btu/hr.
13. Conduit entry/exit locations.
14. SPs, wiring diagrams, etc.
15. Installation details: Include modifications or further details required.
16. Spares, expendables, and test equipment.

D. Quality Control Submittals:

1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
   e. Factory and field certified test reports.
   f. Software documentation: Updated version of software.
      1) Hardcopy and electronic version of installed programs in controllers and equipment.
   g. Calibration, startup, and commissioning reports.
      1) Include complete lists of equipment furnished, including the Manufacturer's model numbers, correct settings, alarm points, and operating ranges.
   h. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
   i. Final As-Built Drawings:
      1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         a) Drawings shall be on a standard DW provided title block and border.

b) As-Builts and Manufacturer's drawings shall be provided:
(1) On a standard DW provided title block and border.
(2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
(3) Text: Minimum 0.1 inches, maximum 0.2 inches.
(4) Titles: 0.2 inches.

j. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
1. Fuses: A minimum of three of each type and each current rating installed.
2. Lamps and LEDs for indicating lights: Two of each type.

1.4 QUALITY ASSURANCE

A. Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services:
1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
a. Installation assistance and inspection of installation: 1.
b. Functional and performance testing: 1.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the generator control and protection equipment system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. GPS:
1. Basler Model BE1-11G

B. OPS:
1. Basler BE1-11F

C. Transformer Differential Relay (87T):
1. Basler Model BE1-11T

D. Generator differential relay (87G):
1. Basler Model BE1-11G

E. Sync-Check Relay (25SC):
1. Basler Model BE1-25

F. Automatic Synchronizer (25A):
1. Basler Model BE1-25A

G. Line Voltage Over/Under Relay (27/59):
1. Basler Model BE1-700

H. Low Power Relay (37):
1. Basler Model BE3-32

I. Control Switches and Lockout Relays:
1. Electroswitch Series 24

J. RTD Temperature Monitor/Relay (38/49):
1. BE1-11 RTD Module with twelve RTD inputs, four analog inputs, and four analog outputs
2. Honeywell TVMIGR-88-4-62-4-050-002ET-000

K. Switchboard Power Meters (KW#):
1. General Electric Multilin EPM 6000 model PL6000-6-5A-THD-E

L. Test Blocks and Plugs (STB# & TBK#):
1. General Electric, Model PK-2 6422120G and PK-2 6129533G

2.2 COMPONENTS

A. GPS
1. General requirements: The relay shall provide protective, metering, and control functionality, with setup, control, and monitoring programmable logic, front panel HMI and remote RS232, RS485, and Ethernet communications.
2. Specific requirements:
a. The relay shall have the following functions and features:
1) Overcurrent: The relay shall have directional inverse time overcurrent elements monitoring current on all three phases, two neutral current calculated by the relay from phase current summation, and the calculated negative sequence current. The user shall have the option of phase element being voltage controlled, voltage restrained, or neither (e.g., normal voltage independent overcurrent relays). Functions: 51P-VC/VR, 51N[G], 151N[G], 46.

2) The relay shall have instantaneous time overcurrent elements with a user-settable time delay monitoring all three phases, the neutral calculated by the relay from phase current summation, and the calculated negative sequence current. Functions: 50P, 50N[G].
3) The relay shall have a wide selection of definite time, moderately inverse, inverse, very inverse, and extremely inverse curves for coordination with common IEC, WH-CO, and GE-IAC curves. The relay shall have user-programmable curve shape capabilities. The reset rate shall be user-selectable to either integrating reset to mimic the slow return to zero of induction disks, or instantaneous reset.
4) The relay shall have setting ranges as required.
5) The relay shall detect breaker failure by monitoring current flow after a breaker failure initiate has been issued. Breaker failure initiate may be either internally generated or externally generated via the programmable inputs. Delay range: 100 ms to 500 ms. Function: BF.
6) The relay shall be suitable for monitoring either three-wire or four-wire VT configurations. The relay shall monitor phase over voltage, phase under voltage, and shall calculate and monitor negative sequence (V2) voltage. If the relay is monitoring a four-wire system, it shall also calculate and monitor zero sequence (3VO) voltage. The user may set phase over voltage element to trip only for one, two, or three phases out of range. Each element shall have user-settable fixed time delay tripping. Phase element shall monitor either phase-phase or phase-ground. Maximum phase setting shall be 300 VPP. Function: 27P, 59P, 59N-3VO, 47.
7) There shall be a Vx input capable of monitoring the generator neutral point voltage. The relay shall monitor for fundamental frequency over voltage and third harmonic under-voltage. Each element shall have user-settable fixed time delay tripping. Function: 59X-Fund, 27-3rd.
8) The relay shall have a minimum of six independent frequency SPs with independent time delays. Each SP shall be settable to operate as an over or under frequency element. Function: 81, 181, 281, 381, 481, 581.
9) The relay shall have two independent SPs for over power monitoring, each settable as forward or reverse looking. Each and shall have user-settable fixed time delay tripping. Function: 32.
10) The relay shall have two independent SPs for loss of excitation monitoring that shall trip on excessive VAR flow into the generator, indicating the generator is acting as an inductor as seen by the system. Each shall have user-settable fixed time delay tripping. Function: 40Q.
11) The relay shall have four auxiliary timers usable to delay any element or for other functions. Function: 62.
12) A standard IRIG input, format B002 from IRIG 200, shall be provided for receiving time synch signals from a master clock.
13) The relay shall monitor line currents and voltages and provide the following information:
    a) Present values: Phase, neutral and negative sequence currents, volts; forward and reverse watts, VARs, watt-hours, VAR-hours.
    b) Demand values: Phase, neutral, and negative sequence current, three-phase watts and VARs; peak today, peak yesterday, and peak since last demand reset.
14) Relay shall have a flexible user-definable programmable logic. Logic shall be able to inter-tie relay control inputs, output contacts, HMI and SCADA addressable switches, protective element logical I/O, reclosing element I/O, timer element I/O, settings group control, and relay internal alarms.
15) The relay shall have two independent setting groups selectable by user logic. The logic may utilize relay hardwire inputs, HMI or remote communications commands, or relay internal logic. It shall be possible to change relay settings groups on the fly with no momentary removal of the relay from service.
16) The relay shall be capable of monitoring breaker systems including the trip circuit, breaker trip time, breaker duty statistics, as well as power system conditions including overloads and unbalances and alarming for such conditions. User-defined logic points shall be programmable as major or minor alarms.
17) The relay shall provide a detailed sequence of events showing internal logic change of state for an event. The relay shall provide multiple oscillographic reports for currents showing pre-fault, faulted, and post-fault currents.
18) Communication shall be via front and rear RS232/485 communication ports or via a front panel HMI LCD/keypad. There shall be a multiple level password access system.
19) The relay shall have one front Ethernet communication port and at least two rear independent communications port, Ethernet and RS485, usable for relay set up or remote metering, status interrogation, and control. The relay shall have a complete command language which can be integrated into a SCADA system. Communication formats supported shall include Modbus.
20) The relay shall have a HMI that allows reading of measured values and performing basic setting changes. The display shall be capable of being programmed to automatically display and scroll user-specified information.
21) The relay shall be controllable via virtual switches which shall be HMI or SCADA addressable.
22) One virtual breaker control switch, accessible locally from the optional HMI or remotely from the communications ports, can be used to provide trip and close control of a selected breaker: 101. To provide additional control, four virtual switches with three modes of operation, accessible locally from the optional HMI or remotely from the communications ports, can be used.
23) The relay shall have a minimum of seven hardwired control inputs. Each input shall be programmable to represent system status or control any user-defined function or logic point.

24) The relay shall have a minimum of five normally open output contacts plus one normally closed major/relay alarm contact. Contacts shall be programmable to follow custom user-defined logic schemes. Make and carry 30 A, 0.2 second, 7 A continuous, break 0.3 ADC at L/R=0.04.
25) A trip circuit monitor function shall be provided to monitor the trip circuit of a breaker or lockout relay for loss of voltage, fuse blown, or loss of continuity, trip coil open.
26) The relay power supply shall be 125 VDC, unless otherwise shown on the Drawings.
27) The relay shall meet the isolation, surge withstand, fast transient, impulse, and radio interference standards in accordance with IEEE C37.90.1 and IEEE C37.90.2.
28) Future firmware enhancements shall be made through flash memory.
29) The relay shall be fully draw-out from its case with automatic CT shorting and output contact opening upon draw-out.

B. OPS:
1. The relay shall provide protective, metering, and control functionality, with setup, control, and monitoring programmable logic, front panel HMI, and remote RS232, RS485, and Ethernet communications.
2. The relay shall have the following functions and features:
   a. The relay shall have directional inverse time overcurrent elements monitoring current on all three phases, two sets of neutral current calculated by the relay from phase current summation or an independent ground CT, and calculated negative sequence current. Each element may be set as forward, reverse, or non-directional. The user shall have the option of phase element being voltage controlled, voltage restrained, or neither (e.g., normal voltage independent overcurrent relays). Functions: 51P, 51N, 151N[G], 51Q. Targeting shall show 67 if element is set as forward or reverse.
   b. The relay shall have a minimum of two sets of directional instantaneous time overcurrent elements with a user-settable time delay monitoring all three phases, the neutral calculated by the relay from phase current summation, the independent ground CT, and the calculated negative sequence current. Each element may be set as forward, reverse, or non-directional. Functions: 50Ph, 50N, 50N[G], 50Q, 150Ph, 150N[G], 150Q. Targeting shall show 67 if the element is set as forward or reverse.
   c. The relay shall have a wide selection of definite time, moderately inverse, inverse, very inverse, and extremely inverse curves for coordination with common IEC, WH-CO, and GE-IAC curves. The relay shall have user-programmable curve shape capabilities. The reset rate shall be user-selectable to either integrating reset, to mimic the slow return to zero of induction disks, or instantaneous reset. The relay shall have the setting ranges as required and as approved by the ENGINEER.
   d. The relay shall detect breaker failure by monitoring current flow after a breaker failure initiate has been issued. Breaker failure initiate may be either internally generated or externally generated via the programmable inputs. Delay range: 100 ms to 500 ms. Function: BF.
   e. The relay shall be suitable for monitoring either three-wire or four-wire VT configurations. The relay shall monitor phase over voltage, phase under voltage, and shall calculate and monitor negative sequence (V2) voltage. If the relay is monitoring a four-wire system, it shall also calculate and monitor zero sequence (3VO) voltage. The user may set phase over voltage element to trip only for one, two, or three phases out of range. Each element shall have user-settable fixed time delay tripping. Phase element shall monitor either phase-phase or phase-ground. Maximum phase setting shall be 300 VPP. Function: 27P, 59P, 59N-3VO, 47.
   f. The relay shall have a minimum of six independent frequency SPs with independent time delays. Each SP shall be settable to operate as an over or under frequency element. Function: 81, 181, 281, 381, 481, 581.
   g. The relay shall have an over power function settable as forward or reverse looking and shall have user-settable fixed time delay tripping. Function: 32.
   h. The relay shall have a minimum of two auxiliary timers usable to delay any element or for other functions. Function: 62.
   i. The unit shall have a four shot reclosing element. The reclosing element shall be capable of changing logic mid-stream to block any protective element on any reclose attempt. Relay logic shall allow reclose blocking through a simple HMI procedure, via communication port commands, or via control inputs. Function: 79.
   j. The relay shall monitor line currents and voltages and provide the following information:
      1) Present values: Phase, neutral and negative sequence currents, volts; forward and reverse watts, VARs, watt-hours, VAR-hours.
      2) Demand values: Phase, neutral, and negative sequence current, three-phase watts and VARs; peak today, peak yesterday, and peak since last demand reset.
   k. Relay shall have a flexible user-definable programmable logic. Logic shall be able to inter-tie relay control inputs, output contacts, HMI and SCADA addressable switches, protective element logical I/O, reclosing element I/O, timer element I/O, settings group control, and relay internal alarms.
   l. The relay shall have four independent setting groups selectable by user logic. The logic may utilize relay hardwire inputs, HMI or remote communications commands, relay internal logic, reclose status, or an automatic dynamic selection based on recent load levels. It shall be possible to change relay settings groups on the fly with no momentary removal of the relay from service and allow change of setting groups during a reclose operation.
   m. The relay shall have thorough self-testing and alarming. The relay shall be capable of monitoring breaker systems including the trip circuit, breaker trip time, breaker duty statistics, as well as power system conditions including overloads and unbalances and alarming for such conditions. User-defined logic points shall be programmable as major or minor alarms.

n. A standard IRIG input, format B002 from IRIG 200, shall be provided for receiving time synch signals from a master clock.
o. The relay shall provide a detailed sequence of events showing internal logic change of state for an event. The relay shall provide multiple oscillographic reports for currents showing pre-fault, faulted, and post-fault currents.
p. Communication shall be via front and rear RS232/485 communication ports or via a front panel HMI LCD/keypad. There shall be a multiple level password access system.
q. The relay shall have one front Ethernet communication port and at least two rear independent communications ports, Ethernet, RS232 or RS485, usable for relay set up or remote metering, status interrogation, and control. The relay shall have a complete command language which can be integrated into a SCADA system. Communication formats supported shall include ASCII, DNP3.0, or Modbus.
r. The relay shall have a HMI that allows reading of measured values and performing basic setting changes. The display shall be capable of being programmed to automatically display and scroll user-specified information.
s. The relay shall be controllable via virtual switches which will HMI or SCADA addressable. The switches may be usable for on/off/pulse of any user-selected function or logic point (e.g., instantaneous element block or reclose enable).
t. One virtual breaker control switch, accessible locally from the optional HMI or remotely from the communications ports, can be used to provide trip and close control of a selected breaker: 101. To provide additional control, four virtual switches with three modes of operation, accessible locally from the optional HMI or remotely from the communications ports, can be used (e.g., to trip and close additional switches or breakers, or to enable and disable certain functions).
u. The relay shall have a minimum of seven hardwired control inputs. Each input shall be programmable to represent system status, e.g., breaker position, or control any user-defined function or logic point.
v. The relay shall have a minimum of five normally open output contacts plus one normally closed major/relay alarm contact. Contacts shall be programmable to follow custom user-defined logic schemes. Make and carry 30 A, 0.2 second, 7 A continuous, break 0.3 ADC at L/R=0.04.
w. A trip circuit monitor function shall be provided to monitor the trip circuit of a breaker or lockout relay for loss of voltage, fuse blown, or loss of continuity, trip coil open.
x. The relay power supply shall be 125 VDC, unless otherwise shown on the Drawings.
y. The relay shall meet the isolation, surge withstand, fast transient, impulse, and radio interference standards in accordance with IEEE C37.90.1 and IEEE C37.90.2.
z. Future firmware enhancements shall be made through flash memory.
aa. The relay shall be fully draw-out from its case with automatic CT shorting and output contact opening upon draw-out.

C. Transformer Differential Relay (87T):

1. The transformer differential relay shall provide primary protection for the main power transformer against internal faults. The solid-state relay shall compare three-phase current entering and leaving the transformer.
2. The relay system shall provide protective, metering, and control functionality, with setup, control, and monitoring via a front panel HMI and remote RS232, RS485, and Ethernet communications. The relay shall have flexible user-programmable logic and programmable I/O.
3. Restrained and unrestrained phase differential (87R, 87U) protection shall be provided. The relay shall include as a minimum a ten to one tap range between inputs. The 87R function shall have user-settable second and fifth harmonic restraint with settable differential slope and settable minimum operate current. The relay shall be able to perform a ground differential (87ND) between the wye winding and the transformer ground bushing. Each current circuit shall have overcurrent protection functionality which shall include three-phase, ground, and negative sequence time overcurrent (51P, 51N/G, 51Q) and instantaneous overcurrent (50P, 50N/G, 50Q).
4. Other protective functions shall be auxiliary timers (62), multiple settings groups; alarms for self-test, breaker wear, and user-programmable logic conditions; oscillography and sequence of events reporting; and status and control from the front panel HMI or remote communication RS232/485 ports, using Modbus communication protocol.
5. Metering shall include present amperes, a four thousand point data array of historical metering information, and demand amperes.

D. Generator Differential Relay (87G):

1. The generator differential relay shall provide primary protection for the generator against internal faults. The solid-state relay shall compare three-phase current entering and leaving the generator.
2. The relay system shall provide protective, metering, and control functionality, with setup, control, and monitoring via a front panel HMI and remote RS232, RS485, and Ethernet communications. The relay shall have flexible user-programmable logic and programmable I/O.
3. The protection system shall also include current differential protection. Restrained and unrestrained phase differential (87R, 87U) protection shall be provided. The relay shall include as a minimum a ten to one tap range between inputs. The 87R function shall have user-settable second and fifth harmonic restraint with settable differential slope and settable minimum operate current.
4. The relay shall be able to perform a ground differential (87ND) between the wye winding and the generator high voltage phase bushings. Each current in the differential relay shall have overcurrent protection functionality which shall include three-phase, ground, and negative sequence time overcurrent (51P, 51N/G, 51Q) and instantaneous overcurrent (50P, 50N/G, 50Q).

E. Sync-Check Relay (25SC): The synchronism check relay shall compare the frequency, voltage magnitude, and phase angle difference between the phase voltage input and an auxiliary Vx input and allow a close if all three parameters are within a user-specified range. The function shall also have a voltage monitor feature that will allow for closing with a dead phase or dead Vx input.

F. Automatic Synchronizer (25A):
   1. The automatic synchronizer initiates closure of the generator circuit breaker when voltage magnitude, slip frequency, and phase difference are within preset limits. The automatic synchronizer operation shall minimize system transients that can result from differences in speed, voltage level, or phase angle at the instant of the breaker closure.
   2. The automatic synchronizer shall include frequency matching including bump pulse circuitry interfaced to the governor digital controller to reduce the time required to move the phase angle when the generator frequency is matched to the bus but the phase difference is greater than permitted for synchronization. The automatic synchronizer shall cause the governor to change speed slightly to decrease the phase difference.
   3. The automatic synchronizer shall include a dead bus enable contact input to immediately energize the breaker closure output relay.

G. Line Voltage Over/Under Relay (27/59):
   1. The line voltage over/under relay shall be suitable for monitoring either three-wire or four-wire VT configurations. The relay shall monitor phase over voltage, phase under voltage, and shall calculate and monitor negative sequence (V_2) voltage.
   2. The relay system shall provide protective, metering, and control functionality, with setup, control, and monitoring via a front panel HMI and remote RS232 and RS485 communications. The relay shall have flexible user-programmable logic and programmable I/O.
   3. The relay shall be coordinated and selected to provide complete over/under voltage protection. The 27/59 relay shall have the following features:
      a. Pickup setting continuously adjustable over a wide range.
      b. Instantaneous function to provide immediate response to extreme voltage conditions.
      c. Individually adjustable definite, short inverse, medium inverse, or long inverse timing for each time-delayed under/over voltage function.
      d. High speed operation with low sensing and supply burdens.
      e. Operating power: 125 VDC, unless otherwise shown on the Drawings.

H. Low Power Relay (37):
   1. Provides low power shutdown for trips not requiring immediate shutdown. The relay shall be adjustable from 1% to 20% of the full load power of the generator. The relay shall be provided with three-phase sensing and an adjustable time delay to avoid tripping due to transients. The repeatability of the relay shall be 0.5%.
   2. The relay shall be provided with two independently adjustable output contacts. Each output contact shall be independently adjustable for different low power SPs. Multiple one independently adjustable output contact relays may be provided.

I. Control Switches and Lockout Relays:
   1. Control switches shall include, but not be limited to: 86T, 86G, VS, AS, 52T-cs, 42G-cs, 52A-CS SES-AM, SES-RSL, 65C-RSL, as specified in this Section.
   2. Control, selector, and transfer switches shall be of the multiple stage, rotary, heavy duty switchboard type. Type and number of contacts, position names, and action shall be as shown on the Drawings.
   3. The 86T and 86G lockout relays shall be high speed, maximum 8 ms, electric trip, manual reset, oval handle, with a minimum of sixteen contacts rated 3 A at 125 VDC.
   4. The voltmeter and ammeter selector switches shall be four position maintained switches with a knurled handle.
   5. The 52T-CS, 42G-CS, and 52A-CS shall be provided with pistol grip handles, spring return type with indicating targets, red – close, green – trip.
   6. SES-AM shall be maintained two position selector switch with pistol grip handle and a minimum of four spare contacts. SES-RSL and 65C-RSL shall be spring return type with pistol grip handles. Contacts shall be rated a minimum of 3 A at 125 VDC.

J. RTD Temperature Monitor/Relay (38/49):
   1. The RTD temperature monitor/relay shall be a paperless recorder, 1/2 DIN size data acquisition and operator interface device. Data shall be displayed with exceptional clarity on a 3 inch by 4 inch color active matrix LCD display with bargraph, trend, digital indicator, and alarm status capabilities. Information shall be viewed in real time and as historical data. Data can be stored as an average, peak, valley, or instantaneous value and reviewed in a compressed mode, with cursor function or utilize search conditions.
   2. The RTD temperature monitor/relay shall display time, date, and percent data storage used with configurable data screens. Inputs are configurable via touchscreen programming. Input ranges, scales, engineering units, alarm SPs, tag numbers, and storage rates are configurable on a per point basis.
   3. The RTD temperature monitor/relay shall use a convenient reusable 3 1/2-inch disk to store data and unit configuration information. The files can be transferred to PC via RS485 interconnection or transported directly on the disk. Files can be exported to spreadsheets, database or analytical software, as well as for permanent storage and hardcopy printouts.
   4. The RTD temperature monitor/relay shall be provided to accept twelve inputs. Universal isolated signal conditioner modules shall allow mixing or matching of mV, V, current, T/C, and RTD input types. A 16-bit analog to digital converter provides high resolution for accurate scaling up to 10 VDC spans. Data point records are

stored in an internal buffer by the multi-tasking 32-bit microprocessor for display functions, alarm detection, use in calculations, or archiving.

5. Computational capabilities shall include 32-bit floating point math. Standard math functions include square root, hi peak, lo peak, moving average, time average and totalize. Enhanced math functions such as square root, exponential powers, natural and base ten logarithms along with Boolean logic are also available. The functions can be utilized with up to fifteen programmable constants in a forty operand expression. The result can be displayed, trended, alarmed, and archived like any direct input data.
6. The color touchscreen display enables the user to configure the unit without external handheld devices or limited selection buttons. Point type, input and output scaling, engineering units, alarm SPs, sample rate, display formats, serial communications, and other configurable parameters are programmed with easy-to-use pull down menu selections or full screen alphanumeric keypads.
7. Alarm output relays, six, with form C contacts shall be provided. Points can be programmed with up to five alarm settings: Hi-hi, hi, lo, lo-lo, rate of change and each setting can be programmed to activate a relay.
8. Control inputs are contact or 5 VDC to 12 VDC inputs that can be configured for functions as event inputs, start/stop recording, record at high or low sample rate, reset alarms, or calculated points.
9. Archived data is stored on a 3 1/2-inch disk or PC card. The sample rate and memory card capacity determine how much data can be stored.
10. The RTD temperature monitor/relay shall be provided with a companion software that package works directly with the recorder via the bi-directional Ethernet and RS232C or RS485 interface so that viewing recorded data on the monitor, manipulating and storing data on the PC hard drive in various formats, searching data, and configuring the recorder shall be possible.
11. The RTD temperature monitor/relay software shall run in a Microsoft Windows environment. The user can read and write files directly from or to the memory cards, load and save configuration files, test cards, and erase files or the entire card either through the serial port or directly from the RTD temperature monitor/relay. In addition, data from the card/disk can be saved to the hard drive, either on a per file basis or as an entire card/disk image. Existing hard drive files may be read into the program for analysis or comparison with files from memory card. Data can also be exported in CSV (comma and delimited) or ASCII format which can be read by third-party spreadsheet and databases. In addition, compressing and zooming data, setting search point, and finding predefined conditions shall also be possible.

K. Switchboard Power Meters (KW#):
1. The switchboard power meters shall be provided and installed in accordance with the Contract Documents.
2. Power meters features:
   a. Revenue accurate to utility metering standards.
   b. Measures watts, watt-hours, and watt demand.
   c. Two relay outputs and one kyz pulse output.
   d. Two channel, 4 mA to 20 mA AO.
   e. kW label.

L. Miscellaneous:
1. Test blocks and plugs (STB# & TBK#): Provide and install in accordance with the Contract Documents. Provide with the following features:
   a. Molded textolite covers with internal plug contacts.
   b. Test plug with each block.
   c. For CTs circuits, auxiliary contacts shall automatically short-circuit the test block, not break current circuit, when the cover, or plug, is removed.
   d. The test blocks and plugs shall include auxiliary contacts, jumpers, screws, bushings, and connectors.
   e. Contact rating shall be 10 A continuous at 250 VAC.
2. CT and PT: As specified in SECTION 26 05 10.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install equipment in accordance with NEMA ICS 2.3, Submittal Drawings, and the Manufacturer's instructions and recommendations.
B. Control and protection equipment shall be installed and secured with anchor bolts of sufficient size and number adequate for specified seismic conditions.
C. Install equipment plumb and in longitudinal alignment with pad or wall.
D. Coordinate terminal connections with installation of feeders.
E. Grout mounting channels into floor or mounting pads.
F. Retighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.
G. Field adjust trip settings of protective devices and SPs as specified in SECTION 26 05 70, SECTION 26 08 00, and SECTION 48 70 00.

3.2 QUALITY CONTROL

A. Verify wiring, layout, installation, and identification.
B. Inspect racking, support, and grounding connection.
C. Verify proper system operation: PT voltages and CT currents, connection torque and resistance values, trips, alarms, and other system settings.
D. Provide installation certification.

E. As specified in SECTION 48 70 00.

END OF SECTION

SECTION 26 12 13
PAD-MOUNTED TRANSFORMERS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for pad-mounted transformers.

B. Related Sections:
1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):
1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

B. ASTM International (ASTM):
1. D 4059 – Standard Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography

C. Institute of Electrical and Electronics Engineers (IEEE):
1. C57.12.00 – Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
2. C57.12.10 – Standard Requirements for Liquid-Immersed Power Transformers
3. C57.12.28 – Standard for Pad-Mounted Equipment – Enclosure Integrity
4. C57.12.90 – Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

D. National Fire Protection Association (NFPA):
1. 70 – National Electrical Code (NEC)

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings shall include:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Equipment sectional and plan views, plan showing conduit openings, anchor bolt pattern, bushing arrangement, terminal arrangement, dimensions, weight, construction details, lifting means, etc.
4. Transformer diagrammatic nameplate data.
5. Submit the following data:
   a. Core losses.
   b. Winding losses.
   c. Exciting current at 100% and 110% rated voltage.
   d. Percent impedance.
   e. Efficiencies shall be provided at loading levels of 100%, 75%, 50%, and 25%.
   f. Percent regulation shall be provided at 0.8 PF to 1.0 PF.
6. Schematic and connection diagrams.
7. Infrared inspection windows to provide monitoring coverage of connections in the high voltage and low voltage compartments without opening the compartment doors. The size, quantity, and location of the windows shall be indicated on the Shop Drawings and data sheets.
8. Certified factory test reports.
9. Field test reports.
10. Installation manuals.
11. Winding and core arrangement, materials, ratings, and insulation details.
12. The Equipment Manufacturer shall submit a certified letter stating that the materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the Project and site environmental conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating, for ENGINEER approval.
13. Calculations shall verify transformer oil containment volume with a minimum freeboard curb height of 4 inches.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
   e. Factory and field certified test reports.
   f. Software documentation: Updated version of software.
      1) Hardcopy and electronic version of installed programs in controllers and equipment.

g. Calibration, startup, and commissioning reports.
   1) Include complete lists of equipment furnished, including the Manufacturer's model numbers, correct settings, alarm points, and operating ranges.
h. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
i. Final As-Built Drawings:
   1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
      a) Drawings shall be on a standard DW provided title block and border.
      b) As-Builts and Manufacturer's drawings shall be provided:
         (1) On a standard DW provided title block and border.
         (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
         (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
         (4) Titles: 0.2 inches.
j. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver the following extra materials prior to 75% of the Substantial Completion date:
   1. Fuses and fuse links: A minimum of three of each type and each current rating installed.

1.4 QUALITY ASSURANCE
A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.
C. Manufacturer's Services:
   1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
      a. Installation assistance, and inspection of installation: 1.
      b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.5 SITE CONDITIONS
A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY
A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the pad-mounted transformer system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
A. ABB – ASEA Brown Boveri
B. Eaton/Cooper Power Systems
C. General Electric
D. Tank and Terminal Compartment Fluid:
   1. Envirotemp FR3
E. Infrared Inspection Windows:
   1. IRISS model VPFR-75 or approved equal.

2.2 COMPONENTS
A. Transformers, Three-Phase:
   1. Rating:

kVA	High-Voltage (HV) Phase/Line (V)	HV minimum BIL (kV)	Low-Voltage (LV) Line (V)	LV minimum BIL (kV)
3,000	13,200D	150	4,160Y/2,400	75

   2. Tap changer:
      a. Furnish with full capacity high-voltage taps.
      b. The tap changer shall be clearly labeled to reflect that the transformer shall be de-energized before operating the tap changer in accordance with IEEE C57.12.10, Section 5.1.1.
      c. The taps shall be provided on the higher voltage of dual voltage primary units.
      d. The tap changer switch shall be an externally-operated, snap-action switch with a lever handle.
      e. The lever handles shall have padlocking provisions.
      f. The unit shall have the following tap configuration: Two, 2.5% taps above and below rated voltage.
   3. The average winding temperature rise above ambient temperature, when tested at the base transformer rating, shall not exceed 131°F; when tested at 112% of the base rating, it shall not exceed 149°F.
   4. The transformer impedance shall be in the 2.5% to 6.0% range.
   5. High-voltage bushings and terminals:
      a. The transformer shall be provided and arranged for radial feed, dead front bushings.

b. One-piece integrated bushings for use with elbow terminators and parking stands for disengaged elbows shall be provided. Bushings shall be externally clamped to allow external replacement.
c. The Transformer Manufacturer shall provide 600 A non-load-break elbow terminators for each bushing.

6. Low-voltage bushings and terminals:
   a. The low-voltage line and neutral bushings shall be one-piece epoxy or fiberglass polyester material with tinned copper eight-hole terminal spades.
   b. The low-voltage bushings shall be bolted on and externally clamped.
7. Tank and terminal compartment:
   a. The core and coil shall be vacuum processed to ensure maximum penetration of insulating fluid into the coil insulation system. While under vacuum, the windings shall be energized to heat the coils and drive out moisture, and the transformer shall be filled with pre-heated filtered degassed insulating fluid.
   b. The core shall be manufactured from burr-free, grain-oriented silicon steel and shall be precisely stacked to eliminate gaps in the corner joints.
   c. The coil shall be insulated with B-stage, epoxy-coated, diamond pattern, insulating paper, which shall be thermally cured under pressure to ensure proper bonding of conductor and paper.
   d. Copper windings shall be provided.
   e. The dielectric coolant shall be listed less-flammable fluid meeting the requirements of NFPA 70, Section 450-23, including a minimum fire point of 572°F.
   f. The fluid shall be biodegradable, non-toxic, and non-bioaccumulating.
   g. It shall be FMG approved and UL classified.
   h. Transformer oil shall be bulk tested for PCBs in accordance with ASTM D 4059 and certified, upon request, as having no detectable level of PCB.
   i. In addition to the regular locking provision, access doors or hood shall be secured by a recessed, captive, hexhead bolt in accordance with IEEE C57.12.28.
   j. The tank shall be welded using precision cut, cold-rolled steel plate and equipped with extra-heavy duty, welded-in-place lifting lugs and jacking pads.
   k. The tank base shall be designed to allow skidding or rolling in any direction.
   l. The transformer shall be of sealed tank construction of sufficient strength to withstand a pressure of 7 psig without permanent distortion, and 15 psig without rupturing or affecting cabinet security.
   m. The tank shall include a pressure relief valve with a flow at 15 psig of 35 scfm, minimum.
   n. The tank shall be cleaned with an alkaline cleaning agent to remove grease and oil.
   o. An iron phosphate coating shall then be chemically bonded to the metal to ensure coating adhesion and retard corrosion.
   p. The tank shall be primed with an electrodeposited powder epoxy to provide a barrier against moisture, salt, and corrosives.
   q. The tank shall then be coated with an electrostatically-applied, oven-cured polyester powder coat to enhance abrasion and impact resistance.
   r. The top-coat shall be a liquid polyurethane coating to seal and add UV protection.
   s. The tank coating shall be in accordance with IEEE C57.12.28 including:
      1) Salt spray test.
      2) Crosshatch adhesion test.
      3) Humidity test.
      4) Impact test.
      5) Oil resistance test.
      6) UV accelerated weathering test.
      7) Abrasion resistance – taber abraser.
   t. The pad-mounted equipment shall be in accordance with IEEE C57.12.28 including but not limited to the pry test, pull test, and wire probe test.
   u. The tank shall be complete with an anodized aluminum laser engraved nameplate. Nameplate B shall be in accordance with IEEE C57.12.00.
8. Grounding transformer:
   a. Power transformers shall each be interfaced with a high resistance grounding system. The resistance grounding transformer and secondary connected resistor shall be designed to reduce magnitude of line to ground short-circuit conditions.
   b. The grounding transformer shall be separately mounted, dry type, air-cooled single-phase transformer with class B insulation. It shall be rated for the charging current of the system on which it is applied and have the same on-time rating as the resistor of the same system. The transformer shall be rated for 2,400 V primary, single-phase operation with a 240 V secondary; system shall be rated for a minimum 20 kVA, continuous duty, capable of limiting ground current between 2 A and 10 A, depending on capacitive charging current at the Project site.
9. Accessories:
   a. The following accessories shall be provided:
      1) Natural seed oil ester Envirotemp FR3 fluid.
      2) Bay-O-Net expulsion fuses and current limiting fuses. Bay-O-Net fuses shall be coordinated with Electrical Systems Analysis
      3) Infrared inspection windows to monitor connections in the high voltage and low voltage compartments without opening the compartment doors, infrared window shall be provided.

4) Lifting lugs: Four.
5) Bolted cover with nut guard.
6) Steel divider between high-voltage and low-voltage compartments.
7) 1-inch upper fill plug.
8) 1-inch drain/sampling valve in LV compartment.
9) Automatic pressure relief valve.
10) Cabinet hinges and mounting studs.
11) HV warning signs.
12) Ground connectors.
13) Touch-up paint.
14) Hexhead captive bolt.
15) Low-voltage eight-hole spade.
16) Copper windings.
17) Globe type upper fill valve.
18) FMG approved transformer.
19) Liquid level gauge.
20) Dial type thermometer.
21) Pressure/vacuum gauge.
22) SST ground pads: Three.
23) Bleeder valve.
24) Winding temperature indicator and auxiliary contacts.
25) Auxiliary contacts for liquid level gauge.
26) Auxiliary contacts for dial type thermometer.
27) Auxiliary contacts for pressure/vacuum gauge.
28) Auxiliary contacts for pressure relief device.

10. Testing and tolerances:
    a. Units shall be tested for the following:
        1) No-load, 85°C, losses at rated current.
        2) Total, 85°C, losses at rated current.
        3) Percent Impedance, 85°C, at rated current.
        4) Excitation current, 100% voltage, test.
        5) Winding resistance measurement tests.
        6) Ratio tests using tap settings.
        7) Polarity and phase relation tests.
        8) Induced potential tests.
        9) Full wave and reduced wave impulse test.
    b. In addition, the Manufacturer shall provide certification upon request for design and other tests listed in IEEE C57.12.00, Table 17, including verification the design has passed short-circuit criteria in accordance with IEEE C57.12.00 and IEEE C57.12.90.
    c. The Manufacturer shall provide the guaranteed average no-load and load losses for the unit at 85°C. The losses shall be subject to the tolerance specified in IEEE C57.12.00, Table 19.
    d. Basic electrical materials and methods as specified in SECTION 26 05 10.

PART 3 EXECUTION

3.1 GENERAL

A. The equipment shall be leveled and anchored directly to a concrete equipment pad as shown on the Drawings. Provide hardware and metal shims for installation. Anchor bolts shall be 1/2 inch galvanized steel.
B. Install the equipment in accordance with the Manufacturer's instructions.
C. Touch-up damaged paint finishes.
D. Ground neutrals and enclosures in accordance with applicable codes.

3.2 QUALITY CONTROL

A. Field Testing:
    1. Testing as specified in SECTION 26 08 00.
    2. Engage the services of an independent testing firm to inspect and test the installed equipment prior to energization. The testing firm shall provide material, labor, equipment, and technical supervision to perform the tests and inspection. Notify the OWNER and the ENGINEER at least 2 weeks prior to scheduling any testing.
    3. Equipment testing and inspection shall be performed in accordance with ANSI/NETA ATS and shall include:
        a. Visual and mechanical inspection.
        b. Ground resistance test.
        c. Insulation resistance tests, winding-to-winding and winding-to-ground, using a megohmeter, at nominal tap position with all cables disconnected.
        d. Perform insulation PF tests or dissipation factor tests on windings and bushings. Test voltage shall be limited to the line-to-ground voltage rating of the winding.
        e. Sample and test insulating liquid for dielectric breakdown voltage, acid neutralization number, specific gravity, interfacial tension, color, and visual condition.
        f. Perform individual excitation current tests on each phase.
    4. In the event of an equipment fault, notify the ENGINEER and the OWNER immediately. After the cause of the fault has been identified and corrected, a joint inspection of the equipment shall be conducted by the

CONTRACTOR, the ENGINEER and the OWNER, and the Equipment Manufacturer's factory service technician. Repair or replace the equipment as directed by the ENGINEER and the OWNER prior to placing the equipment back into service.

3.3 CLEANING

A. Remove rubbish and debris from inside and around the equipment. Remove dirt, dust, or concrete spatter from the interior and exterior of the equipment using brushes, a vacuum cleaner, or clean, lint-free rags. Do not use compressed air.

3.4 ADJUSTING

A. Adjust voltage taps to obtain rated output voltage under normal operating load conditions.

END OF SECTION

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SECTION 26 12 15
SECONDARY SUBSTATION TRANSFORMERS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for secondary substation transformers.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):

1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

B. ASTM International (ASTM):

1. D 4059 – Standard Test Method for Analysis of Polychlorinated Biphenyls in Insulating Liquids by Gas Chromatography

C. Institute of Electrical and Electronics Engineers (IEEE):

1. C57.12.00 – Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
2. C57.12.10 – Standard Requirements for Liquid-Immersed Power Transformers
3. C57.12.28 – Standard for Pad-Mounted Equipment – Enclosure Integrity
4. C57.12.90 – Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers

D. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Dimensioned equipment and layout drawings.
4. Conduit entrance locations.
5. Bus data.
6. One-line, three-line, and control schematic drawings.
7. Point-to-point compartment wiring diagrams for metering, relay, and control circuits.
8. Show wire and terminal numbers.
9. Product data sheets and catalog numbers for circuit breakers and trip devices.
10. List options, trip adjustments, and accessories furnished specifically for this Project.
11. Certified protective devices: Copies of time-current trip curves.
12. Certified copies of factory and production test reports.
13. Field test and inspection reports.
14. Anchoring instructions and details.
15. The Equipment Manufacturer shall submit a certified letter stating that materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site environmental conditions. The Equipment Manufacturer shall include any derating calculations and Standards applicable to the derating. The ENGINEER shall approve equipment derated values.
16. Equipment sectional and plan views, plan showing conduit openings, anchor bolt pattern, bushing arrangement, terminal arrangement, dimensions, weight, construction details, lifting means, etc.
17. Transformer diagrammatic nameplate data.
18. Submit:
    a. Core Losses.
    b. Winding losses.
    c. Exciting current at 100% and 110% rated voltage.
    d. Percent impedance.
    e. Efficiencies shall be provided and guaranteed as minimums at loading levels of 100%, 75%, 50%, and 25%.
    f. Percent regulation shall be provided at 0.8 PF to 1.0 PF.
19. Schematic and connection diagrams.
20. Infrared inspection windows to provide monitoring coverage of connections in the high voltage and low voltage compartments without opening the compartment doors. The size, quantity, and location of the windows shall be indicated on the Shop Drawings and data sheets.
21. Certified factory test reports.
22. Field test reports.
23. Installation manuals.
24. Winding and core arrangement, materials, ratings, and insulation details.

25. Calculations to verify transformer oil containment volume with a minimum freeboard curb height of 4 inches.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Legend abbreviation lists.
      d. Shop Drawing Submittal information.
      e. Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: https://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         1) Drawings shall be on a standard DW provided title block and border.
         2) As-builts and Manufacturer's drawings shall be provided:
            a) On a standard DW provided title block and border.
            b) With the drawing graphics and text assigned to a pen 2 color (yellow).
            c) Text: Minimum 0.1 inches, maximum 0.2 inches.
            d) Titles: 0.2 inches.
      f. Factory and field certified test reports.
      g. Device O&M manuals for components, electrical devices, and mechanical devices shall include:
         1) Operations procedures.
         2) Installation requirements and procedures.
         3) Maintenance requirements and procedures.
         4) Troubleshooting procedures.
         5) Internal schematic and wiring diagrams.
      h. List of spares and expendables required and recommended.
      i. Manufacturer's certificate of proper installation.
      j. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
   1. Fuses: A minimum of six of each type and each current rating installed.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services:
   1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
      a. Installation assistance, and inspection of installation: 1.
      b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the secondary substation transformers system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS:

A. Eaton/Cooper Power Systems

B. ABB/General Electric

C. Square D

D. Infrared Inspection Windows:
   1. IRISS model VPFR-75 or approved equal.

2.2 COMPONENTS

A. Transformers, Three-Phase:
   1. Rating:

kVA	High-Voltage (HV) Phase/Line (V)	HV minimum BIL (kV)	Low-Voltage (LV) Line (V)	LV minimum BIL (kV)
300	4,160D	60	480Y/277	30

2. Tap changer:
   a. Furnished with full capacity high-voltage taps.
   b. The tap changer shall be clearly labeled to reflect that the transformer shall be de-energized before operating the tap changer in accordance with IEEE C57.12.10, Section 5.1.1.
   c. The taps shall be provided on the higher voltage of dual voltage primary units.
   d. The tap changer switch shall be an externally operated, snap action switch with a lever handle.
   e. The lever handles shall have padlocking provisions.
   f. The unit shall have the following tap configuration: 2, 2 1/2% taps above and below rated voltage.
3. The average winding temperature rise above ambient temperature, when tested at the base transformer rating, shall not exceed 131°F, and when tested at 112% of the base rating, shall not exceed 149°F.
4. The transformer impedance shall be approved by the ENGINEER, 4% to 5% range is anticipated.
5. High-voltage bushings and terminals:
   a. The transformer shall be provided and arranged for radial feed, dead front bushings.
   b. One-piece integrated bushings for use with elbow terminators and parking stands for disengaged elbows shall be provided.
   c. Bushings shall be externally clamped to allow external replacement.
   d. The Transformer Manufacturer shall provide 600 A non-load-break elbow terminators for each bushing.
6. Low-voltage bushings and terminals:
   a. The low-voltage line and neutral bushings shall be one-piece epoxy or fiberglass polyester material with tinned copper eight-hole terminal spades.
   b. The low-voltage bushings shall be bolted on and externally clamped.
7. Tank and terminal compartment:
   a. The core and coil shall be vacuum processed to ensure maximum penetration of insulating fluid into the coil insulation system.
   b. While under vacuum, the windings shall be energized to heat the coils and drive out moisture, and the transformer shall be filled with preheated filtered degassed insulating fluid.
   c. The core shall be manufactured from burr-free, grain-oriented silicon steel and shall be precisely stacked to eliminate gaps in the corner joints.
   d. The coil shall be insulated with B-stage, epoxy-coated, diamond pattern, insulating paper, which shall be thermally cured under pressure to ensure proper bonding of conductor and paper.
   e. Copper windings shall be provided.
   f. The dielectric coolant shall be listed less-flammable fluid in accordance with NFPA 70, Section 450-23, including a minimum fire point of 300°C.
   g. The fluid shall be biodegradable, non-toxic, and non-bioaccumulating.
   h. It shall be FMG approved and UL classified, Envirotemp FR3 fluid.
   i. Transformer oil shall be bulk tested for PCBs in accordance with ASTM D 4059 and certified, upon request, as having no detectable level of PCB.
   j. In addition to the regular locking provision, access doors or hood shall be secured by a recessed, captive, hexhead bolt that meets the dimensions in accordance with IEEE C57.12.28.
   k. The tank shall be welded using precision cut, cold-rolled steel plate and equipped with extra-heavy duty, welded-in-place lifting lugs and jacking pads.
   l. The tank base shall be designed to allow skidding or rolling in any direction.
   m. The transformer shall be of sealed tank construction of sufficient strength to withstand a pressure of 7 psig without permanent distortion, and 15 psig without rupturing or affecting cabinet security.
   n. The tank shall include a pressure relief valve with a flow at 15 psig of 35 scfm minimum.
   o. The tank shall be cleaned with an alkaline cleaning agent to remove grease and oil.
   p. An iron phosphate coating shall then be chemically bonded to the metal to assure coating adhesion and retard corrosion.
   q. The tank shall be primed with an electrodeposited powder epoxy to provide a barrier against moisture, salt, and corrosives.
   r. The tank shall then be coated with an electrostatically-applied, oven-cured polyester powder coat to enhance abrasion and impact resistance.
   s. The top coat shall be a liquid polyurethane coating to seal and add UV protection.
   t. The tank coating shall be in accordance with IEEE C57.12.28 including:
      1) Salt spray test.
      2) Crosshatch adhesion test.
      3) Humidity test.
      4) Impact test.
      5) Oil resistance test.
      6) UV accelerated weathering test.
      7) Abrasion resistance: Taber abraser.
   u. The pad-mounted equipment shall meet the requirements for tamper resistance in accordance with IEEE C57.12.28 including, but not limited to, the pry test, pull test, and wire probe test.
   v. The tank shall be complete with an anodized aluminum laser engraved nameplate. The nameplate shall be in accordance with IEEE C57.12.00 for Nameplate B.

w. Secondary substation transformer tanks shall have side wall-mounted bushings with flanges for connection to switchgear or air terminal compartments.

8. Secondary, outgoing/load, section:
   a. Close coupled secondary switchgear.
   b. Control wires shall be marked at terminated ends.
   c. Basic electrical materials and methods as specified in SECTION 26 05 10.
   d. Control wiring shall be SIS type wire.
   e. Wiring shall have origin/destination labels that identify each end of the wire where both ends of the wire are connected. Maximum voltage at front panels and instrumentation shall be 120 V.
9. Marking and identification:
   a. Provide nameplates on each transformer and secondary disconnects.
   b. Nameplates shall be engraved as specified on the Drawing or as directed, using lettering approximately 5/8 inch high for unit identification nameplates and 1/4 inch high elsewhere.
   c. The nameplates shall be black and white laminated phenolic material.
   d. The engraving shall extend through the black exterior lamination to the white core.
   e. Nameplates shall be screw fastened.
   f. Provide permanent master nameplate for transformer name and voltages.
   g. Provide permanent nameplate for secondary disconnect name.
   h. Provide warning signs marked DANGER – 4,160 V – KEEP OUT.
   i. Signs shall be adhesive backed mylar, OSHA approved.
   j. Provide permanent nameplate for primary disconnect name and location.
10. Accessories:
    a. Provide:
       1) De-energized tap changer.
       2) Natural seed oil ester Envirotemp FR3 fluid.
       3) Bay-O-Net expulsion fuses and current limiting fuses. Bay-O-Net fuses shall be coordinated with Electrical Systems Analysis
       4) Infrared inspection windows to monitor connections in the high voltage and low voltage compartments without opening the compartment doors, infrared window shall be provided.
       5) Lifting lugs: Four.
       6) Bolted cover with nut guard.
       7) Steel divider between high-voltage and low-voltage compartments.
       8) 1-inch upper fill plug.
       9) 1-inch drain/sampling valve in low-voltage compartment.
       10) Automatic pressure relief valve.
       11) Cabinet hinges and mounting studs.
       12) High-voltage warning signs.
       13) Ground connectors.
       14) Touch-up paint.
       15) Hexhead captive bolt.
       16) Low-voltage eight-hole spade.
       17) Copper windings.
       18) Globe type upper fill valve.
       19) FMG approved transformer.
       20) Liquid level gauge.
       21) Dial type thermometer.
       22) Pressure/vacuum gauge.
       23) SST ground pads: Three.
       24) Bleeder valve.
       25) Forced air fans and forced air fan controls and power.
       26) Winding temperature indicator and auxiliary contacts.
       27) Auxiliary contacts for liquid level gauge.
       28) Auxiliary contacts for dial type thermometer.
       29) Auxiliary contacts for pressure/vacuum gauge.
       30) Auxiliary contacts for pressure relief device.
       31) Auxiliary contacts for winding temperature.
11. Testing and tolerances:
    a. Units shall be tested for:
       1) No-load, 85°C, losses at rated current.
       2) Total, 85°C, losses at rated current.
       3) Percent impedance, 85°C, at rated current.
       4) Excitation current, 100% voltage, test.
       5) Winding resistance measurement tests.
       6) Ratio tests using all tap settings.
       7) Polarity and phase relation tests.
       8) Induced potential tests.

9) Full wave and reduced wave impulse test

b. In addition, the Manufacturer shall provide certification upon request for design and other tests in accordance with IEEE C57.12.00, Table 17, including verification that the design has passed short-circuit criteria in accordance with IEEE C57.12.00 and IEEE C57.12.90.

c. The Manufacturer shall provide the guaranteed average no-load and load losses for the unit at 85°C.

d. The losses will be subject to the tolerances in accordance with IEEE C57.12.00, Table 19.

PART 3 EXECUTION

3.1 GENERAL

A. The equipment shall be leveled and anchored directly to a concrete equipment pad as shown on the Drawings.

B. Provide hardware and metal shims for installation.

C. Anchor bolts shall be 1/2 inch galvanized steel.

D. Install the equipment in accordance with the Manufacturer's instructions.

E. Touch-up damaged paint finishes.

F. Ground neutrals and enclosures in accordance with applicable codes.

3.2 QUALITY CONTROL

A. Field Testing:

1. Testing as specified in SECTION 26 08 00.
2. Engage the services of an independent testing agency to inspect and test the installed equipment prior to energization.
3. The testing agency shall provide material, labor, equipment, and technical supervision to perform the tests and inspection.
4. Notify the OWNER and the ENGINEER at least 2 weeks prior to scheduling any testing.
5. Equipment testing and inspection shall be performed in accordance with ANSI/NETA ATS and shall include:
    a. Visual and mechanical inspection.
    b. Ground resistance test.
    c. Insulation resistance tests, winding-to-winding and winding-to-ground, using a megohmeter, at nominal tap position with all cables disconnected.
    d. Perform insulation PF tests or dissipation factor tests on windings and bushings.
    e. Test voltage shall be limited to the line-to-ground voltage rating of the winding.
    f. Sample and test insulating liquid for dielectric breakdown voltage, acid neutralization number, specific gravity, interfacial tension, color, and visual condition.
    g. Perform individual excitation current tests on each phase.
6. In the event of an equipment fault, notify the ENGINEER and the OWNER immediately.
7. After the cause of the fault has been identified and corrected, a joint inspection of the equipment shall be conducted by the CONTRACTOR, the ENGINEER and the OWNER, and the Equipment Manufacturer's factory service technician.
8. Repair or replace the equipment as directed by the ENGINEER and the OWNER prior to placing the equipment back into service.

3.3 CLEANING

A. Remove rubbish and debris from inside and around the equipment.

B. Remove dirt, dust, or concrete spatter from the interior and exterior of the equipment using brushes, a vacuum cleaner, or clean, lint-free rags.

C. Do not use compressed air.

3.4 ADJUSTING

A. Adjust voltage taps to obtain rated output voltage under normal operating load conditions.

END OF SECTION

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SECTION 26 13 23
MEDIUM-VOLTAGE METAL-ENCLOSED SWITCHGEAR

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for medium-voltage metal-enclosed switchgear.

B. Related Sections:
1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
6. SECTION 26 09 00 – CONTROL AND PROTECTION EQUIPMENT

1.2 REFERENCES

A. American National Standards Institute (ANSI):
1. C37.57 – Switchgear – Metal-Enclosed Interrupter Switchgear Assemblies – Conformance Testing
2. C37.58 – Switchgear – Indoor AC Medium-Voltage Switches for Use in Metal-Enclosed Switchgear – Conformance Test Procedures

B. ASTM International (ASTM):
1. B 117 – Standard Practice for Operating Salt Spray (Fog) Apparatus
2. B 187 – Standard Specification for Copper, Bus Bar, Rod, and Shapes and General Purpose Rod, Bar, and Shapes
3. D 523 – Standard Test Method for Specular Gloss
4. D 714 – Test Method for Evaluating Degree of Blistering of Paints
5. D 1654 – Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
6. D 2794 – Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
7. D 3359 – Standard Test Methods for Measuring Adhesion by Tape Test
8. D 4060 – Standard Test Method for Abrasion Resistance of Organic Coatings by the Taber Abraser
9. D 4585 – Standard Practice for Testing Water Resistance of Coatings Using Controlled Condensation

C. Institute of Electrical and Electronics Engineers (IEEE):
1. C57.12.28 – Standard for Pad-Mounted Equipment – Enclosure Integrity

D. National Electrical Manufacturers Association (NEMA):
1. ICS 2 – AC Vacuum-Break Magnetic Controllers Rated 1,500 V AC

E. National Fire Protection Association (NFPA):
1. 70 – National Electrical Code (NEC)

F. Underwriters Laboratories, Inc. (UL):
1. 347 – Medium-Voltage AC Contactors, Controllers, and Control Centers

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Submit Shop Drawings to the ENGINEER for transmittal to serving electric utility for review and obtain approval prior to equipment fabrication.

D. Shop Drawings:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Use Contract Drawing equipment and device tags and abbreviations.
4. Bus ratings, data, and drawings.
5. Conduit entrance locations.
6. Operational description.
7. System configuration with single-line and three-line diagrams.
8. Detailed descriptions of equipment, including weights, dimensions, foundation requirements, and installation and anchoring requirements.
9. Construction details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, louvers, mounting brackets and tabs, door hinges and latches, and welding.
10. Complete dimensional drawings indicating sizes and clearances required for equipment. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
11. Cable access areas and cable routing
12. Samples of LCPs mimic bus graphic materials, colors, and adhesive. Interconnection and schematic diagrams for power and control wiring showing conduit runs and wiring with terminal numbers for each wire. Clearly identify contacts, terminal blocks, and wire numbers for remote devices. Show field devices and wiring on diagrams.
13. Detailed layouts of metering and monitoring panels. The metering sensing points shall be shown on the single-line diagram.
14. Time-current characteristic curves for overcurrent protection devices.
15. Arc-resistant testing procedures and data. Provide maximum fault current the switchgear can withstand with the rear flap closed and only the front flap working.

16. Utility metering and incoming service cubicle details and layouts. Drawings shall indicate utility equipment and clearances required by the serving utility. References in shop drawings to utility-provided drawings for actual details will not be permitted.
17. Nameplate designations.
18. Factory and site acceptance test procedures. Include a detailed description of tests to be performed.
19. Certified factory test reports..
20. The Equipment Manufacturer shall submit a certified letter stating that materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the site conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

E. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Factory and field certified test reports.
   e. Manufacturer's installation instructions.
   f. Operating instructions and startup procedures including receiving and installation requirements.
   g. Maintenance instructions listing preventive and corrective maintenance procedures. Corrective maintenance procedures shall identify the most probable failures and the appropriate repairs. Reference test measurement levels to specific test points on the installed equipment.
   h. Control schematics, ladder diagrams, and interconnection drawings.
   i. Technical manuals for components of the system.
   j. Warranties issued for the various items of equipment, showing dates of expiration.
   k. Final As-Built Drawings:
      1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         a) Drawings shall be on a standard DW provided title block and border.
         b) All As-Builts and Manufacturer's drawings shall be provided:
            (1) On a standard DW provided title block and border.
            (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
            (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
            (4) Titles: 0.2 inches.
   l. Warranty documentation.

F. Extra Materials:
1. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
   a. Fuses, 0 V to 600 V: A minimum of six of each type and each current rating installed.
   b. Fuses and fuse links, 600 V and above: A minimum of six of each type and each current rating installed.
2. Lamps and LEDs for indicating lights: two of each type.
3. Fuse units, refill units, voltage-transformer fuses, interrupting modules, and control modules shall be furnished, as required, for original installation and for spares.

1.4 QUALITY ASSURANCE

A. Medium-voltage metal-enclosed switchgear, electric utility interface bays shall meet the requirements of the electric utility and the ENGINEER. It is the CONTRACTOR's responsibility to coordinate incoming service feeders and incoming service metering with the electric utility.

B. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

C. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

D. Manufacturer's Services:
1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
   a. Installation assistance, and inspection of installation: 1.
   b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by the CONTRACTOR to facilitate the ingress of equipment to the final installation location.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the medium-voltage metal-enclosed switchgear system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Metal-Enclosed Arc-Resistant Switchgear:
1. S&C, Arc-Resistant Metal-Enclosed Switchgear
2. Fuses:
a. S&C Fault Fiter Electronic Power Fuses:
1) Interrupting Module 802600R2
2) Control Module: Determined based on Electrical System Analysis coordination study

B. Fused Load-Break Switchgear:
1. ABB/General Electric, BreakMaster Load Interrupter Switch
2. Eaton
3. Square D

2.2 COMPONENTS

A. Metal-Enclosed Arc-Resistant Switchgear General:
1. The metal-enclosed arc-resistant switchgear shall consist of one or more outdoor self-supporting bays containing interrupter switches and fuses with the necessary accessory components completely factory-assembled and operationally checked.
2. The ratings for the integrated switchgear assembly shall be:
a. Nominal: 13.8 kV.
b. Maximum: 15.5 kV.
c. BIL: 95 kV.
d. Main bus continuous: 600 A.
e. Short-circuit ratings:
1) Rms symmetrical: 25,000 A.
2) Three-phase symmetrical at rated nominal voltage: 600 MVA.
3) Duty-cycle fault-closing, rms asymmetrical: 40,000 A.
3. The momentary and duty-cycle fault-closing ratings of switches, momentary rating of bus, and interrupting ratings of fuses shall equal or exceed the short-circuit ratings of the metal-enclosed switchgear.
4. Certification of ratings:
a. The Metal-Enclosed Switchgear Manufacturer shall be completely and solely responsible for the performance of the basic switch and fuse components and the complete integrated assembly as rated.
b. The Manufacturer shall furnish certification of ratings of the basic switch and fuse components and the integrated metal-enclosed switchgear assembly consisting of the switch and fuse components in combination with the enclosure(s).
c. The integrated switchgear assembly shall have a BIL rating established by test on the switchgear of the type and kind to be furnished as specified in this Section. Certified test abstracts establishing such ratings shall be furnished.

B. Metal-Enclosed Arc-Resistant Switchgear Construction:
1. To ensure a completely coordinated design, the metal-enclosed switchgear shall be constructed in accordance with the minimum construction specifications of the Fuse and Switch Manufacturer to provide adequate electrical clearances and adequate space for fuse handling.
2. Enclosure construction:
a. The Switchgear Manufacturer shall provide enclosures proven by UL, Inc. to be in compliance with the Category A enclosure test requirements in accordance with ANSI C37.57.
b. In establishing the requirements for the enclosure design, consideration shall be given to relevant factors such as controlled access; tamper resistance; corrosion resistance; protection from ingress of rodents, insects, and weeds; and the possibility of arcing faults within the enclosure.
c. The enclosure of each bay shall be unitized monocoque construction to maximize strength, minimize weight, and inhibit corrosion.
d. The material for external sides of the enclosure and the roof shall be 11 gauge hot-rolled, pickled, and oiled steel sheet.
e. Each bay containing high-voltage components shall be a complete unit in itself, with full side sheets resulting in double-wall construction between bays. To guard against unauthorized or inadvertent entry, side and rear sheets and the top shall not be externally bolted.
f. The base shall be a continuous steel channel of a thicker gauge material than used for the enclosure and shall extend completely around all four sides of each bay.
g. Access to the interior of the enclosure shall be from the front only, allowing placement of the metal-enclosed switchgear assembly tight against a wall or back-to-back to minimize floor space requirements.
h. To guard against unauthorized or inadvertent entry, there shall be no access to high voltage through side or rear sheets of the metal-enclosed switchgear assembly; and no access to high voltage by means of externally removable panels.

i. To guard against corrosion, hardware, including door fittings, fasteners, etc., operating-mechanism parts, and other parts subject to abrasive action from mechanical motion shall be of either nonferrous materials, or galvanized or zinc-nickel plated materials.
j. Cadmium-plated ferrous parts shall not be used.
k. Externally accessible hardware shall not be used for support of high-voltage components or switch-operating mechanisms within the switchgear.

3. Door construction:
   a. Doors shall be constructed of 11 gauge hot-rolled, pickled, and oiled steel sheet.
   b. Doors shall have 90 degree flanges and shall overlap with the door openings. For strength and rigidity, and to minimize exposure, the door flanges shall be welded at the corners and shall be formed, at the top and both sides as a minimum, with a double bend so that the sheared-edge flanges at the top and both sides fold back parallel to the inside of the door. The double bend is not required on arc-resistant switchgear.
   c. Doors over 40 inches in height shall have a minimum of three concealed galvanized steel or nonferrous hinges with SST hinge pins. Doors 40 inches in height or less shall have a minimum of two such hinges.
   d. Each door shall be equipped with a door handle. The door handle shall be padlockable. On outdoor gear, each door shall incorporate a hood to protect the padlock shackle from tampering.
   e. In consideration of controlled access, tamper resistance, and arcing faults, each door over 40 inches in height shall have a minimum of three concealed, interlocking, high-strength latches. Doors 40 inches in height or less shall have a minimum of two sure latches.
   f. Doors providing access to interrupter switches or interrupter switches with power fuses shall be provided with a wide-view window, constructed of an impact-resistant material, to facilitate checking of switch position without opening the door.
   g. Doors providing access to fuses or fused voltage transformers shall have provisions to store spare fuse units, refill units, or interrupting modules.
   h. Doors providing access to high-voltage components shall be provided with a sturdy, self-latching door holder, which shall be zinc-nickel plated and chromate-dipped.
4. Access control:
   a. Doors providing access to interrupter switches with fuses shall be mechanically or key interlocked to guard against: Opening the door if the interrupter switch on the source side of the fuse is closed, and closing the interrupter switch if the door is open.
   b. Doors providing access to interrupter switches only, which are operated by stored energy type switch operators, shall be mechanically or key interlocked to guard against operating the interrupter switch if the door is open.
   c. Doors and hinged-bolted panels providing access to high-voltage components shall be provided with flush-mounted key-operated snaplocks and shall have provisions for padlocking.
5. Internal protective screens:
   a. In addition to the enclosure door, each bay or compartment thereof containing high-voltage components shall be provided with an internal protective screen, bolted closed, to guard against inadvertent entry to bays containing the components when the enclosure door is open.
   b. Each bay containing a control-power transformer capable of 5 kVA or greater output shall be provided with an internal protective screen, bolted closed, to guard against inadvertent contact with the primary fuse when the enclosure door is open. In such cases, the screen shall also be interlocked to ensure that the secondary load has been disconnected prior to removal of the fuses.
6. Insulators:
   a. The interrupter-switch and fuse-mounting insulators, main-bus support insulators, insulated operating shafts, and, if applicable, push rods shall be of a cycloaliphatic epoxy resin system with characteristics and restrictions as follows:
      1) Operating experience of at least 15 years under similar conditions.
      2) Adequate leakage distance.
      3) Adequate strength for short-circuit stress established by test.
      4) Conformance with applicable ANSI standards.
      5) Homogeneity of the cycloaliphatic epoxy resin throughout each insulator to provide maximum resistance to power arcs. Ablation due to high temperatures from power arcs shall continuously expose more material of the same composition and properties so that no change in mechanical or electrical characteristics takes place because of arc-induced ablation. Furthermore, any surface damage to insulators during installation or maintenance of switchgear shall expose material of the same composition and properties so that insulators with minor surface damage need not be replaced.
7. Bus:
   a. High-voltage main bus:
      1) Bus and interconnections shall consist of tin-plated copper bar CA110, square edge, hard temper in accordance with ASTM B 187. Bolted tin-plated copper-to-copper connections shall have silvered interfaces and shall be made with 1/2 inch, thirteen SST bolts with two brass flat washers per bolt, one under the bolt head and one under the nut, and with a SST split lockwasher between the flat washer and the nut. The bolts shall be tightened to 35 ft-lbs torque.
      2) Bus to which cable will be terminated shall be equipped with grounding provisions. Grounding provisions shall also be provided on the ground bus in such bays.

b. Ground bus:
   1) A ground bus of short-circuit rating equal to that of the integrated assembly shall be provided, maintaining electrical continuity throughout the metal-enclosed switchgear.
   2) The ground bus shall consist of copper bar CA110, square edge, hard temper in accordance with ASTM B 187. Bolted copper-to-copper connections shall have silvered interfaces and shall be made with 1/2 inch, thirteen SST bolts with two brass flat washers per bolt, one under the bolt head and one under the nut, and with a SST split lockwasher between the flat washer and the nut.
   3) Two ground cable connectors accommodating No. 2 through 500 kcmil conductors shall be provided in each switchgear bay, for connection of ground bus to station ground grid.

8. Low-voltage components:
   a. Low-voltage components, switch operators (except those integrally mounted in the switchgear stile), source-transfer controls, meters, instruments, and relays, shall be located in grounded, metal-enclosed compartments separate from high voltage to provide isolation and shall be arranged to allow complete accessibility for operation without exposure to high voltage.
   b. Space heaters shall have a grounded, perforated, galvanized steel guard.
   c. To provide isolation from high voltage, low-voltage wiring, except for short lengths such as at terminal blocks or at secondaries of sensing devices, shall be in grounded conduit, cable trays, or raceways.
   d. Provide indicating light incoming power on the incoming section and blown fuse indication or indicating light “load side power on” for each feeder section.

9. Cable-termination space:
   a. To facilitate cable pulling and installation of cable terminators, provisions shall be made for:
      1) Full front access for positioning and removal of cable pulling sheaves.
      2) Free access without interference from nonremovable structural members or from mechanical linkages between the interrupter-switch blades and operating mechanism.

C. Metal-Enclosed Arc-Resistant Switchgear Finish and Features:

1. Outdoor switchgear:
   a. Outdoor finish:
      1) The enclosure finish shall be in accordance with IEEE C57.12.28.
      2) During fabrication, the areas of structural parts which may later become inaccessible, such as folded edges and overlapping members, shall be given an ironoxide zinc-chromate anticorrosion primer to ensure surfaces are protected.
      3) Full coverage at joints and blind areas shall be achieved by processing enclosures independently of components such as doors and roofs before assembly into the unitized structures.
      4) To remove oils and dirt, to form a chemically and anodically neutral conversion coating to improve the finish-to-metal bond, and to retard underfilm propagation of corrosion, surfaces shall undergo a thorough pretreatment process comprised of a fully automated system of cleaning, rinsing, phosphatizing, sealing, drying, and cooling before any protective coatings are applied. By utilizing an automated pretreatment process, the enclosure will receive a highly consistent thorough treatment, eliminating fluctuations in reaction time, reaction temperature, and chemical concentrations.
      5) After pretreatment, protective coatings shall be applied that shall help resist corrosion and protect the steel enclosure. To establish the capability, representative test specimens coated by the Enclosure Manufacturer’s finishing system shall satisfactorily pass the following tests:
         a) 4,000 hours of exposure to salt-spray testing in accordance with ASTM B 117 with:
            (1) Underfilm corrosion not to extend more than 1/32 inch from the scribe in accordance with ASTM D 1654, Procedure A, Method 2 (scraping).
            (2) Loss of adhesion from bare metal not to extend more than 1/8 inch from the scribe.
         b) 1,000 hours of humidity testing in accordance with ASTM D 4585 with no blistering in accordance with ASTM D 714.
         c) 500 hours of UV accelerated weathering testing using lamp UVB-313 with no chalking, and no more than a 10% reduction of paint gloss in accordance with ASTM D 523.
         d) Crosshatch adhesion testing in accordance with ASTM D 3359 Method B with no loss of paint.
         e) 160 in-lb impact adhesion testing in accordance with ASTM D 2794 with no paint chipping or cracking.
         f) Oil-resistance testing consisting of a 3-day immersion bath in mineral oil with no shift in color, no streaking, no blistering, and no loss of hardness.
         g) 3,000 cycles of abrasion testing in accordance with ASTM D 4060 with no penetration to the substrate.
      6) Certified test abstracts substantiating the above capabilities shall be furnished upon request.
      7) A heavy coat of insulating no-drip compound shall be applied to the inside surface of the roof structure to prevent condensation of moisture thereon.
      8) After the enclosures are completely assembled and the components (switches, fuses, bus, etc.) are installed, the finish shall be inspected for scuffs and scratches. Blemishes shall be touched up to restore the protective integrity of the finish.
      9) Touch-up materials, with complete instructions, shall be included with each shipment of metal-enclosed switchgear for touch-up in the field.
      10) The finish shall be light gray, satisfying the requirements of ANSI 61.

b. Outdoor features:
   1) Arc-resistant with top hat and blow-out vents on the front and back.
   2) Enclosure ventilation:
      a) Ventilation openings shall be provided at the top and bottom on the front and rear of each bay. Ventilation openings on the front of arc-resistant switchgear shall be provided at the top only.
      b) Vents shall be rain-resistant and corrosion-resistant.
      c) Each vent shall have an inside screen and a baffle to exclude insects and to protect against insertion of foreign objects.
   3) Lifting eyes shall be removable. Sockets for lifting eyes shall be blind-tapped.
   4) Gasketing and sealing:
      a) Door openings and openings for hinged bolted panels and bolted panels providing access to low-voltage components shall have resilient compression gasketing to prevent water from entering the enclosure.
      b) Gasket seals shall be provided at the top and side edges of adjoining bays to prevent water entry between the double walls.
      c) The top and both sides of bus openings between bays shall be covered with channel gaskets as an additional protection against entrance of water or external labyrinthine metal rainshields shall be provided over enclosure roof flanges between adjacent bays.
      d) Roofs shall be weather-sealed in place with a suitable sealant.
   5) Space heaters:
      a) Space heaters with sheaths of high-temperature chrome steel shall be provided to maintain air circulation inside the enclosure.
      b) There shall be a space heater in each bay.
      c) Space heaters shall be wired with thermostats.
      d) A low-voltage circuit breaker shall be provided in the strip heater circuit.

D. Metal-Enclosed Arc-Resistant Switchgear Basic Components:
1. Interrupter switches:
   a. Interrupter switches in combination with power fuses shall safely withstand the effects of closing, carrying, and interrupting all possible currents up to the assigned maximum short-circuit rating in accordance with NFPA 70.
   b. Shall have a one-time or two-time duty-cycle fault-closing rating equal to or exceeding the short-circuit rating of the switchgear. The ratings define the ability to close the interrupter switch either alone, unfused, or in combination with the appropriate fuse, once or twice, as applicable, against a three-phase fault with asymmetrical current in at least one phase equal to the rated value, with the switch remaining operable and able to carry and interrupt rated current. Tests substantiating the ratings shall be performed at maximum voltage. Certified test abstracts establishing such ratings shall be furnished upon request.
   c. Interrupter switches intended for manual operation shall be operated by means of an externally-operable, non-removable handle. The handle shall have provisions for padlocking in both the open and the closed positions.
   d. Shall utilize a quick-make, quick-break mechanism installed by the Switch Manufacturer that shall swiftly and positively open and close the interrupter switch independent of the switch-handle or switch operator operating speed. For manually operated interrupter switches, the quick-make, quick-break mechanism shall be integrally mounted to the switch frame.
   e. Shall be completely assembled and adjusted by the Switch Manufacturer on a single rigid mounting frame. The frame shall be of welded steel construction such that the frame intercepts the leakage path which parallels the open gap of the interrupter switch, to positively isolate the load circuit when the interrupter switch is in the open position.
   f. Shall be provided with a single blade per phase for circuit closing including fault closing, continuous current carrying, and circuit interrupting. Spring-loaded auxiliary blades shall not be permitted.
   g. Shall be accomplished by use of an interrupter which is positively and inherently sequenced with the blade position. Circuit interruption shall take place completely within the interrupter with no external arc or flame. Any exhaust shall be vented in a controlled manner through a labyrinthine muffler or a deionizing vent.
   h. Shall have a readily visible open gap when in the open position to allow positive verification of switch position.
   i. Terminals on interrupter switches to which cable will be terminated shall be equipped with grounding provisions. Grounding provisions shall also be provided on the ground bus in such bays.
   j. Terminals on interrupter switches rated 1,200 A and, for entrance-bay applications only, terminals on interrupter switches that are used in conjunction with fuses rated 600 A or greater shall be equipped with provisions for two cables per phase.
2. Solid-material power fuses:
   a. Shall be of the solid-material type and shall utilize refill-unit-and-holder or fuse-unit-and-end-fitting construction. The refill unit or fuse unit shall be readily replaceable.
   b. For switchgear rated up through 270 MVA at 4.16 kV, 860 MVA at 25 kV, and 1,000 MVA at 34.5 kV, mountings for solid-material power fuses shall be disconnect style. Non-disconnect style mountings for power fuses shall be used only where higher ratings are required.
   c. Fusible elements shall be non-aging and non-damageable so that it is unnecessary to replace unblown companion fuses following a fuse operation.
   d. Fusible elements for refill units or fuse units, rated 10 A or larger, shall be helically coiled to avoid mechanical damage due to stresses from current surges.

e. Fusible elements that carry continuous current shall be supported in air to help prevent damage from current surges.
f. Shall have melting time-current characteristics that are permanently accurate with a maximum total tolerance of 10% in terms of current. Time-current characteristics shall be available that permit coordination with protective relays, automatic circuit reclosers, and other fuses.
g. Shall be capable of detecting and interrupting faults whether large, medium, or small, down to minimum melting current, under realistic conditions of circuitry, with line-to-line or line-to-ground voltage across the power fuses, and shall be capable of handling the full range of transient recovery voltage severity associated with the faults.
h. Arcing accompanying power fuse operation shall be contained within the fuse, and any arc products and gases evolved during fuse operation shall be vented through exhaust control devices that effectively control fuse exhaust.
i. Shall be equipped with a blown fuse indicator that provides visible evidence of fuse operation while installed in the fuse mounting.
j. Solid-material power fuses in feeder bays shall be equipped with grounding provisions on the load side of each fuse and on the enclosure ground bus.

3. Electronic power fuses shall utilize an expendable interrupting module and a reusable control module:
a. The interrupting module shall consist of a main-current section and a fault-interrupting section. The sections shall be arranged coaxially and contained within the same housing.
b. The main-current section shall carry current under normal operating conditions.
c. The fault-interrupting section shall operate only under fault conditions. It shall not carry current continuously and shall not determine the time-current characteristic minimum operating curve shape.
d. The fusible-element section shall not be subject to damage due to current surges.
e. Arcing accompanying operation of the electronic power fuse shall be contained within the interrupting module and fuse operation shall be silent, without any exhaust.
f. The control module shall continuously monitor the line current through an electronic sensing circuit.
g. The electronic components shall be located within a cylindrical cast aluminum housing that shall serve as a path for continuous current and as a shield to protect the electronic components against interference from external electric fields.
h. To prevent damage to the control-module circuits by surges, such as due to lightning or inrush currents, the control module shall be free of external control wiring and connections to ground, and shall incorporate a device that acts as a buffer to isolate the electronic components at a level of circuit well below their surge-withstand capability.
i. The control module shall be factory-sealed to ensure a dry, contaminant free environment for the electronic components. It shall be self-powered with the capability to supply power for operating the sensing logic circuits and to actuate the interrupting module when a fault occurs and shall include one or more integrally mounted CTs to provide both the sensing signal and the control power.
j. The CTs used to provide control power shall be designed to act as a buffer against surges in the line by saturating at a level of current well below the surge-withstand capability of the electronic components.
k. No leads, including coaxial leads, between the CTs and the electronic components shall be exposed.
l. To make the integrity of the electrical connection be the interrupting and control modules independent of the mechanical force with which the modules are joined, the connection shall be through a louvered ring-type sliding contact.
m. Electronic power fuses in feeder bays shall be equipped with grounding provisions on the load side of each fuse and on the enclosure ground bus.
n. Electronic power fuses shall be equipped with a blown fuse indicator that shall provide visible evidence of fuse operation while installed in the fuse mounting. Fuse mounting shall be disconnect style.
o. It shall not be necessary to replace unblown companion interrupting modules following the operation of an electronic power fuse.
p. Electronic power fuses shall have time-current characteristics that are permanently accurate. Time-current characteristics shall be available which permit coordination with a variety of source-side and load-side protective devices, e.g., protective relays, automatic circuit reclosers, other power fuses, etc.

E. Fused Load-Break Switchgear:
1. Structure:
a. The load-break switchgear shall consist of three single steel structures containing:
1) Horizontal power and ground bus provisions to feed the adjacent motor controllers.
2) Terminal provisions for the incoming medium-voltage feeder conductors.
3) Removable backplates.
4) An allowance for top and bottom entry of the power and control conductors.
5) Removable lifting angles.
6) NEMA Type 12 rubber-gasketed enclosure, designed to give protection against dust.
7) Low-voltage wireway across the roof.
8) Load-break switchgear bolted together with the motor controller and switchgear to form a rigid, freestanding assembly, and designed to permit bus extension for future motor controller and switchgear additions.

9) Load-break switchgear assembled in such a manner that it is not necessary to have rear accessibility to install, connect and support structures, bus bars, and incoming cables and wires, or to remove any devices or components.
10) A non-removable base channel and removable lifting angle, lifting brackets on single section structures, for ease of installation.
11) Power bus and ground bus:
    a) The load-break switchgear shall be assembled in such a manner that it is not necessary to have rear accessibility to perform maintenance and splicing of the power bus and ground bus.
    b) The load-break switchgear's power and ground bus shall be designed to connect directly to the motor controllers and switchgear with the ability to accommodate additional equipment. New power and ground bus splice kits shall be provided as needed to splice the load-break switchgear and the motor controllers together.
    c) The main horizontal power bus shall be located in the center, at the back of the structure to provide optimum heat distribution, ease of maintenance, and splicing. It shall be mounted on edge in a common vertical plane to provide better short-circuit withstand ability. It shall be mounted on a molded bus support insulator to protect against the accumulation of dust and tracking between phases. The power bus shall be made of tin-plated copper and shall be rated a minimum of 1,200 A.
    d) The horizontal/vertical tin-plated copper buswork and the cabling/bus in the main power cell shall be braced and tested in accordance with NEMA ICS 2-324 through ICS 2-325, and UL 347 (paragraph 29). The buswork and cabling shall be braced to withstand the let-through energy allowed by the largest fuse during a short-circuit test.
    e) A continuous copper ground bus shall be provided along the entire length of the load-break switchgear and shall be provided with a splice kit as needed to connect directly with the motor controllers and switchgear. The ground bus shall be located near the power bus and bottom of the load-break switchgear on the inside rear of the enclosure. Each load-break switch ground bus shall be provided with two mechanical lugs for #8 AWG to #1/0 AWG and two mechanical lugs for #6 AWG – 250 MCM cable. The ground bus shall be 1/4 inch by 2 inch bare copper.

2. Load interrupter switch:
   a. The load interrupter switch shall be a 5 kV, three-pole, two-position, gang-operated, bottom-hinged, stationary load-break type, mounted on a rigid, welded-steel frame. The incoming load interrupter switch shall provide for bottom entry, side busbar exit. The tie breaker load interrupter switch shall provide for top entry, side busbar exit. The transformer load interrupter switch shall provide for bottom entry, side busbar exit. The main switch blades shall be high conductivity, hard drawn copper. Mechanical linkages shall be porcelain or epoxy, with leakage and flashover distances equal to the mounting insulators. The circuit interrupting arc shall be completely contained and vented within the arc chutes. The load-break switches shall meet the following:
      1) 1,200 A stationary switch, fused.
      2) Fused/unfused amperes rating in a vented enclosure: 1,200 A.
      3) Maximum rated voltage: 5 kV.
      4) Minimum short-circuit interrupting capacity in symmetrical, fused, at 4,800 V: 38 kA.
      5) Momentary rating, asymmetrical, fused: 61 kA.
      6) Fault closing current, fused, rms, asym: 61 kA.
      7) BIL: 60 kV.
      8) Minimum dielectric strength: 19 kV.
   b. Manual switch operator: Quick-make, quick-break non-defeatable, high speed, stored energy operating mechanism actuated by a non-removable, external operating handle, capable of being padlocked in either the open or closed position. Opening and closing shall be accomplished by a single upward or downward stroke of the handle. The operating speed of the interrupting switch shall be independent of the operator handle speed. The Manufacturer shall provide permanent open-closed switch position targets.
   c. Power fuses: Fuses shall be current-limiting, bolt-on type, non-aging, solid material type with visible fuse condition indicators, silencers, and disconnect style mounting. Fuses shall be ENGINEER-approved. The fuses shall be completely coordinated with other protective devices, as determined and recommended in the coordination study, to provide complete short-circuit protection. Continuous current ratings shall be as recommended by the load-break Switchgear Manufacturer, the Motor Controller Manufacturer, the Transformer Manufacturer, and approved by the ENGINEER. Time-current characteristics shall be approved by the ENGINEER during Shop Drawing review. Blown fuse indication shall be provided. The blown fuse mechanism shall detect a blown fuse thereby causing a contactor to be actuated. Mounted on the front of the load-break switchgear door, there shall be an amber indicating light, powered by UPS or generator backed panelboard. The incoming blown fuse contactors and blown fuse indicating lights shall be a separate circuit connected to terminal boards. Each blown fuse contactor shall include additional normally open contacts. The amber indicating light shall have the following nameplate identifying it: BLOWN FUSE.
   d. Additional features to be provided:
      1) In accordance with ANSI C37.57 and ANSI C37.58.
      2) Cable terminations: Two-hole NEMA buss-pads with provisions for attaching compression/crimp type cable terminals suitable for copper cable of the number and type indicated in the Contract Documents. Provide adequate vertical clearance for electric stress cone cable terminations.
      3) Front access only. Rear or side access shall not be acceptable for service to components.

4) Blown fuse indicator lights and blown fuse indicator contacts.
5) Exterior and interior, except for the power cell and low-voltage backplates, shall be painted ANSI 61 light gray. The backplates of the power cell and low voltage compartments shall be painted high-visibility gloss white. Unpainted parts shall be plated for corrosion resistance.

F. Switchgear Accessories:
1. General:
a. Control power shall be 120 VAC, provided from an internal source; control power shall be protected by current-limiting fuses within the controllers.
b. Contactors, relays, and devices shall be provided with surge suppression across the coils. Surge suppression shall be mounted directly across the coil terminals.
c. Lifting lugs on equipment.
d. Anchor bolts: Galvanized, 1/2 inch minimum diameter. Anchoring shall be as recommended by the Manufacturer and approved by the ENGINEER.
2. Wiring:
a. The power cells shall be wired with flexible, stranded, copper wire supported and neatly bundled using self-locking cable ties. Power wire shall be marked at terminated ends. The power wire shall be marked using plastic sleeve type markers.
b. The power cells shall be wired with an appropriate size of power circuit conductor in accordance with NFPA 70 such that it will handle full amperage capacity at the maximum voltage rating. The power wire shall be type XLPE rated at the appropriate voltage.
c. Control wiring shall be a minimum of #14 AWG, extra flexible, stranded, tinned-copper control wire; type SIS, rated at 600 V, except for specific circuits for which a larger wire size is required. Crimp-type, insulated spade terminals shall be furnished on wire ends, except where non-insulated ring terminals are used to connect to fuse blocks, instrument studs, etc.
d. Wiring for the grounding transformer and grounding resistors shall be sized for the appropriate amperage in accordance with NFPA 70. Control wiring larger than #12 AWG shall be type XLP insulated copper conductor rated at 600 V, phase to phase, at conductor temperatures not exceeding 90°C for normal, 130°C emergency overload, and 250°C short-circuit conditions.
e. Control wiring shall be supported and neatly bundled using self-locking cable ties. The control wire shall be isolated from high voltages components in the power cell, whenever possible.
f. Control wires shall be marked at terminated ends. The wiremarkers shall be plastic sleeve type.
3. Nameplates:
a. Laminated plastic, white surface, engraved to black core, white with black letters.
b. Provide for devices internal and external to the controllers and grounding system.
c. Engrave with the inscription as shown on the Drawings and as approved by the ENGINEER.
d. Attach with SST panhead screws on the face of controllers.
4. Basic electrical materials and methods including, but not limited to, CTs, PTs, push buttons, indicating lights, selector switches, control relays, elapsed time meters, and time delay relays, as specified in SECTION 26 05 10.
5. Control and protective equipment including, but not limited to, control switches, lockout relays, test blocks and plugs, protective relays, as specified in SECTION 26 09 00.

PART 3 EXECUTION

3.1 INSTALLATION

A. Examination:
1. Examine installation area to ensure there is enough clearance to install controllers and grounding equipment.
2. Check concrete pads for uniformity and level surface.
3. Verify that medium-voltage controllers are ready to install.
4. Verify field measurements are as indicated in the Contract Documents, as instructed by the Manufacturer, and as approved by the ENGINEER.
5. Verify that required utilities are available, in proper location, and ready for use.
6. Beginning of installation means installer accepts conditions.

B. Install in accordance with the Manufacturer’s instructions. Install required safety labels.

C. Furnish and completely install controllers and grounding equipment in accordance with the Contract Documents and NFPA 70.

D. Install equipment in accordance with Standards, Submittal Drawings, and the Manufacturer's instructions and recommendations.

E. Secure equipment to mounting pads with anchor bolts of the sufficient size and number adequate for specified seismic conditions; anchoring of the equipment shall be approved by the ENGINEER.

F. Install equipment plumb and in longitudinal alignment with pad or wall.

G. Coordinate terminal connections with the installation of feeders.

H. Grout mounting channels into the floor or the mounting pads.

I. Retighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.

J. Metal-Enclosed Arc-Resistant Switchgear and Fused Load-Break Switchgear Labeling:
1. Warning signs:
a. External doors and hinged bolted panels providing access to high voltage shall be provided with “Danger – High Voltage – Keep Out” signs.

b. Internal protective screens providing access to high voltage shall be provided with “Danger – High Voltage – Keep Out – Qualified Persons Only” signs.
c. Internal protective screens providing access to interrupter switches shall be provided with warning signs indicating that “Switch Blades May Be Energized in Any Position.”
d. Internal protective screens providing access to fuses shall be provided with warning signs indicating that “Fuses May Be Energized in Any Position.”

2. Rating nameplates:
a. The integrated switchgear assembly shall be provided with an external nameplate indicating: Manufacturer’s drawing number; voltage ratings, kV, nominal; kV, maximum; kV, BIL; main bus continuous rating, amperes; short-circuit ratings, amperes, rms symmetrical and MVA three-phase symmetrical at rated nominal voltage; and the momentary and fault-closing ratings, amperes, rms asymmetrical. When the assembly is UL listed, the external nameplate shall include the UL classification markings comprised of UL in a circle, the word “Listed”, the assigned control number, and the product identity.
b. Each individual bay shall bear a nameplate indicating the ratings of the interrupter switch, amperes, continuous and interrupting; the maximum rating of the fuse in amperes; and the catalog number of the fuse units, refill units, interrupting module, or control module. When the individual bay is to be UL listed, the nameplate shall include the UL classification markings comprised of UL in a circle, the word “Listed”, the assigned control number, and the product identity. In addition, the enclosure category shall be specified.

3.2 QUALITY CONTROL

A. Inspect installed controllers for anchoring, alignment, grounding, and physical damage.
B. Megger and record phase to phase and phase to ground insulation resistance of each bus section. Measured insulation resistance shall meet the Manufacturer’s requirements and shall be approved by the ENGINEER.
C. Check the tightness of accessible mechanical and electrical connections with a calibrated torque wrench. Minimum acceptable values are specified in the Manufacturer’s instructions.
D. Test the system for proper functioning.
E. As specified in SECTION 26 08 00.

3.3 CLEANING

A. Clean interiors of controllers to remove construction debris, dirt, and shipping materials.
B. Repaint scratched or marred exterior surfaces to match original finish.

3.4 ADJUSTING

A. Adjust switches, access doors, and operating handles for free mechanical and electrical operation as described in the Manufacturer's instructions.
B. Adjust relay trip and time delay settings to the values specified and determined by the Manufacturer and the ENGINEER.

END OF SECTION

SECTION 26 13 26
MEDIUM-VOLTAGE METAL-CLAD SWITCHGEAR

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for medium-voltage metal-clad switchgear.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
7. SECTION 26 09 00 – CONTROL AND PROTECTION EQUIPMENT
8. SECTION 26 12 13 – PAD MOUNTED TRANSFORMERS

1.2 REFERENCES

A. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Use Contract Drawing equipment and device tags and abbreviations.
4. Bus ratings, data and drawings, including connection to main power transformer.
5. Conduit entrance locations.
6. Protective devices: Copies of time-current characteristics.
7. Anchoring instructions and details.
8. Operational description.
9. Incoming line section equipment data.
10. Typed tabulation:
    a. Tag, equipment, and numbers as shown on the Drawings.
    b. Hp or kVA.
    c. Nameplate full load current.
    d. Measured load current and voltage.
    e. Protective device trip settings.
    f. Calculated system charging current to support ground resistance system capability.
11. Control diagrams:
    a. In addition to standard NEMA control diagrams, provide:
        1) Remote control devices.
        2) Remote indication and/or pilot lights.
        3) Interconnections and interlocking circuits between switchgear and remote equipment.
        4) Remote sensors.
        5) Tag numbers associated with control devices and equipment.
12. System configuration with single-line and three-line diagrams.
13. Detailed descriptions of equipment, including weights, dimensions, foundation requirements, and installation and anchoring requirements.
14. Construction details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, louvers, mounting brackets and tabs, door hinges and latches, and welding.
15. Complete dimensional drawings indicating sizes and clearances required for equipment. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
16. Cable access areas and cable routing.
17. Samples of LCPs mimic bus graphic materials, colors, and adhesive. Interconnection and schematic diagrams for power and control wiring showing conduit runs and wiring with terminal numbers for each wire. Clearly identify contacts, terminal blocks, and wire numbers for remote devices. Show field devices and wiring on diagrams.
18. Detailed layouts of metering and monitoring panels. The metering sensing points shall be shown on the single-line diagram.
19. Key interlock scheme drawing and sequence of operations.
20. Provide detailed calculations to support the system to be provided, its respective duty-cycle, tap settings, voltage ratings, current ratings, power ratings, settings, etc. The calculations shall include:
    a. Detailed capacitive charging current of materials, equipment, and the system with backup data.
    b. Complete material and equipment ratings and settings.

21. The Equipment Manufacturer shall submit a certified letter stating that materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the site conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

D. Quality Control Submittals:
  1. Testing related Submittals.
  2. O&M manuals:
     a. Provide preliminary and final manuals.
     b. As specified in SECTION 01 78 23.
     c. Shop Drawing submittal information.
     d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
     e. Factory and field certified test reports: Measured system charging current to support ground resistance system resistor settings.
     f. Calibration, start-up, and commissioning reports.
     g. Complete lists of equipment furnished, including Manufacturer model numbers, correct settings, alarm points, and operating ranges.
     h. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
     i. Final As-Built Drawings:
        1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
           a) Drawings shall be on a standard DW provided title block and border.
           b) As-Builts and Manufacturer's drawings shall be provided:
              (1) On a standard DW provided title block and border.
              (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
              (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
              (4) Titles: 0.2 inches.
     j. Warranty documentation.

E. Extra Materials:
  1. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
     a. Fuses, 0 to 600 V: A minimum of three of each type and each current rating installed.
     b. Fuses and fuse links, 600 V and above: A minimum of three of each type and each current rating installed.
     c. Lamps and LEDs for indicating lights: Two boxes of each type.
     d. Exterior switchgear ventilation system equipment filters: Two complete sets.
     e. Exterior switchgear ventilation system belts: One set.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services:
  1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
     a. Installation assistance, and inspection of installation: 1.
     b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by the CONTRACTOR to facilitate the ingress of equipment to final installation.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the low-voltage motor control system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Eaton Cutler-Hammer

B. ABB/General Electric

C. Square D

D. Terminal Blocks:
  1. General Electric; Type EB-5

2.2 MATERIALS

A. The medium-voltage metal-clad switchgear includes all accessories in accordance with the Contract Documents.

B. Outdoor Metal-Clad Switchgear:

1. Shelter-clad common aisle outdoor metal-clad switchgear with horizontal draw-out, vacuum circuit breakers. General construction features shall be of a coordinated design so that shipping groups are easily connected together in the field into a continuous lineup. Necessary standard connecting materials shall be furnished.
2. The general arrangement of single line diagram of equipment shall be as shown on the Drawings.
3. The switchgear shall be 5 kV class, with a maximum design voltage of 5 kV. The equipment shall operate on a service voltage of 4.16 kV, three-phase, three-wire, 60 Hz.

2.3 COMPONENTS

A. Medium-Voltage Metal-Clad Switchgear, 4.76 kV, for use on 4.16 kV:

1. General:
   a. The group of indoor switchgear shall include:
      1) 1,200 A, three-phase, main bus.
      2) Ground bus.
   b. The Drawings show the locations of necessary PT drawers, with fused draw-out type PTs.
   c. Each feeder section cell shall contain, as a minimum, the following:
      1) Unless designated as a space provision, one vacuum circuit breaker, rated as detailed herein.
      2) One MOC auxiliary switch six-stage.
      3) One TOC switch, four-stage.
      4) Two sets of three CTs single secondary, ratios as shown on the Drawings, with single ration primary.
      5) One space heater, 208 VAC.
      6) One thermostat.
2. Enclosure:
   a. Switchgear shall consist of breaker and auxiliary units, as shown on the Drawings, assembled to form a rigid, self-supporting, metal-enclosed structure. Metal-clad switchgear shall be enclosed in a NEMA 1 gasketed enclosure, doors with keyed lock; protected ventilation openings; interior lighting, utility outlets with protective devices; and equipment heaters with protective devices. In each unit, major primary circuit parts (breaker, buses, transformers) shall be completely enclosed by grounded metal barriers, including a front barrier as part of the circuit breaker.
   b. Switchgear units shall be arranged as shown on the Drawings.
   c. For rigidity during fault conditions, connections to roll-out PT trays and control power transformer trays shall be rigid bus bars insulated to full voltage rating of switchgear assembly.
   d. Circuit breaker compartments shall be designed to house 4.76 kV removable-element circuit breakers. Stationary primary disconnect contacts shall be silver-plated copper. Grounded metal safety shutters shall isolate primary connections in compartment when breaker is withdrawn from connected position.
   e. Furnish nameplates for each device as shown on the Drawings. Nameplates shall be black letters on white background. Nameplates shall be fastened by screws. There shall be a master nameplate that indicates equipment ratings, Manufacturer's names, shop order number, and general information.
   f. Shelter-clad design – common aisle:
      1) The shelter-clad common aisle switchgear shall consist of two line-ups of indoor type circuit breaker and auxiliary sections located in a weatherproof steel housing having a common operating aisle space of sufficient size to permit withdrawal of the circuit breakers for inspection, test, or maintenance. An access door shall be located at each end of the aisle. Each door shall have an integral keyed lock, keyed to DW's standard electric shop key on the outside. Each door shall be furnished with a panic bar door operator so that the door can be opened from the inside regardless of whether or not it has been locked on the outside. The aisle space shall have adequate lighting which will be controlled by means of a three-way switch at each access door.
      2) Included in the switchgear shall be:
         a) Louvers – provide combination damper/louver for intake and exhaust penetrations:
            (1) Drainable combination louver damper.
            (2) 16 gauge galvanized steel frame, 18 gauge galvanized steel drainable front blades, 16 gauge galvanized steel adjustable rear damper blades.
            (3) Size: 12 inches by 12 inches or sized to maintain face velocities less than 700 fpm, with pressure drop less than 0.05 inch water gauge.
            (4) Two-position spring return actuator. Sized to fully open and close damper in conditions between -22°F through 122°F, 180 in/lb minimum torque, 120 VAC, fail closed.
            (5) Paint louver to match exterior of building.
         b) Ventilation fan: Provide a wall-mounted inline exhaust fan:
            (1) Capacity: 150 cfm or ten air changes per hour, whichever is greater.
            (2) Motor: NEMA Premium, thermal overload protection, open drip proof casing, permanently lubricated bearings, 1.15 SF, and brake hp shall not exceed the motor's nameplate rating.
            (3) Electrical: 120/1/60.
            (4) Enclosed fan blade or OSHA rated fan guard.
            (5) Balance ventilation fan.
            (6) Operated and meets performance requirements at site elevation.

(7) Equipment identification plates: Furnish the Manufacturer's ID plate including make, model, and Manufacturer.
(8) Install level and plumb with vibration isolators.
(9) Controls: Furnish one heavy duty line voltage thermostat. Temperature range 55°F to 95°F. Install on north wall with insulation media between thermostat and exterior wall.

c) Filtered intake: Provide intake filter box with replaceable 1-inch pleated panel filter.
d) Unit heaters: Provide a self-contained electric-resistant unit heat:
(1) Capacity: 5 kW.
(2) Electrical: 208 V/three-phase/60 Hz.
(3) Integral disconnect switch.
(4) Integral summer switch.
(5) Totally enclosed fan motor, rated for continuous duty.
(6) Dynamically balanced fan.
(7) Individually adjustable louvers.
(8) Cabinet: 18 gauge steel arranged for wall or ceiling mounting brackets.
(9) Electric heating coil: Fintube heating elements have corrosion-resistant steel fins that are furnace brazed to the tubular element.
(10) Thermal overload protection with automatic reset.

e) Two utility duplex receptacles with integral ground fault protection, one at each aisle access door, for electric tools, extension cords, etc.
f) An exterior-mounted weatherproof switch at each door for arc flash reduction levels while personnel are inside equipment. The switch shall be labeled and the switch position shall be visible.

3) Switchgear shall be shipped in convenient groups for erection in the field, and shipping groups ordinarily shall not exceed 16 feet in length.
4) The weatherproof enclosure for the aisleway shall be shipped in sections for erection in the field. Necessary erection hardware shall be furnished.

3. Main bus: Rated 1,200 A, tin-plated copper. Bus bars shall have a continuous current rating based on temperature rise and documented by design tests. Joints will be tin-plated with at least two bolts per joint. Bus bars will be braced to withstand magnetic stresses developed by currents equal to main power circuit front panels. Bus bars shall have fluidized bed epoxy flame retardant and non-hydroscopic insulation with a continuous current rating.
4. Ground bus: A ground bus, 1/4 inch by 2 inch copper, shall extend throughout assembly with connections to each breaker grounding contact and cable compartment ground terminal; two station ground grid connection points shall be located in each section.
5. Circuit breakers:
   a. The vacuum circuit breakers shall be:
      1) Nominal voltage class: 4.16 kV.
      2) Rated maximum voltage: 4.76 kV.
      3) Rated continuous current: 1,200 A.
      4) Rated short-circuit current at maximum voltage: 50 kA.
      5) Rated interrupting time: Three cycles.
      6) Maximum symmetrical interrupting capability: 50 kA.
      7) Short-time, 3 second, current carrying capability: 50 kA.
      8) Closing and latching capability, peak: 130 kA.
   b. The circuit breaker shall be three -pole, single throw, mechanically and electrically trip-free, with position indicator, operation counter, auxiliary switches, primary and secondary disconnecting devices, and mechanical interlocks to prevent making or breaking load current on the primary disconnects.
   c. Circuit breakers shall be able to be racked from one position to another with the compartment door closed. There shall be three distinct positions: Connected, test, and disconnect. The circuit breakers shall be equipped with a stored energy operator. The control voltages shall be:
      1) Spring charging motor: 120 VAC.
      2) Spring release, close, coil: 120 VAC.
      3) Trip coil: 120 VAC.
   d. The source of control power shall be the 120 VAC or as shown on the Drawings.
   e. Circuit breakers of equal rating shall be interchangeable. Circuit breakers shall be operated by an electrically charged, mechanically and electrically trip-free, storage-energy spring.
   f. Circuit breakers shall be equipped with secondary disconnecting contacts which shall automatically engage in the connected position.
   g. Each breaker compartment shall have a breaker rackout device. Using a rackout device, a breaker will be self-aligning and will be held rigidly in the operating positions. In the disconnection positions, the breaker shall be easily removable from the compartment. The breaker racking shall be accomplished with the door closed and latched. Insert the handle through a hole in the front door to operate the rackout device.
   h. An indicating tape shall show the breaker position when the racking breakers are in or out of their connected positions.

i. Interlocks shall prevent moving the breaker to or from operating position unless the main contacts are open. Operating springs shall be discharged automatically when the breaker is rolled fully into the connected or disconnected position. The rackout device shall have provisions to padlock in the connected or disconnected position. When locked in the disconnected position, the breaker shall be removable from the compartment using a portable lifting device. The padlock shall not interfere with breaker operation.
j. Automatic shutters shall cover primary disconnect stabs when the breaker is withdrawn to the test/disconnect position. Shutters shall be positively driven by linkages connected to the racking mechanism. A stationary barrier shall be located in front of the shutters for additional safety.
k. Thermostat-controlled breaker cubicle space heaters.

6. Instrument transformers:
   a. Additional voltage and CT requirements: As specified in SECTION 26 05 10.
   b. CT ratios shall be as shown on the Drawings. Transformer mechanical ratings shall equal the momentary rating of the circuit breakers. Transformers, mounted in switchgear assemblies, shall be rated for the full voltage of the switchgear.
   c. Voltage transformers shall be draw-out type, with current-limiting fuses and with BIL rating equal to the switchgear. Transformer ratios shall be as shown on the Drawings.
   d. Secondary control wiring shall be No. 12, extra flexible, stranded, tinned-copper control wire, Type SIS XLP, rated 600 V, except for specific circuits requiring larger wire. Crimp-type, uninsulated spade terminals shall be furnished on wire ends, except where non-insulated ring terminals are used to connect to fuse blocks, instrument studs, or terminal block points with two or more wire connections. Secondary control wires shall be armored where they pass through primary compartments.
7. Devices and metering:
   a. As specified in this Section.
   b. Thermostat controlled space heaters.
8. Accessories, 4.76 kV:
   a. Lift truck.
   b. Manual racking handles.
   c. One floor level ramp to be used for removal of breakers in the lower cells.
   d. Integral overhead crane and trolley system for the removal of breakers in upper cells.
   e. Kirk key interlock system.
   f. Each breaker compartment shall include provisions of an arc flash reduction mode switch that reduces the protective relaying settings to a lowered, instantaneous setting when maintenance is being performed on the cell or adjacent cells. Provisions shall be made in each switch to accept via terminal blocks, a remote dry-contact closure to activate the switch.
9. Testing:
   a. The switchgear equipment and circuit breakers shall receive factory production test as listed herein:
      1) Equipment:
         a) Low frequency dielectric test.
         b) Grounding of instrument cases.
         c) Control wiring and device functional test.
         d) Polarity verification.
         e) Sequence test.
         f) Low frequency withstand voltage test on major insulation components.
         g) Low frequency withstand test on secondary control wiring.
      2) Breakers:
         a) Coil check test.
         b) Clearance and mechanical adjustment.
         c) 300 electrical and mechanical operation test.
         d) Timing test.
         e) Conductivity of current path test.
         f) Hi-potential testing of breaker.
         g) Vacuum bottle integrity test.
   b. The Manufacturer shall provide documents verifying the completion of factory production tests to the ENGINEER.
10. Finish:
   a. Steel surfaces shall be chemically cleaned and given an iron phosphate corrosion-resistant treatment providing a strong bond for paint adhesion. Parts shall be immersed in paint applying 0.7 mils to 0.8 mils of cathodic epoxy paint electrically bonded to surfaces for maximum adhesion. The finish shall be cured in an oven at to ensure maximum toughness and prolong service in severe environments.
   b. Exterior surfaces of the switchgear assembly shall be given final finish coats of ANSI 61 light gray air dried acrylic enamel. DFT shall be a minimum of 2.7 mils.

2.4 ACCESSORIES

A. General:
   1. Control power shall be 120 VAC or 125 VDC as specified in this Section and as shown on the Drawings, provided from an external source, control power shall be protected by current-limiting fuses within the switchgear.

2. Contactors, relays, and devices shall be provided with surge suppression across the coils. Surge suppression shall be mounted directly across the coil terminals.
3. Lifting lugs on equipment.
4. Anchor bolts: Galvanized, 1/2 inch minimum diameter. Anchoring shall be as recommended by the Manufacturer and approved by the ENGINEER.

B. High Resistance Grounding System:
1. System shall consist of a grounding transformer and adjustable grounding resistor connected to the secondary of each main power transformer or generator.
2. System shall be enclosed in metal-clad enclosure located in the switchyard. Auxiliary control power for the system controls and space heater shall be derived from panelboards. Include provisions for a strip space heater located within the equipment enclosure.
3. The high resistance grounding transformer shall be as specified in SECTION 26 12 13; it shall be grounded and bonded to the ground grid.
4. The neutral grounding resistor shall connect to the secondary of the grounding transformer and shall be located within the same common compartment as the neutral grounding transformer. The neutral grounding resistor and grounding transformer shall not be provided with any means of disconnection.
5. The resistor shall consist of high grade chromium SST elements. Resistor frame shall be insulated with a rating equal to or greater than the voltage rating of the grounding transformer secondary.
6. The estimated size and rating of the neutral grounding resistor 1.6 ohms, 111.8 continuous current, 20 kVA. Submit the actual neutral grounding resistor sizing calculations for approval.
7. Provide devices and equipment to provide a fully functional high resistance grounding system. Indicating and interface devices shall be door-mounted. The devices and equipment shall include, but not be limited to:
   a. Adjustable ground protection voltage meter relay. The relay shall be mounted in the incoming switchgear. The relay shall be provided with contacts for alarms and indication. The relay shall be provided with four normally open and four normally closed, upscale and downscale alarm contacts.
   b. Ammeter, displaying ground current.
   c. “Ground fault alarm” amber indicating light.
   d. “Normal” green indicating light.
   e. “Normal-pulse” selector switch.
   f. “Test” push button (momentary).
   g. Instruction plate mounted on the door.
   h. Control power transformer.
   i. Pulsing contactor and relay
   j. Portable ground-current detector with carrying case.
8. Perform, document, and submit an ENGINEER-witnessed measurement of system charging current on both main lines with one tie breaker open and on both main lines with both tie breakers closed and the opposite main line breaker open.

C. Wiring:
1. The power cells shall be wired with flexible, stranded, copper wire supported and neatly bundled using self-locking cable ties. Power wire shall be marked at terminated ends using plastic sleeve type markers.
2. The power cells shall be wired with an appropriate size of power circuit conductor in accordance with NFPA 70 such that it will handle full amperage capacity at the maximum voltage rating of the cable. The power wire shall be type XLPE rated at 5,000 V.
3. Control wiring shall be a minimum of #14 AWG, extra flexible, stranded, tinned-copper control wire; type SIS, rated at 600 V, except for specific circuits for which a larger wire size is required. Crimp-type, insulated spade terminals shall be furnished on wire ends, except where non-insulated ring terminals are used to connect to fuse blocks, instrument studs, etc.
4. Control wiring shall be supported and neatly bundled using self-locking cable ties. Whenever possible, the control wire shall be isolated from high voltage components in the power cell.
5. Wire markers shall be plastic sleeve type.

D. Terminal Blocks:
1. Enclosed in steel wiring troughs.
2. Rated 600 V, 30 A minimum, one-piece barrier type with strap screws.
3. Shorting type for CT leads.
4. Provide terminal blocks for:
   a. Conductors connecting to circuits external to switchgear.
   b. Internal circuits crossing shipping splits.
   c. Equipment parts requiring replacement and maintenance.
5. Spare terminals: Not less than 20%.
6. Group terminal blocks for external circuit wiring leads.
7. Maintain a 6 inch minimum space between columns of terminal blocks.
8. Identification: Permanent, for each terminal and columns of terminals blocks.

E. Control wires shall be marked at terminated or spare ends.

F. Basic electrical materials and methods including, but not limited to, CTs, PTs, push buttons, indicating lights, selector switches, control relays, panelboards, electric unit heaters, elapsed time meters, and time delay relays, as specified in SECTION 26 05 10.

G. Control and protective equipment including, but not limited to, control switches, lockout relays, test blocks and plugs, protective relays, as specified in SECTION 26 09 00.

H. Equipment Identification:
1. Master nameplate:
   a. Deep-etched aluminum with the Manufacturer's name and model number.
   b. Riveted to main vertical section.
2. Section identification:
   a. Stamped metallic, riveted to each vertical section.
   b. Serial number, bus rating, and section reference number.
   c. Size: Manufacturer's standard.
3. Nameplate:
   a. Engraved, phenolic for each circuit breaker cubicle and door-mounted device.
   b. White with black block type characters.
   c. Size: Manufacturer's standard.
   d. Inscriptions: As shown on the one-line diagram.
   e. Blank plates for future spaces.
   f. Attachment screws: Self-tapping.
4. Cubicle labels:
   a. Nonmetallic, applied inside each cubicle compartment.
   b. Device serial number, rating, and description.
   c. Size: As required.
5. Switchgear signs:
   a. Two each on front and back of switchgear.
   b. Size: Manufacturer's standard.
   c. Engraved, phenolic.
   d. Color: Red with white.
   e. Inscription: Danger/high voltage/keep out.
   f. Characters: Gothic type, 1 inch high.
   g. Attachment: Four rivets each sign.
   h. Arc flash labels that meet the OWNER’s standard shall be on each section of the switchgear and shall indicate the calculated arc flash rating in accordance with an approved ESA study as specified in SECTION 26 05 70.
6. Device nameplates:
   a. Laminated plastic, white surface, engraved to black core, white with black letters.
   b. Provide for devices internal and external to the switchgear and grounding system.
   c. Engrave with inscription as shown on the Drawings.
   d. Attach with SST panhead screws on face of switchgear.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with the Manufacturer’s instructions. Install required safety labels.

B. Furnish and completely install switchgear sections and grounding equipment in accordance with the Contract Documents and NFPA 70.

C. Install equipment in accordance with Standards, Submittal Drawings, and the Manufacturer's instructions and recommendations.

D. Secure equipment to mounting pads with anchor bolts of sufficient size and number adequate for specified seismic conditions; anchoring of the equipment shall be approved by the ENGINEER.

E. Install equipment plumb and in longitudinal alignment with the pad or the wall.

F. Coordinate terminal connections with the installation of feeders.

G. Grout mounting channels into the floor or the mounting pads.

H. Retighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.

I. Install equipment in accordance with the Manufacturer's instructions and recommendations.

J. Field adjust trip settings of protective devices to meet the requirements of the electric utility, the ENGINEER, and the approved ESA.

3.2 QUALITY CONTROL

A. As specified in 26 08 00.

B. Equipment shall be completely factory-built, assembled, wired, and tested. Equipment and components shall be of new construction.

C. Inspect installed switchgear and grounding equipment sections for anchoring, alignment, grounding, and physical damage.
1. Fill concrete-to-equipment voids:
   a. Larger than 1/2 inch: ENGINEER-approved, non-shrink grout.
   b. Smaller than 1/2 inch: Backer-rod and ENGINEER-approved caulk.
2. Caulk around switchgear and grounding equipment concrete-to-equipment interfaces and conduit stub-ups into equipment sheet steel bottoms to minimize dust and insect intrusion.

D. Megger and record phase-to-phase and phase-to-ground insulation resistance of each bus section. Measured insulation resistance shall meet the Manufacturer’s requirements and shall be approved by the ENGINEER.

E. Check the tightness of accessible mechanical and electrical connections with a calibrated torque wrench. Minimum acceptable values are specified in the Manufacturer's instructions.

F. Test the system for proper functioning.

G. Field measure high resistance grounding system charging current to verify grounding system calculations and to determine final resistor tap settings.

H. Inspection:
   1. Examine the installation area to ensure there is enough clearance to install switchgear assemblies, switchgear equipment aisles, and grounding equipment.
   2. Check concrete pads for uniformity and level surface.
   3. Verify that medium-voltage switchgear sections and grounding equipment is ready to install:
      a. Verify that field measurements are in accordance with the Contract Documents, instructed by the Manufacturer, and approved by the ENGINEER.
         1) Verify that equipment sizes, equipment pads, etc., are of sufficient size, height, and respective spatial relationship to each other to enable Contract equipment to be set in place and connected.
         2) Verify that raceway stubups and penetrations are in the correct position.
   4. Verify that required utilities are available, in proper location, and ready for use.
   5. Beginning of installation means the installer accepts conditions.

3.3 CLEANING

A. Clean interiors of provided equipment to remove construction debris, dirt, and shipping materials.

B. Repair and repaint scratched or marred exterior surfaces to match the original finish. Replace entire surfaces that are not field repairable to ensure there are no visible seams, welds, etc.

3.4 ADJUSTING

A. Adjust switches, access doors, Kirk-Key Systems, and operating handles for free mechanical and electrical operation as described in the Manufacturer's instructions.

B. Adjust relay trip and time delay settings to the values specified and determined by the Manufacturer and the ENGINEER.

END OF SECTION

SECTION 26 18 39
MEDIUM-VOLTAGE MOTOR CONTROL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for medium-voltage motor controls.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
7. SECTION 26 09 00 – CONTROL AND PROTECTION EQUIPMENT
8. SECTION 26 13 23 – MEDIUM-VOLTAGE METAL-ENCLOSED SWITCHGEAR

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):

1. 421.1 – Standard Definitions for Excitation Systems for Synchronous Machines
2. 421.3 – Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines
3. C37.30.1 – Standard Requirements for AC High-Voltage Air Switches Rated Above 1000 V
4. C37.42 – Standard Specifications for High-Voltage (>1000 V) Fuses and Accessories
5. C57.13 – Standard Requirements for Instrument Transformers

B. National Electrical Manufacturers Association (NEMA):

1. 250 – Enclosures for Electrical Equipment (1,000 V Maximum)
2. ICS 2 – Controllers, Contactors and Overload Relays Rated 600 V
3. ICS 3 – Medium Voltage Controllers Rated 2001 to 7200 Volts AC
4. ICS 6 – Industrial Control and Systems: Enclosures

C. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)

D. Underwriters Laboratories, Inc. (UL):

1. 347 – Medium-Voltage AC Contactors, Controllers, and Control Centers

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Use Contract Drawing equipment and device tags and abbreviations.
4. Bus ratings, data and drawings, including connection to isolation switches.
5. Conduit entrance locations.
6. Protective devices: Copies of time-current characteristics.
7. Operational description.
8. Anchoring instructions and details.
9. Typed tabulation:
   a. Motor name; tag (equipment) numbers as shown on the Drawings.
   b. Motor hp.
   c. Nameplate full load current.
   d. Measured load current and voltage.
   e. Protective device trip settings.
   f. Attach above typed, tabulated data to a copy of the Starter Manufacturer's overload heater selection tables for the starters provided.
   g. Calculated system charging current to support ground resistance system capability.
10. System configuration with single-line and three-line diagrams.
11. Detailed descriptions of equipment, including weights, dimensions, foundation requirements, and installation and anchoring requirements.
12. Construction details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, louvers, mounting brackets and tabs, door hinges and latches, and welding.
13. Complete dimensional drawings indicating sizes and clearances required for equipment. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
14. Cable access areas and cable routing.
15. Samples of LCPs mimic bus graphic materials, colors, and adhesive. Interconnection and schematic diagrams for power and control wiring showing conduit runs and wiring with terminal numbers for each wire. Clearly identify contacts, terminal blocks, and wire numbers for remote devices. Show field devices and wiring on diagrams.
16. Detailed layouts of metering and monitoring panels. The metering sensing points shall be shown on the single-line diagram.

17. Control diagrams:
    a. In addition to standard NEMA control diagrams, provide the following:
        1) Remote control devices.
        2) Remote indication and pilot lights.
        3) Interconnections and interlocking circuits between controllers and remote equipment.
        4) Remote sensors.
        5) Tag numbers associated with control devices and equipment.
18. Submit a certified letter stating that the materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
    a. Provide preliminary and final manuals.
    b. As specified in SECTION 01 78 23.
    c. Shop Drawing Submittal information.
    d. Manufacturer's installation instructions.
    e. Factory and field certified test reports.
    f. Operating instructions and startup procedures including receiving and installation requirements.
    g. Software documentation: Updated version of software.
        1) Hardcopy and electronic version of installed programs in controllers and equipment.
    h. Calibration, startup, and commissioning reports.
        1) Include complete lists of equipment furnished, including the Manufacturer's model numbers, correct settings, alarm points, and operating ranges.
    i. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
        1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
                (1) On a standard DW provided title block and border.
                (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
                (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
                (4) Titles: 0.2 inches.
    j. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with Manufacturer's name, description and part number for shipment and long-term storage and deliver prior to 75% on the Final Completion date the following extra materials:
1. Fuses, 0 V to 600 V: A minimum of six of each type and each current rating installed.
2. Fuses and fuse links, 600 V and above: A minimum of six of each type and each current rating installed.
3. Lamps and LEDs for indicating lights: Minimum of two of each type and size.
4. Vacuum contactor coils: Two of each size and type.
5. Vacuum contactor rectifier assemblies/vacuum contactor DC control module: Two of each size and type.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall be in accordance with UL standards and have an applied UL listing mark.

C. Manufacturer's Services: Furnish a Manufacturer's Representative as specified in SECTION 01 44 33 for the following services at the jobsite or the classroom as designated by the ENGINEER for the minimum person-days listed herein, travel time excluded:
1. Installation assistance and inspection, and certification of installation: 1.
2. Startup and functional testing: 1.
3. Training: 1.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by the CONTRACTOR to facilitate ingress of equipment to final installation.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the medium-voltage motor control system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Medium-Voltage Motor Control:
   1. Eaton Cutler-Hammer
   2. ABB/General Electric
   3. Square D

B. Motor Protector Relay:
   1. General Electric, Multilin 369-HI-R-M-00OE

C. SPM:
   1. General Electric, Multilin SPM PF including PG2SPM and other accessories required and shown on the Drawings

D. Terminal Blocks:
   1. General Electric, Type EB-5

2.2 MATERIALS

A. General:
   1. Make adjustments as necessary to wiring, conduit, disconnect devices, motor starters, branch circuit protection, and other affected material equipment to accommodate motors actually provided.
   2. Equipment suitable for four, 160 V, three-phase, high-resistance grounded-wye electrical system having an available short--circuit current at line terminals of 50,000 A rms symmetrical. Designed, tested, and assembled in accordance with NEMA ICS 3 and UL 347.
   3. Like items of equipment shall be the end products of one Manufacturer in order to achieve standardization for appearance, O&M, spare parts and replacement, and Manufacturer's services.
   4. Removable lifting lugs on equipment and devices weighing over 100 lbs.
   5. Anchor bolts: Type 316 SST, sized by the Equipment Manufacturer, 1/2 inch minimum diameter.
   6. Equipment to be fully rated without any derating for operating conditions.
   7. Equipment finish: Electrocoating process applied to over a rust-inhibiting phosphate base coating.
      a. Color:
         1) Exterior color: ANSI 61, light gray.
         2) Interior surfaces of medium-voltage motor control: White.

B. Enclosure:
   1. In accordance with NEMA 250 and NEMA ICS 6.
   2. Type: NEMA 250, Type 1, gasketed.
   3. Construction:
      a. Sheet steel, reinforced with channel or angle iron.
      b. Butt sections flush, end-to-end with similar sections.
      c. Freestanding.
      d. Steel bottom cover plates.
      e. Front accessible with segregated high-voltage and low-voltage.
      f. Low-voltage control compartment with separate door.
      g. High-voltage compartment with separate interlocked door.
      h. Bus compartment with protective barriers and cable entrance compartments.
      i. Equip with defeater to allow intentional access only to qualified personnel.
   4. Vacuum starter unit enclosures: Two high.
   5. Vertical section: 100 inches maximum height, 30 inches deep, and 42 inches wide.

C. Incoming Service Section:
   1. Provide and install medium-voltage metal-enclosed isolation switchgear as specified in SECTION 26 13 23 and the Contract Documents.
   2. Provide and install bus transition section if necessary and approved by the ENGINEER. The bus transition section shall be insulated and shall be isolated from the main bus section.

D. Bus:
   1. Tin-plated copper.
   2. 5 kV insulated main bus with boots on main bus splices between sections.
   3. Horizontal bus: Isolated, three-phase with rating of 1,000 A.
   4. Vertical bus: Insulated, three-phase with rating of 800 A.
   5. Ground bus: Extend continuous throughout sections of control center lineup without cable connections between sections.
   6. Bus bracing: 50,000 A rms asymmetrical.
   7. Connections and joints: Bolted with Belleville washers.

E. Motor Starter Unit:
   1. General:
      a. NEMA ICS 3, Part 1, Section 4.3.2, Class E2 combination controller with current-limiting IEEE C37.42, Class R fuses and three-pole vacuum contactor.
      b. Fixed type construction:
         1) Bolt-on fuse and supper assembly.
         2) Externally-operated disconnect switch.
         3) Vacuum contactor.

4) Mechanically interlocked to prevent:
    a) Opening disconnect when contactor is energized.
    b) Opening door when contactor is closed.
    c) Closing contactor with disconnect in intermediate position.
    d) Closing disconnect when high-voltage door is open.
5) Magnet coil removable without removing contactor from its mounts.

c. Anti-single phase trip mechanism and blown fuse indicator shall be an integral part of the fuse support system.
d. Control power transformer with 120 V secondary and two primary and one secondary current-limiting fuses. CTs installed on each phase.
e. Zero sequence ground fault CT.
f. Terminals for incoming feeder and motor cable connections.
g. Control circuitry.
h. Push button and indicating lights.
i. Autotransformer starter:
    1) One main contactor, one start contactor, and one run contactor and fused isolation switch.
    2) Three autotransformers connected open delta with 50%, 65%, and 80% voltage taps.
    3) Close circuit transition and autotransformer RTD thermal over-temperature protection.

2. Contactors: Electrically operated, three-pole, single-break type in accordance with NEMA ICS 2, Section 324, and UL 347.
    a. Vacuum type:
        1) Fused, magnetically held fixed contactor.
        2) Rated 5 kV, 400 A, 60 kVA BIL rating. Combination fuse and contactor interrupting rating: 400 MVA, three-phase symmetrical at 4,800 V.
        3) Main contacts:
            a) Weld-resistant, copper alloy.
            b) Constructed for low chopping currents.
            c) Three-phase interrupting capacity of 50 MVA rms symmetrical.
    b. Auxiliary contacts:
        1) Rated 10 A, 600 V.
        2) Ten normally open; four normally closed.
3. Disconnect switch:
    a. Fixed, mounted, nonfused, nonload-break, externally operated quick-make, quick-break in accordance with IEEE C37.30.1.
    b. Rated 5 kV, 400 A, 60 kV BIL.
    c. Switch contacts barriered and visible through viewing window.
    d. Lockable operating handle.
4. Power fuses:
    a. Fixed power fuse holders in the power cell.
    b. UL recognized fuses.
    c. Nominal voltage rating of 4,800 V.
    d. Minimum of 50 kA rms symmetrical interrupting current.
    e. Current-limiting fuses: Under fault conditions, the fuse shall start limiting current within the first 1/4 cycle and interrupt within the first 1/2 cycle.
    f. Fast-acting fuses.
    g. Selected for coordination with other system protective devices.
    h. Sufficient capacity to carry starting and full load currents.
    i. Minimum of 50 kA rms symmetrical interrupting capacity.
5. Motor protector relay:
    a. General:
        1) Multifunction, microprocessor based, programmable digital device.
        2) Single, self-contained, door-mounted unit with data input push buttons on face of relay.
        3) Motor protection against overload, over-temperature, phase reversal, phase unbalance, single-phase, ground fault, jam under-load, and bearing over-temperature, plus starts per hour, differential relay input, over and under-voltage protection, phase loss trip, and phase sequence trip.
        4) Motor current integrated with winding temperatures to establish trip times.
        5) Separate trip points for each function.
        6) Visual display to indicate relay status and operation.
        7) Read out to include real-time motor data using push buttons.
        8) System data and trip limit points accessible from same display.
        9) Non-changeable trip limit points except with program jumper via switch inside control wiring compartment.
        10) Separate alarm, auxiliary, and trip output contacts rated 8 A, 230 V.
        11) Alarm contacts wired to remote alarm indicator.
        12) Interconnecting wires terminated on terminal boards.

b. Protective features:
    1) Time overcurrent and instantaneous trip functions.
    2) Winding temperature, motor bearing, and driven equipment bearing RTD software set and adjustable trip and alarm levels.
    3) Ground fault alarm and trip.
    4) Load jam overcurrent and load loss undercurrent.
    5) Unbalanced current trip and alarm.
    6) Current trip for phase reversal and phase loss.
    7) Starts per hour limit.
    8) Overvoltage and under-voltage protection.
    9) Voltage trip for phase loss and phase sequence.
    10) Trip and alarm independently adjustable.
    11) Loss of protection.
c. Measurement and display:
    1) Three-phase line and percent full load currents.
    2) Three-phase line voltage.
    3) kVA and kW.
    4) Ground current.
    5) Current unbalance at trip condition only.
    6) RTD temperatures and hottest RTD.
    7) Normal operating conditions and trip annunciators.
d. Module features:
    1) Programmable trip, alarm, and auxiliary relays.
    2) Relay status.
    3) Lock on programming.
    4) Settable CT radio.
    5) Hold system values at trip.
    6) Communications output.

6. Static excitation:
    a. The existing synchronous motor rotating excitation systems shall be removed and replaced with static excitation units located in the motor controllers. The CONTRACTOR and the Manufacturer shall verify the ratings of the equipment and the interface to be provided. New Manufacturer recommended brushes shall be provided and installed, including proper brush seating.
    b. The synchronous motor static excitation units shall be designed, manufactured, and tested in accordance with IEEE 421.1 and IEEE 421.3.
    c. The synchronous motor static excitation units shall be controlled by the synchronous motor protection and control unit.
    d. Efficient solid-state static excitation units shall be provided and used to supply DC current into the main field of the synchronous motors.
7. Synchronous motor rating: 1,000 hp, 900 rpm, 113 A, 4,000 V, three-phase, 60 Hz, 1.0 PF, DC excitation: 37.3 field amperes, 125 field volts.
8. SPM:
    a. The DC portion of the synchronous motor (rotor assembly) shall be protected and controlled using a draw-out microprocessor based multifunction relay. The relay shall be adaptable to either collector-ring or brushless type synchronous motors. Protection features shall include the following features:
        1) Cage windings and stall protection during start.
        2) Lockout feature to protect a hot rotor after an incomplete start.
        3) Incomplete sequence trip due to failed acceleration.
        4) Automatic acceleration timer adjustment for reduced voltage starting.
        5) PF (pull-out) trip with auto re-synchronizing feature.
        6) Loss of DC field current trip.
        7) Loss of DC field voltage trip.
        8) Field winding over-temperature trip.
    b. After a successful start, the relay shall automatically apply the DC field to the rotor at a prescribed slip and slip angle to minimize mechanical stresses to the shaft as well as minimize possible electrical transients to the power system. This shall be achieved by a dedicated output to close the DC field contactor. The relay shall also be capable of reluctance torque synchronizing (collector-ring machines only).
    c. A dedicated output shall be provided in the relay to enable the loading of the motor following the DC field application and unloading of the motor following a trip and/or loss of synchronization (pole slipping).
    d. Control of the excitation system shall be by means of an AO to maintain PF (PF regulation).
    e. Man-machine interface shall be in the form of a backlit alpha-numeric display and a keypad to accommodate relay programming as well as viewing actual motor parameters which shall comprise:
        1) AC stator current.
        2) PF.
        3) DC field current.
        4) DC field voltage.

5) DC field resistance.
6) Running time meter.

f. Remote communications shall be provided via an RS485 port. ModBus RTU protocol shall be used with data transmission rates selectable up to 115,200 bps.

g. Statistical data shall include number and type of trips. Prior to starting the motor, the relay shall be capable of performing a complete system check.

9. Surge protection: Surge capacitors and station class surge arrestors.

10. Space heaters:
    a. Space heater rated for 120 V, sized for prevention of condensation in each vertical section.
    b. Adjustable thermostat with temperature range of 50°F to 70°F.
    c. Power supply from control transformer.

11. CT:
    a. Types:
        1) Insulated dry indoor.
        2) Window type for relaying and ground sensing.
        3) Wound type for metering.
    b. Transformer accuracy in accordance with IEEE C57.13:
        1) Class C20 or greater for relaying.
        2) Class 1.2 maximum for imposed burden for metering.
    c. One CT per phase plus zero-sequence CT per starter.
    d. Rating: 5 kV.
    e. Mechanical rating: Equal to short-time current-carrying capability of circuit breakers.
    f. Thermal rating: Maximum 55°C rise above 30°C ambient.
    g. Size to operate continuously at rated primary current without insulation damage.
    h. Identify polarity with standard mark or symbol.
    i. Secondary wiring:
        1) Installed in wiring trough.
        2) Terminate on short-circuiting type terminals.
    j. Isolate from adjacent components and circuits by removable insulating or metal barriers.
    k. Accessible for replacement without removing high-voltage contactor.
    l. Additional requirements as specified in SECTION 26 05 10.
    m. GFCT which shall be donut (window) type CTs 50 to 0.025A, General Electric Multilin model number HGF5C Ground Fault CT.
    n. The 4.16 kV motor controller CTs shall be selected so that the full load secondary currents will lie between approximately 2.5 A and 4.0 A. The motor controller shall be provided with three conventional bar (wound) type CTs, one for each phase. Motor controllers shall use conventional bar (wound) type CTs, except for the GFCT which shall be donut (window) type CTs 50 to 0.025A, model number HGF-5-Ground Fault CT. The appropriate power termination, including single crimp lugs and hardware shall be provided to connect the customer's load cables to the CTs.
        1) The CTs shall have the mechanical and electrical ratings to withstand short-circuit current, stresses and heating effect imposed by their load. Transformers shall have the polarity identified, be capable of carrying rated current continuously, and have ample capacity for connect load.
        2) The CTs shall have accuracy ratings at least equal to NEMA standard requirements for the particular application.
            a) Voltage class:
                (1) Bar: 5 kV.
                (2) Donut: 600 V.
            b) BIL.
                (1) Bar: 60 kV.
                (2) Donut: 10 kV.
            c) Momentary (short-circuit) current rating withstands the let through of the largest fuse.
                (1) Secondary current rating: 5 A.
                (2) Maximum continuous sec. current (bar and donut): 7.5 A.

12. PT:
    a. Additional requirements as specified in SECTION 26 05 10.
    b. Type: Insulated dry, indoor.
    c. Rating: 4,200 V/120 V, single-phase with 60 kV BIL rating.
    d. Two PTs per starter.
    e. Thermal capacity: Minimum 55° rise above 30°C ambient.
    f. Mechanical rating: Equal to short-time current-carrying capability of circuit breaker.
    g. Accuracy classification in accordance with IEEE C57.13 for connected burden.
    h. Primary protection: Two integral mounted current-limiting fuses.
    i. Secondary protection: Single, separately mounted, current-limiting fuse.
    j. Identify polarity with standard marking or symbols.
    k. Mount on a draw-out carriage installed in a separate steel compartment.

l. Primary and secondary terminals to be disconnected and the primary fuses grounded when the draw-out carriage is in the open position.

13. Control transformers:
    a. Type: Insulated dry indoor.
    b. Rating:
        1) 4,160 V/120 V, single-phase, three-wire with 60 kV BIL rating with two, two 1/2% taps above, and two, 2 1/2% taps below normal voltage.
        2) kVA rating for control power requirements plus 200 VA for remote devices and future use.
    c. Stationary mounted in separate steel compartment.
    d. Primary protection: Two current-limiting fuses mounted on draw-out carriage.
    e. Secondary protection: Fuses.
    f. Provisions, including switch, terminals, and wiring for test control power.
14. Terminal blocks:
    a. Rating: 600 V, 30 A minimum.
    b. Type:
        1) One-piece barrier with strap screws.
        2) Shorting type for CT leads.
    c. Pull-apart unit control wiring terminal boards:
        1) Disconnecting externally powered control circuits in accordance with NFPA 70.
        2) On draw-out units as required.
    d. Provide for:
        1) Conductors connecting to circuits external to motor control.
        2) Internal circuits crossing shipping splits with plug connectors.
        3) Equipment parts requiring replacement and maintenance.
    e. Spares: Minimum 20% spare unused terminals.
    f. Grouped together terminal blocks for external circuit wiring leads.
    g. 6 inch minimum space between columns of terminal blocks.
    h. Permanently identify each terminal and columns of terminal blocks.
15. Control wiring:
    a. NFPA 70, Type SIS single conductor, Class B, stranded copper, rated 600 V for control, instrumentation, power, and circuits.
    b. Individual seven-strand copper conductors, twisted and covered with a 100% aluminum, polyester shield with tinned copper drain wire and overall outer jacket, rated 600 V, 90°C minimum for transducer output and analog circuits.
    c. Conductor lugs: Pre-insulated, self-locking, spade type with reinforced heat shrink sleeves.
    d. Wire markers: Each wire individually identified with permanent markers at each end.
    e. Splices: Not permitted.
16. Load cable connections:
    a. Two-hole cable lugs for copper conductors.
    b. Cable lugs sized for conductors as shown on the Drawings.
    c. Provide space for cable stress cones.
    d. Cable entrance: Top.
17. Open-stop-close selector switches as specified in SECTION 26 05 10.
18. Basic electrical materials and methods including, but not limited to, CTs, PTs, push buttons, indicating lights, selector switches, control relays, elapsed time meters, and time delay relays, as specified in SECTION 26 05 10.
19. Control and protective equipment including, but not limited to, control switches, lockout relays, test blocks and plugs, protective relays, as specified in SECTION 26 09 00.

F. Equipment Identification:
1. Master nameplate:
    a. Deep etched aluminum with the Manufacturer’s name and model number.
    b. Riveted to the main vertical section.
2. Section identification:
    a. Stamped or engraved metallic, riveted to each vertical section.
    b. Serial number, bus rating, and section reference number.
    c. Size: Manufacturer’s standard, but no less than 6 inches by 2 inches.
3. Nameplate:
    a. Engraved, phenolic for each incoming service section, motor started unit, and tie switch cubicle and door-mounted device.
    b. White with black block type characters.
    c. Character height: 1/4 inch.
    d. Size: As required for three lines, with fifteen characters each line.
    e. Inscriptions: As shown on one-line diagram.
    f. Blank plates for future spaces.
    g. Attachment screws: Self-tapping or SST pinhead.

4. Cubicle labels:
    a. Nonmetallic, applied inside each cubicle compartment.
    b. Device serial number, rating, and description.
5. Metering instruments: Meter type identified on the meter's face below the pointer or dial.
6. Control switches: Deep etched, aluminum escutcheon plate.
7. Signs:
    a. Two signs each on front of motor controllers.
    b. Size: Manufacturer's standard.
    c. Engraved, phenolic.
    d. Color: Red with white.
    e. Inscription: Danger/high voltage/keepout.
    f. Characters: Gothic type one inch height.
    g. Attachment: Four rivets each sign.
    h. Arc flash labels that meet the OWNER's standard shall be on each section of the motor controller and shall indicate the calculated arc flash rating in accordance with an approved ESA study as specified in SECTION 26 05 70.
8. Device nameplates:
    a. Laminated plastic, white surface, engraved to black core, white with black letters.
    b. Provide for devices internal and external to the switchgear and grounding system.
    c. Engrave with inscription as shown on the Drawings.
    d. Attach with SST panhead screws on the face of switchgear.

G. Factory Tests: Test in accordance with UL 347.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with the Manufacturer's instructions. Install required safety labels.

B. Furnish and completely install switchgear sections and grounding equipment in accordance with the Contract Documents and NFPA 70.

C. Install equipment in accordance with Standards, Submittal Drawings, and the Manufacturer's instructions and recommendations.

D. Secure equipment to mounting pads with anchor bolts of sufficient size and number adequate for specified seismic conditions; anchoring of the equipment shall be approved by the ENGINEER.

E. Install equipment plumb and in longitudinal alignment with the pad or the wall.

F. Coordinate terminal connections with the installation of feeders.

G. Grout mounting channels into the floor or the mounting pads.

H. Retighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.

I. Field adjust trip settings of protective devices to meet the requirements of the ENGINEER-approved ESA.

J. Coordinate terminal connections with installations of motor feeders.

3.2 QUALITY CONTROL

A. As specified in SECTION 26 08 00.

B. Equipment shall be completely factory-built, assembled, wired, and tested. Equipment and components shall be of new construction.

C. Inspect installed switchgear and grounding equipment sections for anchoring, alignment, grounding, and physical damage.
1. Fill concrete-to-equipment voids:
    a. Larger than 1/2 inch: ENGINEER-approved, non-shrink grout.
    b. Smaller than 1/2 inch: Backer-rod and ENGINEER-approved caulk.
2. Caulk around switchgear and grounding equipment concrete-to-equipment interfaces and conduit stub-ups into equipment sheet steel bottoms to minimize dust and insect intrusion.

D. Megger and record phase-to-phase and phase-to-ground insulation resistance of each bus section. Measured insulation resistance shall meet the Manufacturer's requirements and shall be approved by the ENGINEER.

E. Check the tightness of accessible mechanical and electrical connections with a calibrated torque wrench. Minimum acceptable values are specified in the Manufacturer's instructions.

F. Test the system for proper functioning.

G. Inspection:
1. Examine the installation area to ensure there is enough clearance to install controller assemblies and grounding equipment.
2. Check concrete pads for uniformity and level surface.
3. Verify that medium-voltage motor control sections and grounding equipment is ready to install.
4. Verify that field measurements are in accordance with the Contract Documents, instructed by the Manufacturer, and approved by the ENGINEER.
    a. Verify that equipment sizes, equipment pads, etc., are of sufficient size, height, and respective spatial relationship to each other to enable contract equipment to be set in place and connected.
    b. Verify that raceway stubups and penetrations are in the correct position.
5. Verify that required utilities are available, in proper location, and ready for use.
6. Beginning of installation means the installer accepts conditions.

H. Motor Data: Provide a typed, self-adhesive label attached inside each motor starter enclosure door displaying the following information:
   1. Motor served by tag number and equipment name.
   2. Nameplate hp.
   3. Motor code letter.
   4. FLA.
   5. SF.
   6. Installed overload relay heater catalog number.

3.3 CLEANING

A. Clean the interiors of provided equipment to remove construction debris, dirt, and shipping materials.

B. Repair and repaint scratched or marred exterior surfaces to match the original finish. Replace entire surfaces that are not field repairable to ensure there are no visible seams, welds, etc.

3.4 ADJUSTING

A. Adjust switches, access doors, and operating handles for free mechanical and electrical operation in accordance with the Manufacturer's instructions.

B. Adjust relay trip and time delay settings to the values specified and determined by the Manufacturer and the ENGINEER.

END OF SECTION

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SECTION 26 23 00
LOW-VOLTAGE METAL-ENCLOSED SWITCHGEAR

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for low-voltage metal-enclosed switchgear.

B. Related Sections:
1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
7. SECTION 26 09 00 – CONTROL AND PROTECTION EQUIPMENT
8. SECTION 26 12 15 – SECONDARY SUBSTATION TRANSFORMERS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):
1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

B. Institute of Electrical and Electronics Engineers (IEEE):
1. C37.13 – Standard for Low-Voltage AC Power Circuit Breakers Used in Enclosures
2. C37.20.1 – Metal-Enclosed Low-Voltage (1000 VAC and Below, 3200 VDC and Below) Power Circuit Breaker Switchgear

C. National Electrical Manufacturers Association (NEMA):
1. C37.50 – Standard for Switchgear – Low Voltage AC Power Circuit Breakers Used in Enclosures – Test Procedures
2. C37.51 – Switchgear – Metal-Enclosed Low Voltage AC Power Circuit Breaker Switchgear Assemblies – Conformance Test Procedures
3. SG-3 Low-Voltage Power Circuit Breakers

D. National Fire Protection Association (NFPA):
1. 70 – National Electrical Code (NEC)

E. Underwriters Laboratories, Inc. (UL):
1. 489 – Plastics – Determination of refractive index
2. 1558 – Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt, unless otherwise specified in the individual Specification Section. Resubmittals will be subject to the same review time.

C. Shop Drawings:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Dimensioned equipment and layout drawings.
4. Conduit entrance locations: Bus ratings, data, and Drawings, including complete information and Drawings of the connection to the main power transformers.
5. One-line, three-line, and control schematic drawings.
6. Point-to-point compartment wiring diagrams for metering, relay, and control circuits.
7. Show wire and terminal numbers.
8. List options, trip adjustments, and accessories furnished specifically for this Project.
9. Certified protective devices: Copies of time-current trip curves.
10. Certified copies of factory and production test reports.
11. Field test and inspection reports.
12. Anchoring instructions and details.
13. The Equipment Manufacturer shall submit a certified letter stating that the materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at Project and site environmental conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
   e. Factory and field certified test reports: Measured system charging current to support ground resistance system resistor settings.
   f. Calibration, startup, and commissioning reports.

g. Complete lists of equipment furnished, including Manufacturer model numbers, correct settings, alarm points, and operating ranges.
h. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
i. Final As-Built Drawings:
   1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
      a) Drawings shall be on a standard DW provided title block and border.
      b) As-Builts and Manufacturer's drawings shall be provided:
         (1) On a standard DW provided title block and border.
         (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
         (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
         (4) Titles: 0.2 inches.
j. Warranty documentation.

1.4 QUALITY ASSURANCE
A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
B. Actions and devices shall be UL listed and labeled. Service equipment shall be UL labeled as suitable for use as service entrance equipment.
C. Furnish a Manufacturer's Representative as specified in Section 01 44 33, for the following services at jobsite or classroom as designated by OWNER, for the minimum person-days listed herein, travel time excluded:
   1. For installation assistance, and inspection of installation: 1.
   2. For functional and performance testing: 1.
   3. For post-startup training of OWNER's personnel: 1.
   4. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER.

1.5 DELIVERY, STORAGE, AND HANDLING
A. Ambient temperature of the area where the equipment will be installed shall be between -22°F and 104°F and shall be protected to prevent moisture from entering the enclosure.
B. Heat the equipment enclosures with a temporary heat source to prevent condensation in accordance with the storage instructions of the Equipment Manufacturer.
C. Handle the equipment in accordance with the Manufacturer's instructions to avoid damaging the equipment, installed devices, and finish.
D. Protect and handle the equipment in accordance with the recommended practices listed in the Manufacturer's installation publications and maintenance manuals.
E. When stored, the equipment shall be located in a clean, dry space and shall maintain factory protection or the equipment shall be covered with heavy canvas to keep out dirt, water, construction debris, and traffic.
F. Make necessary field measurements to verify that the low-voltage switchgear lineup shall fit in the allocated space in full compliance with the minimum required clearances recommended by the Manufacturer, in accordance with NFPA 70, and required by any applicable local/facility requirements.

1.6 SITE CONDITIONS
A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY
A. Manufacturer: Warranty for 18 months from the Substantial Completion date for the satisfactory performance and installation of the low-voltage metal-enclosed switchgear system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
A. Eaton Cutler-Hammer, Magnum DS
B. ABB/General Electric, AKD-20
C. Square D

2.2 MATERIALS
A. Furnish, box, tag, and clearly mark on exterior, identify each item with Manufacturer's name, description and part number, for shipment and long-term storage and deliver prior to 75% on the Final Completion date the following extra materials:
   1. Crank for racking breakers.
   2. Breaker lifting device.
   3. Manual charging handle and maintenance slow closing device for electrically-operated breakers.
   4. Lamps and LEDs: Two of each size and type.
   5. Control and power fuses: Six of each size and type.
B. Spare parts shall be boxed or packaged for long-term storage and clearly identified on the exterior of the package. Identify each item with the Manufacturer's name, description, and part number.
C. Ratings:
   1. Service: 480 V, three-phase, four-wire, 60 Hz.

2. The switchgear and protective devices shall have a fully rated, short-circuit withstand rating of 65,000 rms symmetrical amperes.
   a. Systems employing series connected ratings shall not be used.
   b. Main and feeder devices shall be coordinated for selective tripping.
3. The switchgear shall be rated for service entrance and comply with UL service entrance requirements.
4. The continuous current rating of the bus shall be in accordance with the Contract Documents:
   a. The bus shall be designed to carry its rated continuous current in the specified ambient temperature without exceeding the temperature rise limits in accordance with IEEE C37.20.1.
   b. Bus bracing shall exceed the specified equipment short-circuit rating.
   c. Line and load bus connections to feeder devices shall be rated to carry the full continuous current of the device frame.

D. Construction:
1. The low-voltage metal-enclosed switchgear lineup shall be engineered and fabricated to meet the electrical distribution, protection, and control requirements detailed in this Specification.
2. Specific equipment lineup properties:
   a. Construction shall house live components in a grounded metal enclosure 92 inches high maximum with a code gauge modular designed steel frame with removable plates.
   b. The overall lineup enclosure construction type shall be rated for outdoor use type in accordance with NEMA 3R.
   c. The overall short-circuit value of the switchgear lineup shall be rated and labeled as 65,000 A at rated voltage.
   d. Under normal conditions, the overall short-circuit value of the switchgear shall be a thirty-cycle short-circuit rating and shall not rely on any instantaneous, premature, discriminator, making-current-release function of a protective device to achieve the overall rating.
   e. A ground bus shall be secured to each vertical section structure.
   f. It shall also extend the entire length of switchgear lineup and shall be equipped with a minimum of two, 4/0 terminals in each section for connection to the ground grid.
   g. The ground bus in the switchgear lineup shall be made of copper and shall run through all sections.
   h. A copper neutral bus shall be mounted on stand-off insulators to isolate it from ground.
   i. The specifics of the equipment neutral bus shall have a full rating (100%) neutral bar, the neutral bus.
   j. Equipment shall be considered as service entrance equipment in accordance with NFPA 70.
   k. The same material shall be used at the vertical-to-horizontal bus connections and at points where vertical bus connects to bus bars supplying power to circuit breaker compartments.
   l. Bus material and plating in the switchgear lineup shall be copper buses with full tin plating.
   m. Bus hardware shall be high tensile strength zinc chromate plated steel.
   n. Belleville washers shall be provided on bolted bus joints.
   o. The vertical bus shall be held rigid in support structure of short-circuit resistant, molded glass reinforced polyester bases to inhibit the spread of arcing faults.
   p. Bus bars shall be arranged to permit the addition of future additions.
   q. The switchgear shall have rear cable terminal compartments.
   r. The cable bending space shall be in accordance with NFPA 70.
   s. The maximum overall equipment lineup depth shall be as shown on the Drawings.
   t. Sufficient space shall be provided to accommodate conduit openings, cable entrance, or bus entrances as shown on the Drawings.
   u. The lineup shall be painted using a two-step process.
      1) Step 1: A light gray paint shall be applied using an epoxy electro-deposition process.
      2) Step 2: The paint shall be over sprayed on the exterior surfaces.
      3) The final exterior color of the equipment shall be in accordance with ANSI 61 gray or similar.
      4) The interior color shall be white or similar.
   v. The equipment lineup shall be provided with heaters (the equipment is outdoor in accordance with NEMA 3R).
   w. Breaker door interlock is required to prevent the compartment door from opening unless the breaker is in the test or disconnect position.
   x. Rear floor plates are required. Provide metal plates in the bottom of the power cable compartment along the floor to seal off the compartment:
   y. A test kit shall be provided to independently test breaker tripping and operational readiness.
   z. Insect screens in the equipment lineup are required as there is a concern of possible rodent/insect migration into the switchgear.
   aa. A test cabinet position for the circuit breakers is required for testing of the breaker charging, tripping, and closing functions.
   bb. Provide a device to lift the fully withdrawn circuit breakers off their rail assemblies. A portable hydraulically-operated crane lifting device shall be capable of rolling on the floor and shall be hand-operated.
   cc. In accordance with UL 1558, a label shall be provided on the equipment verifying that the lineup meets the requirements of UL for metal-enclosed low-voltage power circuit breaker switchgear.
   dd. A UL service entrance label is required.
   ee. The rear of the switchgear shall be provided with bolted covers.
   ff. Access to the rear compartment of the switchgear shall not require any additional provisions.
      1) Opening the rear covers shall be accomplished by removing the corner bolts.

2) Securing the rear covers shall be accomplished tightening the corner bolts.
3) Service into the rear sections shall be accomplished by removing the rear covers.
4) Locks on the rear section doors or panels are not required.

gg. The switchgear front doors shall have quarter-turn latches with padlocking provisions to prevent unauthorized entry into the front compartment.

hh. Conductors shall terminate into compression lugs, two-hole long barrel type shall be provided for every cable connection. The direction of the cables being fed from the equipment shall be bottom unless otherwise shown on the Drawings.

ii. The switchgear lineup shall be provided with rear cable space.
1) Cables shall enter and exit using the Manufacturer-defined power cable conduit areas. No additional pull box accessory is required.

3. Transformer secondary (outgoing/load) section:
a. Provide and install close coupled low-voltage power circuit breakers (52STS) mounted in separate metal-enclosed weatherproof in accordance with NEMA 3R compartment within terminal compartment.
b. The circuit breaker shall be accessible through a hinged door.
c. Estimated circuit breaker ratings are as shown on the Drawings and shall be sized and coordinated as part of the ESA short-circuit and protective device coordination studies.
d. Transformer to power circuit breaker transition bussing shall be insulated tin-plated copper, sizing and configuration shall be approved by the ENGINEER.
e. Transformer to power circuit breaker flexible transition bussing shall be insulated tin-plated copper, sizing and configuration shall be approved by the ENGINEER.
f. Low-voltage power breakers shall be provided with adjustable long-time, short-time, instantaneous, and ground fault trip functions.
g. Circuit breakers are required to meet the specified equipment short-circuit rating.
h. Circuit breakers:
1) Protective devices shall be in accordance with UL 489 listed for 100% of continuous ampere rating for use with 70°C conductors at full 75°C ampacity when mounted in switchgear.
2) Frame sizes: As shown on the Drawings with solid-state trip units.
3) Interrupting rating: The rms symmetrical rating shall be as shown on the Drawings at rated voltage.
4) Breakers shall have selective override circuitry with long-time, short-time, and instantaneous adjustment for selectivity up to rated rms value.
5) As specified in SECTION 26 12 15 for coordination with transformer.

4. Structure:
a. Switchgear shall be outdoor type in accordance with NEMA 3R, completely metal-enclosed and sectionalized to isolate and minimize the effects of internal short-circuit currents.
b. The structure shall consist of a framework of preformed steel channels or angles covered with bolted steel sheets.
c. Each individual breaker/metering cell shall be completely segregated from adjacent compartments and sections by steel barriers at top, bottom, rear, and sides.
d. Breaker compartments shall be equipped with shutters to protect against contact with the energized primary disconnects when the breaker is removed from its compartment.
e. Each individual breaker cell, metering, and auxiliary compartment shall be provided with a hinged front panel door.
f. Provide side barriers between adjacent vertical structures in cable and bus compartments.
g. Rear cable compartments shall be isolated from the main and riser bus by insulated or grounded steel barriers.
h. Provide cable supports in each vertical section.
i. Cable compartments shall be extra depth with bending space in accordance with the NFPA 70.
j. Provide hinged and bolted covers on the rear of each vertical section.
k. Shelter-clad common aisle outdoor switchgear:
1) Consists of an indoor type circuit breaker and auxiliary sections located in a weatherproof steel housing having a common operating aisle space of sufficient size to permit withdrawal of the circuit breakers for inspection, test, or maintenance. An access door shall be located at each end of the aisle. Each door shall have an integral keyed lock, keyed to DW's standard electric shop key on the outside. Each door shall be furnished with a panic bar door operator so that the door can be opened from the inside regardless of whether or not it has been locked on the outside. The aisle space shall have adequate lighting which will be controlled by means of a three-way switch at each access door.
2) Included in the switchgear shall be:
a) Louvers – provide combination damper/louver for intake and exhaust penetrations:
(1) Drainable combination louver damper.
(2) 16 gauge galvanized steel frame, 18 gauge galvanized steel drainable front blades, 16 gauge galvanized steel adjustable rear damper blades.
(3) Size: 12 inches by 12 inches or sized to maintain face velocities less than 700 fpm, with pressure drop less than 0.05-inch water gauge.
(4) Two-position spring return actuator. Sized to fully open and close damper in conditions between -22°F through 122°F, 180 in/lb minimum torque, 120 VAC, fail closed.

(5) Paint louver to match exterior of building.

b) Ventilation fan: Provide a wall-mounted inline exhaust fan:

(1) Capacity: 150 cfm or ten air changes per hour, whichever is greater.

(2) Motor: NEMA premium, thermal overload protection, open drip proof casing, permanently lubricated bearings, 1.15 SF, and brake hp shall not exceed the motor's nameplate rating.

(3) Electrical: 120/1/60.

(4) Enclosed fan blade or OSHA rated fan guard.

(5) Balance ventilation fan.

(6) Operated and meets performance requirements at site elevation.

(7) Equipment identification plates: Furnish Manufacturer's ID plate including make, model, and Manufacturer.

(8) Install level and plumb with vibration isolators.

(9) Controls: Furnish one heavy duty line voltage thermostat. Temperature range 55°F to 95°F. Install on north wall with insulation media between thermostat and exterior wall.

c) Filtered intake: Provide intake filter box with replaceable 1-inch pleated panel filter.

d) Unit heaters: Provide a self-contained electric-resistant unit heat:

(1) Capacity: 5 kW.

(2) Electrical: 208 V/three-phase/60 Hz.

(3) Integral disconnect switch.

(4) Integral summer switch.

(5) Totally enclosed fan motor, rated for continuous duty.

(6) Dynamically balanced fan.

(7) Individually adjustable louvers.

(8) Cabinet: 18 gauge steel arranged for wall or ceiling mounting brackets.

(9) Electric heating coil: Fin tube heating elements have corrosion-resistant steel fins that are furnace brazed to the tubular element.

(10) Thermal overload protection with automatic reset.

e) Two utility duplex receptacles with integral ground fault protection, one at each aisle access door, for electric tools, extension cords, etc.

f) An exterior-mounted weatherproof switch at each door for arc flash reduction levels while personnel are inside equipment. The switch shall be labeled and the switch position shall be visible.

3) Switchgear shall be shipped in convenient groups for erection in the field, and shipping groups ordinarily shall not exceed 16 feet in length.

4) The weatherproof enclosure for the aisleway shall be shipped in sections for erection in the field. Necessary erection hardware shall be furnished.

5. Buses:

a. Main bus, riser bus, and circuit breaker connections shall be insulated tin-plated copper, with bolted connections.

b. Bus bars shall not be tapered.

c. Bolted connections shall be made with high-strength bolts and locking hardware.

d. Individual horizontal and vertical phase bus bars shall be insulated where industry standard 600 V clearances cannot be met.

e. Breaker runbacks shall be insulated.

f. Provide a continuous, 1/4 inch by 2 inch, plated copper ground bus extending throughout the entire length of the switchgear, equipped with lugs for external ground connections, sized for cables as shown on the Drawings.

6. Low-voltage power circuit breakers:

a. Circuit breakers shall be air-break, low-voltage, draw-out type, manually or electrically-operated with stored energy closing mechanism.

b. Circuit breakers shall be in accordance with IEEE C37.13, and NEMA SG-3.

c. Each breaker shall have a secondary control power plug which automatically engages a cell-mounted mating receptacle in the connected position and disengages as the circuit breaker is racked out to the test/disconnect position.

d. Provide a means to manually engage the control power plug in the test/disconnect position.

e. Breaker contacts on the removable element auxiliary switch shall be wired to terminal blocks.

f. Provide ten normally open and two normally closed spare auxiliary contacts in addition to the auxiliary contacts required for breaker operation.

g. Normally closed auxiliary contacts shall break before the normally open auxiliary contacts make.

h. Circuit breakers shall be equipped with mechanism-operated auxiliary switch contacts for remote status indication.

i. Provide ten spare A and ten spare B contacts wired to terminal blocks.

j. The cell for future breakers shall be fully equipped with draw-out carriage, racking mechanism, primary and secondary contacts, and CTs.

k. Provide an ARMS to reduce arc flash incident energy when engaged. The ARMS systems shall include the following:

1) Adjustable trip settings.

    2) Indication of maintenance node activated.
    3) Local and remote activation.

7. Breakers shall be a three-pole, electrically and mechanically trip free unit with self-aligning primary and secondary disconnecting contacts, arc quenchers, position indicator, and the necessary hardware to mount on a draw-out mechanism in the compartment.
8. Circuit breakers shall be draw-out type and the primary connections shall be fully silver-plated copper-to-copper.
9. A true closed-door draw-out mechanism shall be employed to permit the circuit breaker to be moved from the connected to disconnected position without opening the cubicle door.
10. If closed-door racking is not available, the Manufacturer's quotation shall note this exception to be considered as a possible acceptable alternative.
11. The draw-out mechanism shall provide four distinct positions: Connected, test, disconnected, and withdrawn.
12. An indicator shall be provided to show the position status.
13. The cubicle door shall be able to close when the circuit breaker is in the connected, test, or disconnect position.
14. Each circuit breaker compartment shall have grounded barriers at top, bottom, front, and sides.
15. Furnish each compartment with draw-out rails and the necessary secondary control contact points.
16. Padlocking provision shall permit locking the breaker in the test and disconnected positions while in the cubicle.
17. Grounding of the breaker frame to the switchgear steel frame shall be maintained throughout the travel of the draw-out mechanism.
18. Each breaker cubicle shall be designed so that only the frame for which the cubicle was designed, or one with higher short-circuit ratings, or combination of higher short-circuit and continuous current ratings, can be inserted.
19. Devices of equal frame size shall be interchangeable.
20. Manual or electrical closing mechanisms shall use an energy storage spring between the operator and the breaker contacts.
    a. The spring shall provide a constant closing speed not influenced by operator speed or control power voltage level.
    b. Electrically type via a motor to charge the closing springs.
    c. Closing shall be accomplished by pressing a close push button.
    d. Opening shall be accomplished by pressing an open/trip push button.
    e. Manual charging of the closing springs may still be accomplished via the front-mounted handle.
    f. The spring charging motor shall have a nominal control voltage rating of 120 VAC.
21. Breaker configuration:
    a. The 52STS main breaker shall have a nominal trip rating of 700 A rating for a 1,500 A sensor.
    b. This nominal setting shall be established via either a current setting rotary switch or a rating plug.
    c. The circuit breakers are a non-fused style breaker.
    d. The compartment connection to the top and bottom shall be as required and as shown on the Drawings.
    e. Service entrance labels are required for main source breakers.
    f. The compartment door shall be provided with a defeatable compartment door interlock to prevent inadvertent opening of the compartment door unless the breaker is in the disconnected position.
    g. The compartment shall be equipped with a position switch (two form A and two form B contacts) shall signal to the automatic throw over system if the breaker is in the racked-in or disconnected position.
    h. The circuit breaker and trip unit system provides a wide variety of protective, signaling, and control functions.
    i. Specific requirements to be supplied with the main circuit breaker:
        1) Long time protection shall be provided with adjustable pickup and delay:
            a) The long time setting shall be available for circuit breaker I2T curves and fuse I4T curves.
            b) Long time settings shall have the flexibility of adjustment of 1.5x pickup commit times ranging from 4.25 to 509.5 seconds and at 15x commit times shall be 0.032 to 3.81 seconds for circuit breaker curves.
            c) Long time settings shall have the flexibility of adjustment of 1.5x pickup commit times ranging from 0.67 to 539.66 seconds and at 15x commit times are 0.025 to 0.13 for fuse curves.
        2) Ground-fault protection is required as an alarm-only function, as the breaker will not trip but will signal an alarm.
        3) It shall be provided with adjustable pickup and delay.
        4) Short-time protection shall be provided with adjustable pickup and delay.
        5) The short-time settings shall be adjustable in 0.05x increments ranging from 1.5x to 12x the long time pickup.
        6) The short-time delay bands shall be adjustable in 55 ms increments.
        7) Instantaneous protection shall be provided with adjustable pickup:
            a) This function shall be a true adjustable with low range settings, not with only high range or fixed high range.
            b) The instantaneous pickup shall range from 1.5x to 30x in 0.5x increments.
        8) To provide field coordination flexibility, either the short-time or instantaneous functions shall be capable of being switched off.
        9) Provide ARMS to reduce arc flash incident energy when engaged or with contact input. The ARMS systems shall include the following:
            a) Adjustable trip settings.
            b) Indication of maintenance node activated.

        c) Local and remote activation.
    j. As the breaker is electrically-operated, the breaker closing springs will be charged via a spring charging motor.
    k. Control voltage/power of 110 VAC to130 VAC shall be provided.
    l. The breaker shall be capable of performing independent tripping functions.
    m. A 120 VAC shunt trip shall be provided on electrically-operated breakers.
    n. The breaker shall be provided with a bell alarm to provide an additional signal that the breaker tripped.
    o. This bell alarm shall be provided with a lockout function such that the breaker cannot be closed until the lockout has been reset.
    p. As there is a need to provide a preemptive alert of a critical breaker tripping, abnormal loading/above nominal ampere draw, the breaker shall be provided with the high current alarm option.
    q. The user adjustable pickup point shall send a signal when the breaker exceeds the established value.
    r. The trip unit shall be provided with adjustable selective instantaneous capability: When used in conjunction with current limiting devices downstream, the trip unit may be set low and still maintain significant levels of selective coordination.
    s. The trip unit shall be provided with a backlit display with the capability to see the three phases on one screen simultaneously.
    t. An IP54 dust-proof circuit breaker and trip unit cover shall be provided.
    u. A circuit breaker mechanical operations counter shall be provided.

22. Secondary wiring and control devices:
    a. Identification of the control wiring within the equipment lineup shall be provided with wire sleeves.
    b. To assist in tracing circuitry, the sleeves will identify the origin and destination of the specific wire/circuit.
    c. As the control circuitry in the lineup will tie into other control circuits and as there is a need for unique/individual/specific/non-repeating wire tags, the sleeves will follow configuration.
    d. Wire terminals for the control wiring within the equipment lineup shall be special ring insulated terminals, and where ring terminals are used to connect CT circuits.
    e. Minimum wire size for the control wiring within the equipment lineup shall be #14 AWG, extra flexible, stranded, tinned-copper, type SIS XLP, rated 600 V, except for specific circuits requiring larger wire.
    f. Wire terminals for the CTs within the equipment lineup shall be crimp-type, insulated ring terminals.
    g. Minimum wire size for the CTs with 5 A secondary, within the equipment lineup, shall be #12 AWG, extra flexible, stranded, tinned-copper, type SIS XLP, and rated 600 V.
    h. Short-circuit terminal blocks shall be provided for CT connections.
    i. The screw terminals shall have no more the two wires under a single screw to allow field swapping of wires: Six screw block for three CTs with no neutral circuit; eight screw block for three CTs with a neutral circuit.
    j. Short-circuit terminal blocks are not required if the CTs are provided with integral open circuit protection.
    k. Instrument and control switches: 600 V switchboard rotary type, rated 20 A continuous, with black molded phenolic escutcheon plates, white characters:
        1) Circuit breaker control switches shall be of the momentary contact, spring return type having mechanical target or flag and a black, fixed, pistol grip handle.
        2) Ammeter and voltmeter transfer switches shall be maintained contact, non-spring return type with black, fixed, knurled handle.
    l. Indicator lights: Provide green, red, and amber pilot lights for each circuit breaker open, closed, and trip indication.

23. Relays:
    a. Voltage sensing relays: Adjustable, solid-state devices with 5 A output contacts and three-phase rms sensing.
    b. Relays shall respond to reverse phase and negative sequence voltage conditions.
    c. Pick-up and drop-out SPs shall be independently adjustable.
    d. Relay accuracy shall not be affected by harmonic distortion of the supply waveform.
    e. Time delay relays: Electro-pneumatic type, either on-delay or off-delay as required, with calibrated timing head and 20 A contacts (120 VAC, resistive).

24. Marking and identification:
    a. Provide nameplates on each breaker cell door and for each control or indicating device.
    b. Nameplates shall be engraved as shown on the Drawings or as directed, using lettering approximately 3/8 inch high for unit identification nameplates and 1/4 inch high elsewhere.
    c. The nameplates shall be black and white laminated phenolic material.
    d. The engraving shall extend through the black exterior lamination to the white core.
    e. Nameplates shall be screw fastened.
    f. Provide permanent master nameplate for switchgear designation, Manufacturer's name, model number, order number and voltage, current, and interrupting ratings.
    g. Provide warning signs marked DANGER – 480 VOLTS KEEP OUT ON EACH REAR COMPARTMENT DOOR.
    h. Signs shall be adhesive-backed mylar, OSHA approved.

25. Basic electrical materials and methods including, but not limited to, CTs, potential transformers, push buttons, indicating lights, selector switches, control relays, elapsed time meters, and time delay relays, as specified in SECTION 26 05 10.

26. Control and protective equipment including, but not limited to, control switches, lockout relays, test blocks and plugs, protective relays, as specified in SECTION 26 09 00.

E. Shop Testing:

1. Perform the Manufacturer's standard production testing and inspection in accordance with ANSI/NETA ATS.
2. If requested by the ENGINEER, the Manufacturer shall submit certified copies of test results to indicate proof in accordance with NEMA C37.50 and NEMA C37.51.

PART 3 EXECUTION

3.1 INSTALLATION

A. The equipment shall be leveled and anchored directly to a concrete equipment pad or finished floor as shown on the Drawings:

1. Provide hardware and metal shims for installation.
2. Grout and caulk voids beneath the equipment base.
3. Anchor bolts shall be 1/2-inch galvanized steel.

B. Install the equipment in accordance with the Manufacturer's instructions.

C. Remove temporary lifting angles, lugs, and shipping braces.

D. Touch-up damaged paint finishes.

E. Make wiring interconnections between shipping splits.

F. Install bus splice plates and torque the connections.

G. Caulk seams, cracks, and openings in outdoor enclosures.

3.2 QUALITY CONTROL

A. Field Testing:

1. Additional testing as specified in SECTION 26 08 00.
2. Engage the services of a recognized, independent testing firm to inspect and test the installed equipment prior to energization.
3. The testing firm shall provide material, labor, equipment, and technical supervision to perform the tests and inspection.
4. Notify the OWNER and the ENGINEER at least 2 weeks prior to scheduling any testing.
5. Equipment testing and inspection shall be performed in accordance with ANSI/NETA ATS.
6. In the event of an equipment fault, notify the ENGINEER and the OWNER immediately.
7. After the cause of the fault has been identified and corrected, a joint inspection of the equipment shall be conducted by the CONTRACTOR, the ENGINEER, and the OWNER, and the Equipment Manufacturer's factory service technician.
8. Repair or replace the equipment as directed by the ENGINEER and the OWNER prior to placing the equipment back into service.

3.3 ADJUSTMENT

A. The Switchgear Manufacturer's factory service technician shall:

1. Calibrate and test circuit breaker trip devices, relays, and controls in accordance with the final version of the Coordination study as specified in SECTION 26 05 70.
2. Adjust and lubricate circuit breaker operating mechanisms and contacts.

3.4 CLEANING

A. Remove rubbish and debris from inside and around the switchgear.

B. Remove dirt, dust, or concrete spatter from the interior and exterior of the equipment using brushes, vacuum cleaner, or clean, lint-free rags.

C. Do not use compressed air.

END OF SECTION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for low-voltage motor controls.

B. Related Sections:
1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
7. SECTION 26 09 00 – CONTROL AND PROTECTION EQUIPMENT
8. SECTION 26 43 00 – LOW-VOLTAGE SURGE PROTECTIVE DEVICES
9. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):
1. ATS – Standard for Acceptance Testing Specifications for Electrical Power Equipment and Systems

B. Institute of Electrical and Electronics Engineers (IEEE):
1. C57.12.28 – Standard for Pad-Mounted Equipment – Enclosure Integrity

C. National Electrical Manufacturers Association (NEMA):
1. 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)
2. ICS 1 – Industrial Control and Systems: General Requirements
3. ICS 2 – Controllers, Contactors and Overload Relays Rated 600 V
4. ICS 2.3 – Instructions for the Handling, Installation, Operation and Maintenance of Motor Control Centers Rated Not More than 600 V
5. KS 1 – Heavy Duty Enclosed and Dead-Front Switches (600 Volts Maximum)

D. National Fire Protection Association (NFPA):
1. 70 – National Electrical Code (NEC)

E. Underwriters Laboratories, Inc. (UL):
1. 98 – Enclosed and Dead-Front Switches
2. 489 – Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures
3. 845 – Motor Control Centers
4. 1008S – Standard for Solid-State Transfer Switches

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt, unless otherwise specified. Resubmittals will be subject to the same review time.

C. Shop Drawings:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Conduit entrance locations.
4. Bus ratings, data, connection information, torque values, and drawings.
5. Protective devices: Copies of time-current characteristics.
6. Anchoring instructions and details.
7. Typed tabulation:
    a. Motor name; tag (equipment) numbers as shown on the Drawings.
    b. Motor hp.
    c. Nameplate full load current.
    d. Measured load current and voltage.
    e. Heater or solid-state overload relay catalog number.
    f. Protective device trip settings.
8. Attach the tabulated data to a copy of the Starter Manufacturer's overload heater selection tables or solid-state overload relay information for the starters provided.
9. Control diagrams:
    a. In accordance with NEMA ICS 2, Section 322.08 Type II(S).
    b. Wiring type B.
    c. In addition to standard NEMA control diagrams, provide:
        1) Remote control devices.
        2) Remote indication and/or pilot lights.
        3) Interconnections and interlocking circuits between starter and remote equipment.
        4) Remote sensors.
        5) Control devices and equipment identification.
        6) Conductor and terminal identification.
10. System configuration with single-line and three-line diagrams.

11. Detailed descriptions of equipment, including weights, dimensions, foundation requirements, and installation and anchoring requirements.
12. Construction details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, louvers, mounting brackets and tabs, door hinges and latches, and welding.
13. Complete dimensional drawings indicating sizes and clearances required for equipment. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
14. Cable access areas and cable routing
15. Samples of LCPs mimic bus graphic materials, colors, and adhesive. Interconnection and schematic diagrams for power and control wiring showing conduit runs and wiring with terminal numbers for each wire. Clearly identify contacts, terminal blocks, and wire numbers for remote devices. Show field devices and wiring on diagrams.
16. Detailed layouts of metering and monitoring panels. The metering sensing points shall be shown on the single-line diagram.
17. Individual unit, bucket, connection diagrams, and dimensioned layout drawings.
18. Equipment layout diagrams.
19. Interconnection diagrams.
20. Automatic transfer switch sizing report.
21. The Equipment Manufacturer shall submit a certified letter stating that the materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site environmental conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
   e. Factory and field certified test reports.
   f. Software documentation: Updated version of software.
      1) Hardcopy and electronic version of installed programs in controllers and equipment.
   g. Calibration, startup, and commissioning reports.
      1) Include complete lists of equipment furnished, including the Manufacturer’s model numbers, correct settings, alarm points, and operating ranges.
   h. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
   i. Final As-Built Drawings:
      1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW’s current CAD Standards and shall include, but not be limited to, the Standards located online in DW’s CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         a) Drawings shall be on a standard DW provided title block and border.
         b) As-Builts and Manufacturer’s drawings shall be provided:
            (1) On a standard DW provided title block and border.
            (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
            (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
            (4) Titles: 0.2 inches.
   j. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer’s name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
1. Fuses: A minimum of six of each type and size.
2. Lamps and LEDs: Minimum of two, of each type and size.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services:
1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
   a. Installation assistance, and inspection of installation: 1.
   b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by the CONTRACTOR to facilitate the ingress of equipment to the final installation location within the building.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the low-voltage motor control system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Eaton Cutler-Hammer

B. ABB/General Electric

C. Square D

D. Automatic Transfer Switch:

1. Eaton
2. Square D
3. Electric Equipment & Engineering Company

2.2 COMPONENTS

A. Motor Control:

1. General:

a. Like items of equipment shall be the end product of one Manufacturer.

b. Make adjustments as necessary to wiring, conduits, disconnect devices, motor starters, branch circuit protection, and other affected material or equipment to accommodate motors provided under the Contract.

c. Refer to Drawings for the actual layout and location of equipment and components; current ratings of devices, bus bars, and components; voltage ratings of devices, components, and assemblies; and other required details.

d. Motor controllers shall be designed for continuous operation of induction motors at 600 V maximum, at 60 Hz, and shall be in accordance with NEMA ICS 2. Starters shall be electrically held and wired to provide low voltage power and release. Coil and contact kit replacement parts shall be shown on the label or coil of the contactor. Starters shall be 120 V coil, three-pole, 600 VAC, 60 Hz, NEMA size 1, minimum. Power wiring shall be straight through the starter with incoming power to the top and load wiring at the bottom. Contacts shall be double break, silver cadmium oxide, and weld-resistant. Contacts shall be isolated to prevent arcing. Coils, magnets, and contacts shall be capable of being removed or replaced, without special tools, in the field. The contactors shall have MOV type, transient voltage surge suppression across the coils. Transient voltage surge suppression shall be mounted directly across the coil terminals of magnetic starters. The suppressor shall limit voltage transients produced by the coil to 220% maximum peak line volts.

e. Solid-state overload protection shall be provided. The solid-state overload relay shall be self-powered requiring no additional wiring or control power and be self-protected from short-circuits in the motor branch circuit. Each overload shall be adjustable over a full two to one FLA adjustment range. The overload shall have a ±2% trip repeatability over its entire operating range. The standard overload shall provide Class 20 overload protection, but Class 10 and Class 30 protection shall also be available. Submersible pump motors shall be provided with Class 10 protection. The overload shall provide phase loss protection by tripping in 3 seconds or less under a phase loss condition. The overload shall be capable of protecting the motor in a starting, full load, or lightly loaded condition against single-phase damage. The overload and phase loss protection shall not be able to be defeated by any changes to the setting of the overload. The overload shall be ambient insensitive and able to operate in a temperature range of -22°F to 159°F. The overload relay shall have a trip-free normally closed contact rated NEMA A600 with a visible trip indication. The overload relay shall be provided with an additional normally closed auxiliary contact rated NEMA A600. The overload shall have a method of being manually tripped for test purposes.

f. Thermal overload protection shall be provided only when shown on the Drawings:

1) Inverse-time-limit characteristic.
2) Heater: Class 10, bimetallic overload, adjustable trip.
3) Relay trip: Standard, Class 20.
4) Manual reset.
5) Provide in each ungrounded phase.
6) Mount within starter unit.

g. Control transformer:

1) Two winding, 120 V secondary, primary voltage to suit.
2) Two current-limiting fuses for primary circuit.
3) One fuse in secondary circuit.
4) Mount within starter unit.

h. Suitable for use with 75°C wire in accordance with NFPA 70, 75°C ampacity.

i. Lifting lugs on equipment and devices weighing over 100 lbs.

j. Anchor bolts: Galvanized, sized by the Equipment Manufacturer, 1/2 inch minimum diameter.

k. Operating conditions:

1) Ambient temperature: Maximum 104°F.
2) Equipment to be fully rated without any derating for operating conditions listed herein.

l. Enclosures: In accordance with NEMA 250 and IEEE C57.12.28.

m. Equipment finish:
    1) Electrocoating process applied over a rust-inhibiting phosphated base coating.
    2) Exterior color: ANSI 61, light gray.

2. Manually-operated starter, fractional hp:
    a. Rating: 16 A continuous at 277 V maximum.
    b. Single-phase, non-reversing, full voltage with overload protection.
    c. Toggle-operated, keyed where shown.
    d. Enclosure: NEMA 250, Type 4.
    e. Neon light: Red.
    f. Handle guard/lock-off attachment.
3. Combination full voltage, magnetic starter:
    a. Rating: Hp rated at 600 V, UL labeled for a minimum of 42,000 A with overload protection.
    b. Three-phase, non-reversing, full voltage.
    c. Control: As shown on the Drawings, or match existing.
    d. Disconnect type: Circuit breaker, or as shown on the Drawings.
    e. Enclosure: NEMA 250, Type 4.
    f. Pilot lights: Red – on; green – off.
    g. Padlockable operating handle.
    h. Nameplates:
        1) Laminated plastic, white surface, engraved to black core (white with black letters).
        2) Engrave with the inscription shown on the Drawings.
        3) Attach with SST panhead screws.
        4) Devices, components, terminal blocks, and equipment as approved by the ENGINEER shall have designated nameplates.

B. MCCs:
1. General:
    a. In accordance with NEMA ICS 2 and UL 845.
    b. Voltage rating: 600 V.
    c. Short-circuit rating: Minimum 42,000 A rms symmetrical, or as shown for entire MCC as a complete assembly.
    d. Controllers, main and branch circuit breakers, wire connections, and other devices to be front-mounted and accessible.
    e. In accordance with NEMA ICS 2, Section 322.08.
        1) Class: II(S).
        2) Type: B.
        3) Provide blank spaces on interconnection diagrams to add control conductor code designations during the installation of equipment.
2. Enclosure:
    a. Type: NEMA 250 Type 12.
    b. Vertical section dimensions: 90 inches high, 20 inches wide, and 20 inches deep.
    c. Construction:
        1) Sheet steel reinforced with channel or angle irons.
        2) Butt sections flush, end-to-end against similar section without bolts, nuts, or cover plates causing interference.
        3) Removable top cover plates and bottom cover plates.
        4) Removable plates on end panels for future bus extension.
    d. Section mounting: Removable formed-steel channel sills and lifting angles to meet specified seismic requirements.
    e. Horizontal wiring compartments: Accessible from the front, full width, top, and bottom.
    f. Vertical wiring compartment: Full height, isolated from unit starters with a separate door.
    g. Terminal board compartment: At unit space indicated with 20% spare terminals.
    h. Unit compartment: Individual compartments separated by steel barriers for each starter, feeder, or other unit capable of being wired from the front without unit removal.
    i. Compartment doors: Separate hinged doors for each starter, feeder, or other unit.
    j. Door interlocking: Interlock starter and feeder doors mechanically so doors cannot be opened with unit energized. Provide defeater mechanism to allow intentional access at any time.
    k. External disconnect handles, padlockable in the off position.
    l. Cable entrance: Main leads enter as shown on the Drawings; control and feeder circuits enter from the top and the bottom.
3. Bus:
    a. Horizontal power bus:
        1) 600 A minimum rated bus, three-phase, tin-plated copper, extending the entire width of the control center rated as indicated.
        2) Construct to allow the future extension of additional sections.
        3) Pressure type solderless lugs for each incoming line cable.
        4) Isolated from the top horizontal wireway.
        5) Provide Belleville washers on bus connection bolts, two bolts minimum.

b. Vertical power bus:
    1) Three-phase, tin-plated copper, full height of section, rated a minimum of 300 A.
    2) Sandwich type bus insulation providing deadfront construction with starter units removed except for bus stab openings.
    3) Insulated and isolated barrier complete with shutters.
    4) Provide Belleville washers on bus connection bolts.
c. Ground bus:
    1) Copper, 33% minimum of phase bus ampacity, the entire width of the control center.
    2) Provide Belleville washers on bus connection bolts.
d. Bus bracing: Minimum 42,000 A rms symmetrical.
e. Neutral bus:
    1) 100% neutral, the entire width of the control center.
    2) Copper, tin-plated.
    3) Provide Belleville washers on bus connection bolts.

4. Motor controller unit:
    a. Construction:
        1) Draw-out combination type with stab connections for starters NEMA ICS, size 4 and smaller.
        2) Readily interchangeable with starters of similar size.
        3) Pull-apart unit control wiring terminal boards on units.
    b. Starters:
        1) NEMA ICS 2, Section 322.08 standard rating, except none smaller than NEMA ICS, size 1.
        2) Rating: Hp rated at 600 V, UL labeled for a minimum of 42,000 A with overload protection.
        3) Three-phase, non-reversing.
        4) Disconnect type: Motor circuit protector.
        5) Combination full voltage, magnetic starter:
            a) Control: As shown on the Drawings.
            b) Pilot lights: Red – on; green – off.
        6) Padlockable operating handle when de-energized.
        7) Unit door interlocked to prevent opening when disconnect is in closed position.
        8) Mechanical interlocked to prevent placing disconnect in the on position when the unit door is open.
        9) Minimum dimensions: 12 inches high by full section width, less vertical wireway.
    c. Disconnecting device:
        1) As shown on the Drawings.
        2) Padlockable in the open position.
    d. Circuit breaker:
        1) In accordance with UL 489.
        2) Molded case with the Manufacturer's recommended trip setting for maximum motor protection.
        3) Thermal-magnetic trip or magnetic trip only as shown on the Drawings.
        4) Tripping indicated by operating-handle position.
        5) Interrupting capacity required for the connection to the system with short-circuit capacity shown on the Drawings.
    e. Fused switch:
        1) Heavy duty, motor rated, load-break, quick-make, quick-break type in accordance with UL 98 and NEMA KS 1.
        2) Current-limiting fuses, with rejection clips.
    f. Motor overload protection:
        1) Solid-state.
        2) Thermal overload protection shall be a temperature compensated, three-pole relay with bimetallic, adjustable trip elements. Thermal overload protection shall be provided only when shown on the Drawings.
        3) Solid-state and thermal overload relays shall be manual reset type.
    g. Motor thermal protector interface: Manual-reset interposing relay for connection to motor-mounted thermal protector system, provided only when shown on the Drawings.
5. Control unit:
    a. Disconnecting device: Capable of de-energizing external source control circuits in unit.
    b. Control devices: As shown on the Drawings and as specified in SECTION 26 05 10.
    c. Control wiring:
        1) Minimum wire size #14 AWG copper.
        2) Permanent machine-printed, plastic sleeve type markers with wire numbers applied to each end of wires, white tubing, black ink, sized to fit conductor insulation.
        3) Terminate wires using insulated locking fork or ring type crimp terminals.
        4) Terminate CT leads on shorting type terminal blocks.
6. Feeder unit and main protective device:
    a. Construction: As specified in this Section.
    b. Incoming service feeder: Cable entering section as shown on the Drawings.
    c. Molded case circuit breaker:
        1) In accordance with UL 489.

2) Feeder protective device.
3) Thermal-magnetic trip and interrupting capacity required for connection to system with short-circuit capacity shown on the Drawings.
4) Indicate tripping by operating-handle position.
5) Suitable for use with 75°C wire at full NEC 75°C ampacity.
6) Shunt trip shall be provided only when shown on the Drawings.

d. Static trip circuit breaker:
1) In accordance with UL 489.
2) Sized for continuous current in accordance with the Contract Documents. The main breakers or rating plugs shall be sized to permit the enclosed main breaker to continuously carry the amperage indicated on the Drawings without exceeding UL specified temperature rise limitations.
3) Molded case breakers with ambient insensitive solid-state trips and having current sensors and logic circuits integral in the breaker frame.
4) Solid-state current control with adjustable ampere setting, and adjustable LSIG protection: Adjustable long-time delay, adjustable short-time trip and delay band, adjustable instantaneous trip, and adjustable ground fault trip and delay band.
5) Provide ARMS to reduce arc flash incident energy when engaged. The ARMS systems shall include:
a) Adjustable trip settings.
b) Indication of maintenance node activated.
c) Local and remote activation.
6) Setting adjustments to be covered by a sealable, tamper-proof, transparent cover.
7) Locate trip button on the front cover of the breaker to permit mechanical simulation overcurrent tripping for test purposes and to trip breaker quickly in an emergency situation.
8) Static trip circuit breaker for MCC shall include 120 VAC shunt trip with leads wired to a terminal block.
9) Main protective device for MCC shall be UL labeled as suitable for service entrance.

e. Fused switches:
1) Heavy duty, motor rated, load-break, quick-make, quick-break type in accordance with UL 98 and NEMA KS 1.
2) Suitable for use with 75°C wire in accordance with NFPA 70, 75°C ampacity.
3) Current-limiting fuses with rejection clips.

7. SPD: As specified in SECTION 26 43 00.
8. Push buttons, indicating lights, selector switches, control relays, CTs, PTs, digital indicating meters, displays, elapsed time meters, relays, timers, etc. shall be as specified in SECTION 26 05 10 and SECTION 40 50 00.
9. Control and protective equipment including, but not limited to, control switches, lockout relays, test blocks and plugs, protective relays, as specified in SECTION 26 09 00.
10. Automatic transfer switch:

a. General: Furnish and install a complete microprocessor type, coordinated ATS. The ATS shall be provided in MCC, unless otherwise indicated. The ATS Manufacturer shall coordinate the size of ATS with the engine generator and the MCC Manufacturer. Submit ATS sizing data to the ENGINEER for approval.

b. Characteristics of operation:
1) When the normal source voltage fails or when any phase voltage drops below the dropout voltage value for an adjustable time delay of 0.5 seconds to 300 seconds, the processor is to close a set of isolated engine starting contacts which will be used to start the engine generator.
2) When the generator has reached the desired operating voltage and frequency for the desired time period, the processor is to operate the transfer breaker system to open the normal source breaker and, after a desired open period, close the alternate source breaker.
3) When the processor detects the return of normal source voltage for the desired time period, it is to operate the transfer breaker system to open the alternate source breaker and, after a desired open period, close the normal source breaker.
4) After the engine has continued to run for an adjustable cool down period, the processor is to stop the engine by opening the isolated engine starting contacts.
5) If the engine fails during the operating sequence outlined herein, the processor is to return the essential loads back to the normal source as soon as the normal source voltage is at an acceptable value. The immediate retransfer to normal function is also to take place if the alternate source voltage is above the pickup voltage value by 10%; is below the alternate source dropout voltage level; or is below the alternate source dropout frequency level. The control system is also to create an artificial power failure condition in response to a 24 VDC remote start voltage pulse of 300 milliseconds in duration. Upon receipt of the remote start pulse, the transfer breaker system is to close the engine starting contacts and then operate as if a power failure condition had occurred.

c. Transfer breaker device: The ATS shall be equipped with thermal overload protective trips in each source, shall be in accordance with UL 1008S, and shall transfer the essential loads from the normal source to the engine source or from the engine source to the normal source in response to signals from the microprocessor control system mentioned herein. The ATS shall utilize circuit breakers as the switching elements and each breaker shall be equipped with a motor operator. A walking-beam type of mechanical interlock is not to utilize the breaker operating handles. De-ion arc quenching shall be used; magnetic blowout systems will not be acceptable. Arc chutes and main contacts shall be fully enclosed to allow safe manual operation. Integral manual operating handles shall be provided to allow emergency operation; when manual operation is attempted, the motor operators shall be de-energized automatically. The circuit breakers in the ATS shall include the necessary auxiliary switches to provide for transfer system indicating lamps, for interlocking purposes to prevent both breakers from attempting closure at the same time, and to provide position information to the microprocessor system. In addition, each transfer breaker element will be equipped with a minimum of four spare 600 V, SPDT auxiliary switches.

d. The ATS will include an insulated neutral bus, and a ground bus. The normal and alternate source breaker elements shall be coordinated with the Engine Generator Manufacturer. Minimum sizes, to be approved by the ENGINEER, shall be 100% rated breakers with interchangeable overcurrent trip elements. The breaker ratings of the ATS shall be coordinated with the Engine Generator Supplier and approved by the ENGINEER. The ATS shall operate at 480/277 V, 60 Hz, three-pole, three-phase, four wire, and have as minimums, a 200 A frame and 42,000 A interrupting capacity, unless otherwise shown on the Drawings.
   1) Adjustable time, voltage, and frequency values: The following ATS values shall be switch selectable, field adjustable without the use of a test or field calibration kit:
      a) Normal to alternate source voltage dropout value of 80 V, 90 V, 95 V, 100 V, 102 V, 105 V, 110 V, or 118 V.
      b) Normal to alternate source voltage pickup value of 105 V, 107 V, 110 V, 112 V, 114 V, 116 V, 118 V, or 120 V.
      c) Time delay before transfer from normal source to alternate source: 0 seconds, 5 seconds, 10 seconds, or 30 seconds or 1 minute, 5 minutes, 15 minutes, or 30 minutes.
      d) Time delay before transfer from alternate source to normal source after the normal source voltage is acceptable: 0 seconds, 5 seconds, or 30 seconds or 1 minute, 5 minutes, 35 minutes, or 60 minutes.
      e) Time delay for engine cool down period: 1 minute, 3 minutes, 5 minutes, or 10 minutes.
      f) Time delay off, to provide a period during transfer when neither source is connected to the load: 0 seconds, 2 seconds, 5 seconds, or 10 seconds.
      g) Alternate source frequency dropout point: 60 Hz, 59 Hz, 57 Hz, or 56 Hz.
      h) Alternate source frequency pickup point: 60 Hz, 59 Hz, 57 Hz, or 56 Hz.
      i) Engine start contact delay time adjustable between 0.5 seconds to 300 seconds.

e. An exercise timer shall be provided to simulate both a fully loaded or an unloaded station test, depending on OWNER choice, of the engine generator system on a weekly basis. The digital timer shall be provided and arranged so that any time-of-day or day-of-week can be programmed. The timer shall display the current time of day and day of week when in normal operation. The ATS indicating lights, power failure selector switch (test switch), and digital exercise timer shall be mounted directly on the MCC enclosure and shall be fully gasketed to maintain the enclosure NEMA rating.

11. Nameplates:
   a. Laminated plastic, white surface, engraved to black core (white with black letters).
   b. Provide for each MCC and each unit.
   c. Engrave with the inscription shown on single-line diagram.
   d. Provide blank nameplates on the spaces for future units.
   e. Attach with SST panhead screws on the face of the control center.
   f. Devices, components, terminal blocks, and equipment as approved by the ENGINEER shall have designated nameplates.
12. Factory testing: In accordance with NEMA ICS 1, Section 109.

C. Circuit Breakers:
   1. Field adjust trip settings of motor starter magnetic-trip-only circuit breakers.
   2. Adjust to approximately eight times motor rated current.
   3. Determine motor rated current from the motor nameplate following installation.

D. Overload relay: Set solid-state overload relays or select overload relay heaters after the actual nameplate full load current rating of motor has been determined.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install equipment in accordance with NEMA ICS 2.3, Submittal Drawings, and the Manufacturer's instructions and recommendations.

B. Secure equipment to mounting pads with anchor bolts of sufficient size and number adequate for specified seismic conditions.

C. Install equipment plumb and in longitudinal alignment with pad or wall.

D. Coordinate terminal connections with the installation of secondary feeders.

E. Grout mounting channels into floor or mounting pads.

F. Retighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.

G. Testing as specified in SECTION 26 08 00.

H. Field adjust protective device, relay, and control settings in accordance with the recommendations of the electrical system analysis studies as specified in SECTION 26 05 70.

3.2 QUALITY CONTROL

A. Motor Data:
   1. Provide a typed, self-adhesive label attached inside each motor starter enclosure door displaying:
      a. Motor served by tag number and equipment name.
      b. Nameplate hp.

c. Motor code letter.
d. FLAs.
e. SF.
f. Solid-state relay setting of installed overload relay heater catalog number.

B. Field Testing:
1. Additional testing as specified in SECTION 26 08 00.
2. Engage the services of a recognized, independent testing agency to inspect and test the installed equipment prior to energization. The testing agency shall provide material, labor, equipment, and technical supervision to perform the tests and inspection. Notify the OWNER and the ENGINEER at least 2 weeks prior to scheduling any testing.
3. Equipment testing and inspection shall be performed in accordance with ANSI/NETA ATS.
4. In the event of an equipment fault, notify the ENGINEER and the OWNER immediately. After the cause of the fault has been identified and corrected, a joint inspection of the equipment shall be conducted by the CONTRACTOR, the ENGINEER, the OWNER, and the Equipment Manufacturer's factory service technician. Repair or replace the equipment as directed by the ENGINEER and the OWNER prior to placing the equipment back into service.

3.3 ADJUSTING

A. The MCC and ATS Manufacturer's factory service technician shall make the following test and adjustments:
1. Set, calibrate, and test protective devices, relays, and controls in accordance with the final version of the ESA as specified in SECTION 26 05 70.
2. Adjust and lubricate operating mechanisms and contacts.

END OF SECTION

SECTION 26 29 23
VARIABLE FREQUENCY DRIVES

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for variable frequency drives.
- B. Related Sections:
  1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
  2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
  3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
  4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
  5. SECTION 26 05 19 – LOW-VOLTAGE CONDUCTORS
  6. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
  7. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
  8. SECTION 26 70 00 – MOTORS
  9. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 DEFINITIONS
- A. Rated Load: Load specified for the equipment.
- B. Rated Speed: Nominal rated (100%) speed specified for the equipment.

1.3 REFERENCES
- A. American National Standards Institute/Hydraulic Institute (ANSI/HI):
  1. Hydraulic Institute Standards
- B. Institute of Electrical and Electronics Engineers (IEEE):
  1. 519 – Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
- C. Insulated Cable Engineers Association/National Electrical Manufacturers Association (ICEA/NEMA):
  1. S-73-532/WC 57 – Standard for Control, Thermocouple Extension, and Instrument Cables
- D. National Electrical Manufacturer's Association (NEMA):
  1. MG 1 – Motors and Generators
  2. CP 1 – Shunt Capacitors
- E. National Fire Protection Association (NFPA):
  1. 79 – Electrical Standard for Industrial Machinery

1.4 SUBMITTALS
- A. As specified in SECTION 26 05 00.
- B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.
- C. Shop Drawings:
  1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
  2. Catalog, descriptive and specification information for equipment, components, and devices.
  3. External power and signal connections.
  4. Scaled drawings showing exterior dimensions and locations of electrical interfaces, mechanical interfaces, and mounting arrangements.
  5. Specific features and configuration data:
     - a. SPs and scale range.
     - b. Engineering Specifications.
     - c. Equipment weights.
     - d. Power and grounding requirements.
     - e. Materials of construction.
  6. Construction drawings:
     - a. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
     - b. Show dimensions and locations of panel-mounted devices, doors, louvers, subpanels, internal and external.
     - c. Complete external and internal dimensioned layout drawings showing components, devices, boards, wiring, cooling equipment, heat sinks, vents, phase shifting transformers, control devices, terminal blocks, CTs, PTs, including views with termination and wiring details.
     - d. Construction details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, louvers, mounting brackets and tabs, door hinges and latches, and welding.
     - e. Cable access areas and cable routing.
     - f. Anchor bolt size and location.
     - g. Installation and mounting detail drawings.
     - h. Equipment weights.
  7. Wiring diagrams:
     - a. Ladder diagrams in a format similar to those shown on the Drawings.
     - b. Diagrams shall be coordinated and show field interfaces.
     - c. Component and panel terminal board identification numbers and external wire and cable numbers.
     - d. Circuit names; identify terminals, cable ID tags, actual cable lengths, and conduit tags.
     - e. Grounding diagram, philosophy, implementation, terminations, type, and connections.
     - f. Complete, detailed VFD drawings shall be provided showing components, wiring diagrams, phase shifting transformer, front section with solid-state components, DC bus with components, output IGBTs components, connections between control boards and devices, cooling devices and wiring, etc.

g. Identify each item with attributes listed.
   1) Wires, conductors, cables: Type, number, size and color.
   2) Terminals: Location, terminal strip number, and terminal block number.
   3) Relay coils:
      a) Tag number and its function.
      b) On the right side of the run where the coil is located, list the contact location by ladder number and sheet number.
   4) Relay contacts: Coil tag number, function, and coil location.

8. Communications configuration, operation, limitations, and diagnostics for LANs, data highway, serial links, and other communication paths.
9. Applications software documentation:
   a. Complete configuration documentation for microprocessor based configurational devices.
   b. For each device, include a program configuration listing showing:
      1) Functional blocks or modules used.
      2) Configuration, calibration, and tuning parameters.
      3) Descriptive annotations.
10. Overall drive system operating data, including efficiencies, input currents, and PFs, at driven equipment actual load and rated system input voltage, at 0%, 40%, 60%, 80%, 100%, and 110% of rated speed.
11. Computer-generated graphs and computations of the individual and total harmonic content, voltage and current, at the locations identified as points of common coupling, PCC#, with the driven equipment load at the following conditions:
    a. All combinations of VFD driven equipment at 25%, 50%, 75%, 100% of rated speed.
    b. The predictive computer-generated conditions shall be the same as the actual test conditions.
    c. PCC locations shall include transformers, generators and electric utility sources. Additional PCC locations as shown on the Drawings.
12. Compliance shall be verified by the VFD Manufacturer, or the Manufacturer’s representative, and witnessed by the ENGINEER with field measurements at all PCC locations. Use TDD and THD factors in accordance with IEEE 519 to designate total harmonic content. VFD output pulse maximum peak voltage, pulse rise time and pulse rate of rise, including any justification for proposed deviation from specified values. Include the Motor Manufacturer's certification that motor insulation will withstand long-term overvoltages caused at motor terminals due to specified output pulse data or any proposed deviation from the data.
13. Data on the shelf life of DC link capacitor.
14. Complete system rating, including nameplate data, continuous operation load capability throughout speed range of 0% to 120% of rated speed.
15. Complete variable frequency controller rating coordinated with motor full load nameplate current rating; list any controller special features being supplied.
16. Controller, reactor, and isolating transformer, if applicable, dimensional drawings; information on size and location of space for incoming and outgoing conduit.
17. Power consumption and heat dissipation, tabulate and summarize:
    a. Required voltages, currents, and phases.
    b. Maximum heat dissipations Btu/hour.
    c. Include calculations.
18. Layout of controller face showing push buttons, switches, instruments, indicating lights, etc.
19. Complete system operating description.
20. Complete system schematic, elementary, wiring diagrams.
21. Complete system interconnection diagrams between controller, drive motor, and related components and controls external to system, including wire numbers and terminal board point identification.
22. One-line diagram of system, including component ratings.
23. Description of diagnostic features being provided.
24. Special shipping, storage and protection, and handling instructions.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M Manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing Submittal information.
      d. Factory and field certified test reports.
      e. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
      f. Software: Provide complete licensed copy of software including interface cables. Software provided shall allow modification of VFD settings and logic. Provide electronic files of final VFD and MPR programs/settings.
      g. Hardcopy and electronic version of installed programs in controllers including VFDs, pressure indicating meters, and MPR.
      h. Calibration, startup, and commissioning reports.
      i. Complete lists of equipment furnished, including Manufacturer model numbers, correct settings, alarm points, and operating ranges.
      j. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.

k. Harmonic analysis study as specified in SECTION 26 05 70.
l. Final As-Built Drawings:
   1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
      a) Drawings shall be on a standard DW provided title block and border .
      b) As-Builts and Manufacturer's drawings shall be provided:
         (1) On a standard DW provided title block and border.
         (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
         (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
         (4) Titles: 0.2 inches.
m. Warranty documentation.
n. Manufacturer's certification of proper installation.
o. Detailed training plan.

1.5 QUALITY ASSURANCE

A. VFDs shall be the end product of one Manufacturer.
B. Manufacturer's Services:
   1. Furnish a Manufacturer's Representative as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
      a. Installation assistance and inspection: 1.
      b. Functional and performance testing and completion of the Manufacturer's certificate of proper installation: 1.
      c. Post-startup training of the OWNER's personnel: 2; one for operators and one for technical personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER.
C. System Description:
   1. Performance requirements:
      a. Composite drive/motor efficiency (CE) is defined as ratio of motor shaft kW to drive input kW. The motor efficiency used shall be 95%. VFD system minimum composite efficiency requirements:
         1) At 60 Hz drive output and 100% load CE equals 92%.
         2) At 50 Hz drive output and 60% load CE equals 89%.
         3) At 40 Hz drive output and 30% load CE equals 84%.
         4) At 30 Hz drive output and 12.5% load CE equals 77%.
      b. Rated continuous operation capacity: Not less than 1.10 times full load current rating of driven motor, as indicated on the motor nameplates, and suitable for continuous operation at any continuous overload which may be imposed on motor by driven pump operating over specified speed range, at the specified altitude.
      c. Basis for harmonic computations: Use the Drawings to create a plant one-line diagram for current and voltage distortion computations, furnish multiple pulse converter arrangements required to meet the current and voltage distortion requirements.
      d. Normal source current harmonic distortion: Compute normal source individual and total current harmonic distortion at the locations identified as a PCC, in accordance with IEEE 519. Individual current harmonic distortion and the TDD expressed as percent of maximum demand load current I_L shall not exceed the values specified in Table 1.

Table 1	
Individual Harmonic Order (Odd Harmonics)	**Harmonic Current Distortion Percent of Max. Demand Load Current I_L**
h < 11	7.0
11 < h < 17	3.5
17 < h < 23	2.5
23 < h < 35	1.0
35 < h	0.5
TDD	8.0

      e. Normal source voltage harmonic distortion: Compute normal source voltage harmonic distortion. THD shall not exceed 5%, and individual voltage harmonic distortion shall not exceed 3%.
      f. Furnish isolating transformers or series reactors necessary for proper system operation. Furnish necessary devices and circuits to prevent operation of one drive from adversely affecting operation of other drives supplied from same transformer or same bus.
      g. When isolation transformers are used, design to meet K-factor requirements of drive(s) connected.
   2. Design requirements:
      a. Design and provide drive system consisting of eighteen-pulse input variable frequency controller, drive motor, constant speed bypass certain auxiliary items, and components necessary for complete operating system and as shown on the Drawings.

b. Other equipment is being powered from the same bus as VFDs. Ensure proper operation of drives and other loads under normal and emergency conditions.
c. Furnish VFDs rated on basis of not less than 1.10 times actual motor full load nameplate current rating and rated on the basis of not less than 1.10 times of the highest actual motor full load nameplate current rating.
d. Drive system: Convert incoming three-phase, 60 Hz AC power to variable voltage, adjustable frequency output for variable speed operation of a standard AC induction squirrel-cage motor, using the PWM technique to produce the adjustable frequency output.
e. Provide an across-the-line constant speed bypass when shown on the Drawings.
f. System rated for continuous industrial duty and suitable for use with ANSI/NEMA MG 1, Design B motors.
g. Incoming line circuit breaker: Provide positive means of disconnecting incoming power and overcurrent protection for the drive system.
h. Incoming line reactors: Design to minimize harmonic distortion on the incoming power feeder. Located on the line side of the VFD; 5% minimum impedance.
i. Load reactors when shown on the Drawings.
j. Additional overload protection on the load side of the VFD.
k. The complete VFD cabinet shall be UL listed.

D. Extra Materials:
1. Furnish for each drive unit:
a. Power, control, semi-conductor, etc.: Six of each size and type of fuse.
b. Diode modules: One complete set of each type and size.
c. IGBT modules: One complete set of each type and size.
d. Gate driver boards: One complete set of each type and size.
e. Main control boards: One of each type.
f. LEDs and lamps: Two of each size and type.
g. Ventilation filters: Two of each type and size.
h. Provide complete licensed copy of software including interface cables. Software provided shall allow modification of VFD settings and logic.

1.6 SITE CONDITIONS
A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY
A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the VFD system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
A. ABB, ACS880 Series
B. Eaton Cutler-Hammer, Clean Power Solution Type
C. MPR:
1. GE Multilin 369-HI-R-M-000-E with 1A secondary Ground Fault CT (GFCT)

2.2 COMPONENTS
A. Drive Units:
1. Incorporate a switching power supply operating from a DC bus, to produce a PWM output waveform simulating a sine wave and providing power loss ride through of 2 milliseconds at full load, full speed.
2. Current-limiting semiconductor fuses for protection of internal power semiconductors.
3. Employ a diode bridge rectifier providing a constant displacement PF of 0.95 minimum at all operating speeds and loads.
4. Use IGBTs for output section, providing a minimum 97% drive efficiency at full speed, full load.
5. Employ DC power discharge circuit so that after removal of input power DC link capacitor voltage level will decay below 50 VDC within 1 minute after de-energizing in accordance with NEMA CP 1 and NFPA 79. Design DC link capacitor for a MTBF of 5 years.
6. Operate with an open circuited output.
7. Input voltage: 460 VAC 10% or -5%.
8. Output voltage: 0 V to 480 V, three-phase, 0 to 66 Hz, minimum.
9. Maximum peak voltage of PWM VFD output pulse of 1,000 V, with pulse rise time of not less than 2 microseconds, and a maximum rate of rise of 500 V per microsecond. Frequency of PWM VFD output pulse (carrier) frequency shall be field adjustable from 1 kHz to 10 kHz.
10. Short-time overload capacity: 150% of rated load in rms current for 1 minute following full load, full speed operation.
11. Equipment short-circuit rating: Suitable for connection to the system with maximum source three-phase, bolted fault, a minimum short-circuit available of 42,000 A rms symmetrical at 480 V.
12. Furnish drives with output current-limiting reactors mounted within equipment enclosure.
13. Diagnostics: Comprehensive for drive adjustment and troubleshooting:
a. Memory battery backup: 100-hour minimum during a power loss.
b. Status messages will not stop the drive from running but will prevent it from starting.
c. Fault condition messages and history: First fault protection function to be activated, ability to store six successive fault occurrences in order. Minimum faults numerically:
1) Overcurrent: Time and instantaneous.

        2) Overvoltage.
        3) Undervoltage: DC and AC.
        4) Overtemperature: Drive, motor windings, motor bearing, pump bearing.
        5) Serial communication fault.
        6) Short-circuit/ground fault: Motor and drive.
        7) Motor stalled.
        8) Semiconductor fault.
        9) Microprocessor fault.

14. Drive protection:
    a. Fast-acting semiconductor fuses.
    b. Overcurrent, instantaneous overcurrent trip.
    c. DC undervoltage protection, 70% dropout.
    d. DC overvoltage protection, 130% pickup.
    e. Overtemperature, drive, inverter, converter, and DC link components.
    f. Overtemperature, motor, and pump.
    g. Single-phase protection.
    h. Reset overcurrent protection: Manual or automatic reset.
    i. Active current limit/torque limit protection.
    j. Semiconductor fault protection.
    k. Short-circuit/ground fault protection.
    l. Serial communication fault protection.
    m. Microprocessor fault.
    n. Visual display of specific fault conditions.
15. Operational features:
    a. Sustained power loss.
    b. Momentary power loss.
    c. Power interruption.
    d. Power loss ride through: 0.1 second.
    e. Start on the fly.
    f. Electronic motor overload protection.
    g. Stall protection.
    h. Slip compensation.
    i. Automatic restart after power return, ability to enable/disable function.
    j. Critical frequency lockout: Three selectable points minimum, by 1.5 Hz steps in 10 Hz bands, to prevent resonance of system.
    k. Drive maintenance system software for complete programming and diagnostics.
    l. Ground fault protection, drive, and motor.
    m. Operate with no motor connected to output terminals.
    n. Diagnostic log and fault log shall record, store, display, and print upon demand the last fifty events including the time, type of fault, mode, etc. The log record shall be accessible via a RS232/RS422 serial link as well as line-by-line on the keypad display.
16. Provide blown fuse indicator card with LED indication for each semiconductor fuse.

B. Rectifier: Three-phase, eighteen-pulse full wave diode bridge rectifier to provide a constant DC voltage to the drive's DC bus.

C. Controller: Microprocessor-controller PWM inverter to convert to DC voltage to variable voltage, variable frequency three-phase AC output. The output voltage shall vary proportionally with the frequency to maintain a constant ratio of V to Hz up to 60 Hz. Above 60 Hz, the voltage shall remain constant, with the drive operating in a constant hp output mode.

D. Enclosure:
1. The VFD shall be stand-alone as detailed on the Drawings. The VFD shall be equipped with heat sinks, fans, and air conditioning as necessary to maintain internal temperature within the VFD to the Manufacturer's specifications while maintaining the enclosure NEMA rating. VFD enclosures shall be properly sized to dissipate the heat generated by the controller within the limits of the specified operating conditions, including ambient temperature and ambient airflow. Enclosure shall not exceed the dimensions shown on the Drawings. Enclosures shall be NEMA 1, gasketed.
2. Furnish drive complete with cable termination compartment door interlocked main circuit breaker, defeatable, lockable in the open position, emergency stop push button, alphanumeric keypad and display, and operator's controls. Components and controls as specified in SECTION 26 05 10.
3. Wire drive from below and above for power and control wiring.
4. Size forced-ventilation for periodic operation to cool each unit with maximum room ambient temperature of 95°F. Furnish filters on ventilation intakes. Furnish with louvers and forced ventilation as required to prevent temperature buildup from equipment mounted inside the panel or on the panel. Size to adequately dissipate heat from equipment mounted inside the panel or in the panel face. Panel louvers shall have industrial, heavy duty, washable aluminum air filters.
    a. Louver construction: Stamped sheet metal.
    b. Ventilation fans:
        1) Furnish where required to provide adequate cooling.

2) Create positive internal pressure within panel.
3) Fan motor power: 120 V, 60 Hz AC, thermostatically controlled.

5. Bundle stranded copper wiring neatly with nylon tie wraps or with continuous plastic spiral binding; label each terminal for permanent identification of leads; identify each wire at each end with imprinted mylar adhesive-back wire markers; incorporate in as-installed wiring diagrams for wire and terminal numbers shown; wiring across door hinges use nineteen-strand, ICEA/NEMA S-73-532/WC 57 Class C stranding looped for proper twist rather than bending at hinge; wire connections internal to panels by crimp-on terminal types. For multiple enclosure systems, complete interconnection wiring with gasketed enclosure openings for wiring; multipoint plug receptacles for any control wiring crossing equipment shipping splits.
6. Selector switches, indicating lights, potentiometers, instruments, protective devices, major system components, etc., identified by means of mechanically attached, engraved, laminated nameplates.
7. The phase shifting transformer required for the VFD eighteen-pulse input shall be enclosed in the VFD cabinet.

E. Operator Interface:
1. Controls: Mount drive operator control interface on the front door of VFD and include control switches, push buttons, and membrane type keypad and display for the following operator functions, as a minimum:
   a. Local/remote control selection, in remote, furnish for remote run command digital input and speed increase/decrease via remote 4 mA to 20 mA analog signal.
   b. Open-stop-close spring return to center, start/stop when in local mode.
   c. Emergency stop mushroom head maintained push button.
   d. On, off, and trip/fault indicating lights.
   e. Discharge valve 10% open indicating light: Blue.
   f. VFD blow main fuse indicating lights.
   g. Elapse time meter.
   h. Discharge pressure digital indicating meter.
   i. Discharge valve position digital indicating meter.
   j. Speed increase from VFD keypad, when in local mode.
   k. Speed decrease from VFD keypad, when in local mode.
   l. Parameter mode selection, recall programmed parameters.
   m. Fault reset, manual for all faults, except loss of AC voltage which is automatic upon return.
   n. Parameter lock, password or key switch lockout of changes to parameters.
2. VFD power and control power shall come from transformers internal to the VFD. Arrange the component and the circuit such that failure of any single component cannot cause cascading failure(s) of any other component(s).
3. Alphanumeric display: During normal operation and routine tests, the following parameters shall be available, as a minimum:
   a. Motor current, percent of drive rated current.
   b. Output frequency, Hz.
   c. Output speed.
   d. Output voltage.
   e. Running time.
   f. Local/remote indicator.
   g. Status of digital I/O.
   h. Analog input and output values.
   i. All test points.
4. Variable parameters: Set drive operating parameters and indicate in a numeric form. Potentiometers may not be used for parameter adjustment. Minimum setup parameters available:
   a. Frequency range, minimum and maximum.
   b. Variable acceleration/deceleration rate.
   c. V per Hz, field weakening point.
   d. Active current limit/torque limit, 0% to 140% of drive rating.
   e. Variable voltage boost, IR compensation.
   f. Preset speed, variable, preset operating point.
   g. Provision for adjustment of minimum and maximum pump speed to be furnished as function of 4 mA to 20 mA remote speed signal.

F. Signal Interface, as a minimum:
1. Digital input:
   a. Accept a remote run command contact closure input.
   b. High temperature contact closure input from motor temperature monitoring relay.
   c. Pressure high-low.
   d. Local/remote control.
   e. Fault relay.
2. Digital output: Furnish three discrete output dry contact closures rated 5 A at 120 VAC.
   a. Drive running.
   b. Drive fault, failsafe with common contact closure for all fault conditions.
   c. Drive in remote mode.
3. Analog input: When local/remote switch is in remote, control drive speed from a remote 4 mA to 20 mA DC signal. Make provisions for adjustment of minimum and maximum motor speed which shall result from the signal. Factory

set the adjustment to comply with the operating speed range designated in driven equipment specifications. Frequency resolution shall be 0.1% of base speed.

4. AO: Furnish two, 4 mA to 20 mA DC signals, for actual frequency, actual load.
5. VFD shall be programmed to allow:
   a. Local/remote switch to be switched from one position to the other. When this occurs, the VFD shall maintain its current speed until adjusted.
   b. The pressure high-low input will switch the VFD maximum speed setting. The ENGINEER will provide maximum speed settings.

G. Push button, indicating lights, selector switches, CTs, PTs, digital indicating meters (displays), elapsed time meters, relays, timers, transformers, relays, contactors, terminal blocks, nameplates, etc.: As specified in SECTION 26 05 10 and SECTION 40 50 00.

H. Conductors: As specified in SECTION 26 05 19.

I. Accessories:
   1. Equipment identification plate: 16 gauge SST with 1/4 inch die-stamped equipment tag number securely mounted in a readily visible location.
   2. Lifting lugs: Equipment weighing over 100 lbs.
   3. Anchor bolts: Galvanized, sized by the Equipment Manufacturer, 1/2 inch minimum diameter.

2.3 FINISHES

A. Enclosure:
   1. Primer: One coat of rust-inhibiting coating.
   2. Finish:
      a. Interior: One coat white enamel.
      b. Exterior: One coat of the Manufacturer's standard gray enamel ANSI 61.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with the Manufacturer's printed instructions.

B. Field adjust protective device, relay, and control settings in accordance with the recommendations of the electrical system analysis studies as specified in SECTION 26 05 70.

3.2 QUALITY CONTROL

A. Factory Inspections: Inspect control panels for required construction, electrical connection, and intended function.

B. Factory Tests and Adjustments: Test control panels actually furnished.

C. Record test data for report.

D. Functional Test:
   1. Perform the Manufacturer's standard tests.
   2. Conduct on each controller.
   3. Inspect controller for electrical supply termination connections, interconnections, proper installation, and quiet operation.
   4. Vibration test: Complete assembly, consisting of motor, load, and flexible shafting, connected and in normal operation, shall not develop amplitudes of vibration exceeding limits in accordance with the ANSI/HI Hydraulic Institute Standards. Where loads and drives are separated by intermediate flexible shafting, measure vibration both at top motor bearing and at two points on top pump bearing, 90 degrees apart.
   5. Record test data for report.

E. Motor Test: As specified in SECTION 26 70 00.

F. Additional testing as specified in SECTION 26 08 00.

G. Performance Test:
   1. Conduct on each controller.
   2. Perform under actual or approved simulated operating conditions.
   3. Test for continuous 12-hour period without malfunction.
   4. Demonstrate performance by operating the continuous period while varying the application load, as the input conditions allow, to verify system performance.
   5. Record test data for report.
   6. With load connected to normal utility source and with load connect to generator island mode source, measure the following to show parameters within specified limits:
      a. Total and individual current and voltage harmonic distortion, up to and including thirty-fifth harmonic, under the following load conditions:
         1) New and existing pump motors at 25%, 50%, 75%, 100% of rated speed.
         2) PF at input side of each drive. Documented verification that PF is maintained at above 90% at 25%, 50%, 75%, 100% of rated speed.
         3) Test equipment.
   7. Use Dranetz or BMI, harmonic distortion monitor and disturbance analyzer to document results, or equipment approved by the ENGINEER.
   8. Provide diagnostic plug-in test card complete with instructions, multi-position selector switch, and meters or built-in diagnostic control panel or ROM-based processor for monitoring AC, DC, and digital signals to assist in troubleshooting and startup of drive.

END OF SECTION

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SECTION 26 29 24
VARIABLE FREQUENCY DRIVES LESS THAN 50 HP

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for variable frequency drives less than 50 hp.
- B. Related Sections:
  1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
  2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
  3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
  4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
  5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
  6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
  7. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES
- A. American National Standards Institute/Hydraulic Institute (ANSI/HI):
  1. Hydraulic Institute Standards
- B. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
  1. 519 – Recommended Practice and Requirements for Harmonic Control in Electric Power Systems
- C. Insulated Cable Engineers Association/National Electrical Manufacturers Association (ICEA/NEMA):
  1. S-73-532/WC 57 – Standard for Control, Thermocouple Extension, and Instrument Cables
- D. National Electrical Manufacturers Association (NEMA):
  1. MG 1 – Motors and Generators
- E. National Fire Protection Association (NFPA):
  1. 79 – Electrical Standard for Industrial Machinery

1.3 DEFINITIONS
- A. Rated Load: Load specified for the equipment.
- B. Rated Speed: Nominal rated, 100%, speed specified for the equipment.

1.4 SUBMITTALS
- A. As specified in SECTION 26 05 00.
- B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.
- C. Shop Drawings:
  1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
  2. Catalog, descriptive and specification information for equipment, components, and devices.
  3. External power and signal connections.
  4. Scaled drawings showing exterior dimensions and locations of electrical interfaces, mechanical interfaces, and mounting arrangements.
  5. Specific features and configuration data:
     - a. SPs and scale range.
     - b. Engineering Specifications.
     - c. Power and grounding requirements.
     - d. Materials of construction.
  6. Construction drawings:
     - a. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
     - b. Show dimensions and locations of panel-mounted devices, doors, louvers, subpanels, internal and external.
     - c. Construction details: NEMA rating, materials, material thickness, louvers, and mounting brackets
     - d. Cable access areas.
     - e. Installation and mounting details.
     - f. Equipment weights.
  7. Wiring diagrams:
     - a. Ladder diagrams shall be in a format similar to those shown on the Drawings.
     - b. Diagrams shall be coordinated and show field interfaces.
     - c. Component and panel terminal board identification numbers, and external wire and cable numbers.
     - d. Circuit names; identify terminals, cable ID tags, actual cable lengths, and conduit tags.
     - e. Grounding diagram, philosophy, implementation, terminations, type, and connections.
     - f. Identify each item with attributes listed:
       - 1) Wires, conductors, cables: Type, number, size, and color.
       - 2) Terminals: Location, terminal strip number, and terminal block number.
       - 3) Relay coils:
         - a) Tag number and its function.
         - b) On the right side of the run where the coil is located, list the contact location by ladder number and sheet number.
       - 4) Relay contacts: Coil tag number, function, and coil location.
  8. Communications configuration, operation, limitations, and diagnostics for LANs, data highway, serial links, and other communication paths.

9. Applications software documentation:
    a. Complete configuration documentation for microprocessor based configurational devices.
    b. For each device, include a program configuration listing showing:
        1) Functional blocks or modules used.
        2) Configuration, calibration, and tuning parameters.
        3) Descriptive annotations.
10. Overall drive system operating data, including efficiencies, input currents, and PFs, at driven equipment actual load and rated system input voltage, at 0%, 40%, 60%, 80%, 100%, and 110% of rated speed.
11. Computer-generated graphs and computations of the individual and total harmonic content, voltage and current, at the locations identified as PCC with the driven equipment load at the following conditions:
    a. Each motor at 25%, 50%, 75%, 100% of rated speed.
    b. All motors together at 25%, 50%, 75%, 100% of rated speed.
12. Complete system rating, including nameplate data, continuous operation load capability throughout speed range of 0% to 120% of rated speed.
13. Complete variable frequency controller rating coordinated with motor full load nameplate current rating; list any controller special features being supplied.
14. Controller, reactor, and isolating transformer, if applicable, dimensional drawings; information on size and location of space for incoming and outgoing conduit.
15. Power consumption and heat dissipation, tabulate and summarize:
    a. Required voltages, currents, and phases(s).
    b. Maximum heat dissipations Btu/hour.
16. Layout of controller face showing push buttons, switches, instruments, indicating lights, etc.
17. Complete system operating description.
18. Complete system schematic, elementary, wiring diagrams.
19. Complete system interconnection diagrams between controller, drive motor, and related components or controls external to system, including wire numbers and terminal board point identification.
20. One-line diagram of system, including component ratings.
21. Description of diagnostic features being provided.
22. Special shipping, storage and protection, and handling instructions.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
    a. Provide preliminary and final manuals.
    b. As specified in SECTION 01 78 23.
    c. Shop Drawing Submittal information.
    d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
    e. Factory and field certified test reports.
    f. Software documentation: Updated version of software.
    g. Hardcopy and electronic version of installed programs in controllers including VFDs.
    h. Calibration, startup, and commissioning reports.
    i. Complete lists of equipment furnished, including Manufacturer model numbers, correct settings, alarm points, and operating ranges.
    j. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
    k. Harmonic analysis study as specified in SECTION 26 05 70.
    l. Final As-Built Drawings:
        1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
                (1) On a standard DW provided title block and border.
                (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
                (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
                (4) Titles: 0.2 inches.
    m. Warranty documentation.
    n. Manufacturer's certification of proper installation.
    o. Detailed training plan.

E. Extra Materials:
1. Furnish for each drive unit:
    a. Power, control, semi-conductor, etc.: Six of each size and type of fuse.
    b. Diode modules: One complete set of each type and size.
    c. IGBT modules: One complete set of each type and size.
    d. Gate driver boards: One complete set of each type and size.
    e. Main control board: One of each type.

f. Ventilation filter: Two of each type and size.
g. LEDs and lamps: Two of each size and type.
h. Provide complete licensed copy of software including interface cables. Software provided shall allow modification of VFD settings and logic.

1.5 QUALITY ASSURANCE

A. System Description:
1. Performance requirements:
a. Rated continuous operation capacity: Not less than 1.15 times full load current rating of driven motor, as shown on the motor nameplates, and suitable for continuous operation at any continuous overload which may be imposed on motor by driven equipment operating over specified speed range, at the specified altitude.
b. Basis for harmonic computations: Use the Drawings to create a plant one-line diagram for current and voltage distortion computations, furnish multiple pulse converter arrangements required to meet the current and voltage distortion requirements. The PCC locations shall be identified as follows:
1) PCC1: Secondary terminals of power source transformer or as shown on the Drawings.
2) PCC2: Primary terminals of distribution equipment or as shown on the Drawings.
c. Normal source current harmonic distortion: Compute normal source individual and total current harmonic distortion at the locations identified as a PCC in accordance with IEEE 519. Individual current harmonic distortion and the TDD expressed as percent of maximum demand load current I_L shall not exceed the values specified in Table 1.

Table 1	
Individual Harmonic Order (Odd Harmonics)	**Harmonic Current Distortion Percent of Max. Demand Load Current I_L**
h < 11	7.0
11 < h < 17	3.5
17 < h < 23	2.5
23 < h < 35	1.0
35 < h	0.5
TDD	8.0

d. Normal source voltage harmonic distortion: Compute normal source voltage harmonic distortion at PCC1. THD shall not exceed 5%, and individual voltage harmonic distortion shall not exceed 3%.
e. Furnish series reactors or filters necessary for proper system operation.
2. Design requirements:
a. Design and provide drive system consisting of variable frequency controller, drive motor, certain auxiliary items, and components necessary for complete operating system and as shown on the Drawings.
b. Furnish VFDs rated on basis of not less than 1.15 times actual motor full load nameplate current rating and rated on the basis of not less than 1.15 times of the highest actual motor full load nameplate current rating.
c. Drive system: Convert incoming three-phase, 60 Hz AC power to variable voltage, variable frequency output for variable speed operation of a standard AC induction squirrel-cage motor using the PWM technique to produce the variable frequency output.
d. System rated for continuous industrial duty and suitable for use in accordance with NEMA MG 1, Design B motors.
e. Incoming line circuit breaker: Provide positive means of disconnecting incoming power, and overcurrent protection for the drive system.
f. Incoming line reactors: Design to minimize harmonic distortion on the incoming power feeder. Located on the line side of the VFD; 5% nominal impedance.
g. Output filters: Provide L-R-C low-pass output filter (dv/dt filter) on the output of the drive.
h. The complete VFD cabinet shall be UL listed.
i. Provide a variable torque or constant torque VFD as required by the driven load.
j. 100% of rated current output on a continuous basis.
k. Minimum VFD system efficiency: 96%.
l. Minimum of 0.95 lagging across the entire speed range. At no speed shall the VFD have a leading PF.

B. VFDs shall be the end product of one Manufacturer.

C. Manufacturer's Services:
1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
a. Installation assistance, and inspection of installation: 1.
b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the VFD less than 50 hp system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. ABB

B. Eaton Cutler-Hammer

2.2 COMPONENTS

A. Drive Units:

1. Incorporate a switching power supply operating from a DC bus, to produce a PWM output waveform simulating a sine wave and providing power loss ride through of 2 milliseconds at full load, full speed.
2. Current-limiting semiconductor fuses for protection of internal power semiconductors.
3. Full wave diode bridge rectifier, three-phase, to provide a constant DC voltage to the drive's DC bus, while providing a constant displacement PF of 0.95 minimum at all operating speeds and loads.
4. Use IGBTs for output section.
5. Employ DC power discharge circuit so that after removal of input power DC link capacitor voltage level will decay below 50 VDC within 1 minute after de-energizing in accordance with NFPA 79.
6. Operate with an open circuited output.
7. Input voltage: 480 V within 10%, three-phase, 60 Hz.
8. Output voltage: 0 V to 480 V, three-phase, 0 Hz to 66 Hz, minimum.
9. Maximum peak voltage of PWM VFD output pulse of 1,000 V, with pulse rise time of not less than 2 microseconds, and a maximum rate of rise of 500 V per microsecond. Frequency of PWM VFD output pulse, carrier, frequency shall be field adjustable from 1 kHz to 10 kHz.
10. Short-time overload capacity: 150% of rated load in rms current for 1 minute following full load, full speed operation.
11. Equipment short-circuit rating: Suitable for connection to the system with maximum source three-phase, bolted fault, a minimum short-circuit available of 42,000 A rms symmetrical at 480 V.
12. Furnish drives with output current-limiting reactors mounted within the equipment enclosure.
13. Diagnostics: Comprehensive for drive adjustment and troubleshooting:
    a. Memory battery backup: 100 hour minimum during a power loss.
    b. Status messages will not stop drive from running but will prevent it from starting.
    c. Fault condition messages and history: First fault protection function to be activated, ability to store six successive fault occurrences in order. Minimum faults numerically:
        1) Overcurrent, time and instantaneous.
        2) Overvoltage.
        3) Undervoltage, DC and AC.
        4) Overtemperature: Drive, motor windings, motor bearing, pump bearing.
        5) Serial communication fault.
        6) Short-circuit/ground fault: Motor and drive.
        7) Motor stalled.
        8) Semiconductor fault.
        9) Microprocessor fault.
14. Drive protection:
    a. Fast-acting semiconductor fuses.
    b. Overcurrent, instantaneous overcurrent trip.
    c. DC undervoltage protection, 70% dropout.
    d. DC overvoltage protection, 130% pickup.
    e. Overtemperature, drive, inverter, converter, and DC link components.
    f. Overtemperature, motor, and pump.
    g. Single-phase protection.
    h. Reset overcurrent protection, manual or automatic reset.
    i. Active current limit/torque limit protection.
    j. Semiconductor fault protection.
    k. Short-circuit/ground fault protection.
    l. Serial communication fault protection.
    m. Microprocessor fault.
    n. Visual display of specific fault conditions.
15. Operational features:
    a. Sustained power loss.
    b. Momentary power loss.
    c. Power interruption.
    d. Power loss ride through, 0.1 second.
    e. Start on the fly.
    f. Electronic motor overload protection.
    g. Stall protection.
    h. Slip compensation.

i. Automatic restart after power return; ability to enable/disable function.
j. Critical frequency lockout; three selectable points minimum, by 1.5 Hz steps in 10 Hz bands, to prevent resonance of system.
k. Drive maintenance system software for complete programming and diagnostics.
l. Ground fault protection, drive, and motor.
m. Operate with no motor connected to output terminals.
n. Diagnostic log and fault log shall record, store, display, and print upon demand the last fifty events including the time, type of fault, mode, etc. The log record shall be accessible via a RS232/RS422 serial link and Ethernet, as well as line-by-line on the keypad display.

B. Controller: Microprocessor-controller PWM inverter to convert to DC voltage to variable voltage, variable frequency three-phase AC output. The output voltage shall vary proportionally with the frequency to maintain a constant ratio of V to Hz up to 60 Hz. Above 60 Hz, the voltage shall remain constant, with the drive operating in a constant hp output mode.

C. Enclosure:
1. VFDs shall be stand-alone. The VFD shall be equipped with heat sinks, fans, and air conditioning as necessary to maintain internal temperature within the VFD enclosure NEMA rating. VFD enclosures shall be properly sized to dissipate heat generated by the controller within the limits of specified operating conditions, including ambient temperature and ambient airflow. Enclosure shall not exceed the dimensions shown on the Drawings. Enclosures shall be NEMA 1, gasketed.
2. Furnish drive complete with cable termination compartment door interlocked main circuit breaker, defeatable, lockable in the open position, emergency stop push button, alphanumeric keypad and display, and operator's controls. Wire drive from below and above for power and control wiring.
3. Size forced-ventilation for periodic operation to cool each unit with maximum room ambient temperature of 95°F. Furnish filters on ventilation intakes. Furnish with louvers and forced ventilation as required to prevent temperature buildup from equipment mounted inside the panel or on the panel. Size to adequately dissipate heat from equipment mounted inside the panel or in the panel face. Panel louvers shall have industrial, heavy duty, washable aluminum air filters.
   a. Louver construction: Stamped sheet metal.
   b. Ventilation fans:
      1) Furnish where required to provide adequate cooling.
      2) Create positive internal pressure within panel.
      3) Fan motor power: 120 V, 60 Hz AC, thermostatically controlled.
4. Bundle stranded copper wiring neatly with nylon tie wraps or with continuous plastic spiral binding; label each terminal for permanent identification of leads; identify each wire at each end with imprinted mylar adhesive-back wire markers; incorporate in as-installed wiring diagrams for wire and terminal numbers shown; wiring across door hinges use nineteen-strand, ICEA/NEMA S-73-532/WC 57 Class C stranding looped for proper twist rather than bending at hinge; wire connections internal to panels by crimp-on terminal types.
5. Selector switches, indicating lights, potentiometers, instruments, protective devices, major system components, etc., identified by means of mechanically attached, engraved, laminated nameplates.

D. Operator Interface:
1. Controls: Mount drive operator control interface on the front door of VFD and include control switches, push buttons, and membrane type keypad and display for the following operator functions, as a minimum:
   a. Local/remote control selection, in remote, furnish for remote RUN command digital input and speed increase/decrease via remote 4 mA to 20 mA analog signal.
   b. Open-stop-close, start/stop, when in local mode.
   c. Emergency stop.
   d. On, off, and trip/fault indicating lights.
   e. Elapse time meter.
   f. Speed increase from VFD keypad, when in local mode.
   g. Speed decrease from VFD keypad, when in local mode.
   h. Parameter mode selection, recall programmed parameters.
   i. Fault reset, manual for all faults, except loss of AC voltage which is automatic upon return.
   j. Parameter lock, password or key switch lockout of changes to parameters.
2. VFD power and control power shall come from transformers internal to the VFD. Arrange component and circuit such that failure of any single component cannot cause cascading failure(s) of any other component(s).
3. Alphanumeric display: During normal operation and routine test, the following parameters shall be available, as a minimum:
   a. Motor current, percent of drive rated current.
   b. Output frequency, Hz.
   c. Output speed.
   d. Output voltage.
   e. Running time.
   f. Local/remote indicator.
   g. Status of digital I/O.
   h. Analog input and output values.
   i. Test points.

4. Variable parameters: Set drive operating parameters and indicate in a numeric form. Potentiometers may not be used for parameter adjustment. Minimum setup parameters available:
   a. Frequency range, minimum, maximum.
   b. Variable acceleration/deceleration rate.
   c. Volts per Hz, field weakening point.
   d. Active current limit/torque limit, 0% to 140% of drive rating.
   e. Variable voltage boost, IR compensation.
   f. Preset speed, variable, preset operating point.
   g. Provision for adjustment of minimum and maximum pump speed to be furnished as function of 4 mA to 20 mA remote speed signal.

E. Signal Interface:
   1. Digital input: Minimum of five programmable discrete inputs dry contact closures rated 5 A at 120 VAC.
      a. Accept a remote run command contact closure input.
      b. High temperature contact closure input from motor temperature monitoring relay.
      c. Local/remote control.
      d. Fault relay.
   2. Digital output: Minimum of five programmable discrete output dry contact closures rated 5 A at 120 VAC.
      a. Drive running.
      b. Drive fault, failsafe with common contact closure for all fault conditions.
      c. Drive in remote mode.
   3. Analog input: Minimum of two programmable analog inputs, configurable as either 0 V to 10 V or 4 mA to 20 mA. When local/remote switch is in remote, control drive speed from a remote 4 mA to 20 mA DC signal. Frequency resolution shall be 0.1% of base speed.
   4. AO: Minimum of two programmable AOs, configurable as either 0 V to 10 V or 4 mA to 20 mA.

F. Push button, indicating lights, selector switches, CTs, PTs, digital indicating meters, displays, elapsed time meters, relays, timers, etc. shall be as specified in SECTION 26 05 10 and SECTION 40 50 00.

G. Accessories:
   1. Equipment identification plate: 16 gauge SST with 1/4-inch die-stamped equipment tag number securely mounted in a readily visible location.
   2. Lifting lugs: Equipment weighing over 100 lbs.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with the Manufacturer's printed instructions.

B. Field adjust protective device, relay, and control settings in accordance with the recommendations of the electrical system analysis studies as specified in SECTION 26 05 70.

3.2 QUALITY CONTROL

A. Factory Inspections: Inspect control panels for required construction, electrical connection, and intended function.

B. Factory Tests and Adjustments: Test control panels furnished.

C. Record test data for report.

D. Functional Test:
   1. Perform the Manufacturer's standard tests.
   2. Conduct on each controller.
   3. Inspect controller for electrical supply termination connections, interconnections, proper installation, and quiet operation.
   4. Vibration test: Complete assembly, consisting of motor, load, and flexible shafting, connected and in normal operation, shall not develop amplitudes of vibration exceeding limits in accordance with ANSI/HI Hydraulic Institute Standards. Where loads and drives are separated by intermediate flexible shafting, measure vibration both at top motor bearing and at two points on top pump bearing, 90 degrees apart.
   5. Record test data for report.

E. Additional testing as specified in SECTION 26 08 00.

F. Performance Test:
   1. Test for continuous 12-hour period without malfunction.
   2. Demonstrate performance by operating the continuous period while varying the application load, as the input conditions allow, to verify system performance.
   3. Record test data for report.

G. Manufacturer's Services:
   1. Provide the services of a VFD Manufacturer Representative for startup assistance and training:
      a. Inspection and field adjustment: Supervise the following and submit written certification that the equipment and controls have been properly installed, adjusted, and is ready for operation.
      b. Startup field testing:
         1) Provide technical direction for testing, checkout, and startup of the VFD equipment in the field.
         2) The drive system shall not be energized without authorization from the Manufacturer's Representative.

END OF SECTION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for engine driven generator system.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 09 90 00 – PAINTING AND COATING
4. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
5. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
7. SECTION 26 24 19 – LOW-VOLTAGE MOTOR CONTROL

1.2 REFERENCES

A. Institute of Electrical and Electronic Engineers (IEEE):

1. 241 – Recommended Practice for Electric Power Systems in Commercial Buildings
2. 446 – Recommended Practice for Emergency and Standby Power Systems for Industrial and Commercial Applications

B. Military Specification and Standards (MIL):

1. I-24092/1 – Insulating Varnish, and Solvent Containing, Air-Dry for Spot Patching and Emergency Repairs, Grade CA, Class 130 and 155 Thermal Class

C. National Electrical Manufacturers Association (NEMA):

1. MG 1 – Motors and Generators

D. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)
2. 99 – Health Care Facilities Code
3. 110 – Standard for Emergency and Standby Power Systems

E. SAE International (SAE):

1. J177 – Measurement of Carbon Dioxide, Carbon Monoxide, and Oxides of Nitrogen in Diesel Exhaust

1.3 DEFINITIONS

A. General: Definitions of terms and other electrical considerations as set forth in the NEC, IEEE, ISA, and NFPA.

B. Specific Definitions:

1. Standby rated duty: Defined as continuous operation for the duration of any power outage.

C. System Description:

1. Provide a complete automatic standby natural gas engine driven generator system, with the necessary components to make a complete and operating standby natural gas driven power supply.
2. The Work covered by this Section consists of furnishing and installing equipment, supplies, and materials, and in performing the operations necessary to provide an assembly which includes a complete automatic standby natural gas engine driven generator system.
3. It is intended that the Specification include, but not be limited to, furnishing a system consisting of the following major items:
   a. Engine driven generator skid.
   b. Radiator and coolant piping system.
   c. Exhaust silencer, exhaust piping system, and insulation.
   d. Start battery, battery stand, and charger.
   e. Necessary flexible connectors.
   f. Gas line accessories.
   g. Engine control panel.
   h. Universal remote panel-mounted annunciator.
   i. Enclosure.
4. Equipment shall be new, of current production, by a national firm which assembles the generator set as a matched unit so that there is one source of responsibility for the warranty, parts, and service through a local representative with factory-trained service personnel.
5. The Work shall also include the supply of such minor details of electrical, plumbing, or mechanical Work not mentioned which are necessary for the successful operation of the automatic standby natural gas engine driven generator required by the Contract Documents.
   a. Extras for such material or labor will not be considered.
6. System equipment description:
   a. Unit type system:
      1) The automatic standby natural gas engine driven generator system shall be complete and ready to be moved into place.
      2) The engine generator, radiator, exhaust system, muffler, controller, battery, and charger shall be furnished as a complete unit on the engine generator skid.
7. Characteristics of operation: Upon power failure or single-phase condition, the automatic transfer equipment shall signal the engine control panel. The engine is to be started and controlled automatically by the auto-start controls:
   a. The engine driven generator is to supply power to the identified loads until such time as the commercial power is again available, as signaled by the automatic transfer equipment.

b. When the commercial power has returned for a predetermined period of time, the loads shall be transferred back to the commercial source as determined by the automatic transfer equipment. After the automatic transfer equipment has re-transferred the loads to the commercial source, the automatic transfer equipment shall signal the engine control panel to stop the engine.
c. After an adjustable cool down period, the engine is to be stopped and made ready for the next power interruption.

1.4 SEQUENCING AND SCHEDULING

A. The authorized Representative of the Engine Generator Manufacturer:
1. Ship the engine driven generator skid and the associated equipment to the jobsite on equipment that will allow the CONTRACTOR to use the equipment he has on-site to efficiently unload the engine driven generator skid.
2. Coordinate the delivery of the shipment with the CONTRACTOR.
3. Prior to startup, furnish written certification that the entire installation and the connections both mechanical and electrical have been inspected and are proper and consistent with the Contract Documents.
4. Furnish the services of factory certified technicians during the startup and adjustment period to ensure that the items furnished are in proper operating condition: Technician(s) shall be completely knowledgeable in the operation, maintenance and startup of the mechanical and electrical systems.
5. Furnish a written report after the startup. The report shall state that the installation is complete and satisfactory: List the items requiring additional attention.
6. Minimum required time on-site by Engine/Generator Technician(s): 1 day at startup to test operation and provide training.

1.5 SUBMITTALS

A. As specified in SECTION 26 05 00.
B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt, unless otherwise specified in the individual Section. Resubmittals will be subject to the same review time.
C. Shop Drawings:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Equipment information:
a. Weight, length, width, and height of engine generator skid.
b. Type of gas recommended. Natural gas pressure required at intake.
c. Gas and lubricating oil consumption at:
1) 1/2 load.
2) 3/4 load.
3) Full load.
d. Grade lubricating oil recommended.
e. Amount of lubricating oil required per oil change.
f. Normal lubricating oil consumption.
g. Recommended lubricating oil change periods:
1) By hours run.
2) By time.
h. Combustion air required.
i. Cooling air required.
j. Heat rejection by engine generator to the room area.
k. Oil and temperature gauges normally furnished with the engine and the normal operating range of each.
l. Time interval from startup contact closure until full load capabilities are available.
m. List of at least four installations using major components of the same type furnished for this application.
n. Number of cylinders, bore, stroke, and piston speed.
o. Rpm at 60 Hz.
p. Size of exhaust outlet.
q. The following gaseous exhaust emissions in grams/BHP-HR:
1) NOx.
2) HC.
3) CO.
4) These levels shall be reported at rated speed and load in accordance with SAE J177 recommended practices.
r. Voltage and frequency variation with the step application and removal of 1/4, 1/2, and 3/4 of resistive load.
s. Generator data:
1) Armature time constant (Ta).
2) Subtransient period (T''d).
3) Short-circuit time constant (T'd).
4) Zero sequence reactance (X0).
5) Transient reactance (X'd).
6) Subtransient reactance (X''d).
7) Synchronous reactance (Xd).
t. Battery discharge ampere ratings at the 8-hour rate and the 1-minute rate to 1 3/4 V per cell.

u. Certified published engine hp curves showing the Manufacturer's engine rating for generator set standby and prime power application.
v. Free field mechanical noise level at 3 feet. Provide overall db (A) rating.
w. Exhaust noise level at 5 feet from discharge end of silencer.
x. Start battery catalog number and descriptive bulletin.
y. Displacement in cubic inches.
z. Compression ratio.
aa. Peak to peak amplitude limits of vibration velocity in any direction for the engine and the generator.
bb. Complete nameplate schedule.
cc. Detailed descriptive product bulletins, specific only to the equipment being furnished for the electrical components.
dd. Detailed product Specifications, installation, and instruction sheets:
    1) Governor, actuator, speed control.
    2) Voltage regulator.
ee. Recommended spare parts.
ff. Manufacturers of:
    1) Engine.
    2) Generator.
    3) GCP.
    4) Radiator.
gg. Guaranteed calendar days required to ship unit.
hh. Space and ambient temperature requirements for the engine control panel.
ii. Minimum length recommendations for the flexible connections as a function of diameter.

4. The Manufacturer shall submit complete loading calculations to support the recommended size of the engine generator based upon actual facility loads.
5. Cooling calculations:
    a. Performed on a proprietary program (KULI or equivalent) demonstrating that the engine generator will not overheat under full load and the most severe specified operating conditions with a safety factor to prevent any pre-alarm conditions for high coolant temperature.
    b. Air side calculations:
        1) Total air flow required in cfm at site altitude:
            a) Include pressure drop through the factory and field components.
            b) Include design conditions for entering and leaving air temperature.
            c) Radiator cooling fan curves with the operating point based on the pressure drop and air flow conditions.
            d) Fan hp needed to provide the air flow.
        2) Total heat being rejected by the engine and the generator: Radiation, conduction, and convection forms of heat transfer to surrounding air and engine jacket water and aftercooler cooling fluid. Take into account of outdoor enclosure and outdoor temperatures.
        3) Radiator heat rejection:
            a) Use specific heat for the specified glycol solution, the flow rate of coolant, and the entering and leaving air temperatures at radiator and aftercooler.
            b) Provide expected jacket water and aftercooler temperatures for 25%, 50%, 75%, and 100% full load under the most severe operating conditions.
            c) Establish the pre-alarm temperature limit and alarm limit for overheating for the cooling system. Provide at least 5°F separation between the actual coolant temperature, the pre-alarm limit temperature, and the alarm limit temperature for overheating of the cooling system.
6. Layout drawings: The successful equipment supplier shall provide the ENGINEER with detailed dimensional and to scale layout Drawings which include:
    a. A single Drawing incorporating the equipment furnished: Submittals that consist solely of individual drawings for each component and require that these sheets be compiled by the ENGINEER, in order to view the entire piece of equipment, are not acceptable.
    b. Building penetrations required by the engine driven generator system.
    c. Recommended intake and exhaust areas, including complete dimensions.
7. Detailed electrical wiring diagrams of the engine and the generator including:
    a. Complete engine generator detailed wiring diagrams for the unit being provided.
    b. Engine interconnection terminal box.
    c. Generator interconnection terminal box.
    d. Gas system drawings.
    e. Interface drawings between the engine driven generator skid and the transfer equipment.
    f. Wiring diagrams to show wire numbers and terminal block identifications:
        1) Wire numbers shall correspond to the wire number on the equipment.
        2) Wires shall be numbered.
    g. Complete interior and exterior control panel layout:
        1) Scaled.
        2) With device descriptions.
        3) With nameplates.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing Submittal information.
      d. Operating instructions and a maintenance manual presenting full details for care and maintenance of equipment of every nature furnished and installed in accordance with the Contract Documents.
      e. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
      f. Software documentation: Updated version of software.
      g. Hardcopy and electronic version of installed programs in the controllers including VFDs, pressure indicating meters, etc.
      h. Calibration, startup, test, and commissioning reports.
      i. Complete lists of equipment furnished, including Manufacturer model numbers, correct settings, alarm points, and operating ranges.
      j. Electrical controls:
         1) Adjustment and test instructions covering the steps involved in the initial test, adjustment, and startup procedures.
         2) Detailed control instructions which outline the purpose and operation of every control device used in normal operation.
         3) Description of the sequence of operation which outlines the steps which the controls follow during commercial power failure and commercial power return conditions.
         4) Schematic, wiring, and external diagrams. Also, internal device wiring and schematic diagrams for the sub-assemblies used in the equipment: Drawing to be furnished in a reduced 11 inches by 17 inches and shall be fully legible at that drawing size.
      k. Engine and generator:
         1) Standard operational manuals normally furnished by the Manufacturer.
         2) Repair parts manuals normally furnished by the Manufacturer: Detailing the parts and sub-assemblies which are available as repair parts.
      l. Shop maintenance manuals:
         1) Provide an on-site shop manual which is equivalent to the manual used by factory-authorized shop repair personnel.
         2) Manuals for the following equipment:
            a) Engine.
            b) Radiator.
            c) Generator.
            d) Engine GCP.
      m. SDS:
         1) Complete SDS forms for the substances.
         2) Located in O&M manual.
         3) Include a separate manual labeled SDS with additional copies of the SDS forms.
      n. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
      o. Test reports:
         1) Furnish complete reports for testing in accordance with the Contract Documents.
         2) Provide additional reports for testing as specified in SECTION 26 08 00.
      p. Final As-Built Drawings:
         1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
               (1) On a standard DW provided title block and border.
               (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
               (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
               (4) Titles: 0.2 inches.
      q. Warranty documentation.
E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver the following extra materials prior to 75% of the Substantial Completion date:
   1. Furnish sufficient lubrication products so that the entire system may be flushed and replaced after initial burn in period.
   2. Filters: Two of each style, size, and type.
   3. Fuses: Six of each size and type.

1.6 QUALITY ASSURANCE

A. The entire engine driven generator system including the exhaust and coolant systems is to be reviewed and the drawings and calculations shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

B. Codes and Standards:
   1. The engine generator shall be in accordance with NFPA 99 or NFPA 110 Type 10 (10 second) transfer requirements.
   2. The automatic transfer switch shall be in accordance with NFPA, NFPA 70, IEEE 241, and IEEE 446.

C. The Manufacturer’s technicians shall provide training:
   1. As specified in SECTION 01 44 33.
   2. These technicians will instruct the OWNER's personnel regarding the O&M of the items supplied.
   3. Mechanical maintenance training shall cover preventive maintenance and normal operational conditions: Covering the mechanical operations, day to day maintenance, periodic maintenance, and detailed and overhaul maintenance of the engine and generator.
   4. Electrical maintenance training shall cover preventive maintenance, normal operational conditions, settings, and adjustments, for the duration specified in this Section: Covering the control system, operations, maintenance, and adjustments of the complete electrical and control system for the engine generator.

1.7 DELIVERY, STORAGE, AND HANDLING

A. The engine driven generator skid shall be equipped with removable lifting and jacking angles, eye bolts, etc. to facilitate unloading and move-in operations.

B. The engine driven generator skid is to be shipped from the factory complete with lifting eyes, jacking angles, etc. attached to the structural base.

1.8 SITE CONDITIONS

A. Environmental Requirements: Materials and equipment shall be designed and constructed for continuous operation, at rated current and voltage, at 6,000 feet above mean sea level, -30°F (exterior and non-environmentally controlled areas) to 104°F ambient temperature and 95% relative humidity. The Equipment Manufacturer shall submit a certified letter in the Shop Drawing submittal stating the equipment provided meets this requirement.

1.9 WARRANTY

A. Manufacturer: Warranty for 1 year from Substantial Completion date for the satisfactory performance and installation of the engine driven generator system and associated appurtenances.

B. Without additional charge, the Equipment Supplier shall replace any Work or material they have provided which develops defects within 2 years or 2,000 engine hours, whichever occurs first, from the date of acceptance of the entire Project.

C. Materials and equipment shall be guaranteed against defective materials, design, and workmanship.

D. During the warranty period, the Equipment Supplier or its authorized dealer will be required to make the necessary repairs or replacements on-site.

E. Warranties which mention that the part shall be returned to the factory will not be acceptable.

F. During the warranty period, the OWNER will not accept charges for:
   1. Travel time.
   2. Mileage.
   3. On-site repair labor.

G. The warranty shall list the items excluded. The warrantee is not to exclude items such as:
   1. The engine coolant heater.
   2. The engine start battery.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Engine Driven Generator:
   1. Caterpiller/Olympian
   2. Cummins/Onan

B. Fire-Safe Ball Valves:
   1. Contromatics
   2. Jamesbury

C. Asbestos-Free Calcium Silicate Pipe Insulation, 2 1/2 Inches Thick:
   1. Owens-Corning Kaylo

D. Universal Remote Panel-Mounted Annunciator:
   1. Cummins model number 300-5929-01

2.2 MATERIALS

A. Equipment Ratings and Configuration:
   1. Engine driven generator set minimum size and configuration:
      a. 125 kW minimum rating at altitude as indicated on the plans:
         1) It is the Manufacturer’s responsibility to properly size the engine generator based upon site conditions and actual loads. Increases in size as a result of Manufacturer sizing shall be at no additional costs to the OWNER, including any and all conduit and wire size changes.
      b. 277 V/480 V, grounded wye, three-phase.
      c. Four-wire.
      d. 60 Hz.
      e. 0.80 PF.

f. Maximum allowable voltage dip upon motor starting on the generator bus 5%.
g. Standby power rated.
h. Maximum ambient 104°F.
i. Minimum altitude 6,000 feet above mean sea level. Minimum outside air ambient operating temperature -30°F.

2. Unit-mounted engine GCP.
3. Unit-mounted engine start battery.
4. Battery charger, trickle type, low current, located on unit.
5. Unit-mounted radiator with duct flange.
6. Exhaust silencer, critical grade mounted inside enclosure, and prefabricated exhaust system.
7. Exhaust flexible section.
8. Gas system components, including flexible fuel line, gas filter, shutoff valves, accessories, and fittings.
9. Weather protective sound attenuated enclosure.

B. Characteristics of Assembled Unit:
1. The engine driven generator shall consist of a natural gas engine directly coupled to an electric generator to provide continuous electric power for the duration of any power failure of the normal utility power supply.
2. The generator set shall be rated for standby power operation.
3. The engine driven generator shall be furnished on a steel sub-base to support engine, generator, and accessories as a unit:
a. The base shall be of welded construction.
b. The engine shall be direct connected through a flexible coupling to a single bearing generator.
c. The system shall be free of injurious torsional and bending vibrations within a speed range from 10% below to 10% above synchronous speed.
d. The engine driven generator is to be balanced such that the peak to peak amplitude of vibration velocity in any direction does not exceed either the engine or the Generator Manufacturer's published limits.
e. If shims are required under the feet of the generator for alignment purposes, they shall be of one-piece laminated shim stock and shall cover at least 90% of the foot.
f. The assembled engine driven generator skid shall be such that only the following field connections are required:
1) Standby power leads from generator to standby section of automatic transfer equipment, located as shown on the Drawings.
2) Control connections to:
a) Automatic transfer switch.
b) Pump station control system.
3) Exhaust system.
4) Gas system.
g. Connections to engine driven generator skid:
1) Flexible connections are required on the connections to the engine generator and shall be supplied by the Engine Driven Generator Supplier.
2) These connections shall include but are not limited to:
a) Exhaust.
b) Gas.
3) The length of the flexible connections shall exceed the Flexible Connector Manufacturer's minimum length recommendations for the diameter used and for the misalignment as measured after installation.

C. Engine Generator Base:
1. Support system:
a. The engine driven generator is to be bolted to steel pads which are an integral part of the structural support base.
b. The inboard generator pad is to be equipped with an adjustable foot with vibration isolation material attached. This adjustable foot is to be used to reduce the skid floor vibration at the inboard generator vibration pad.
c. Vibration isolators shall be provided between the engine generator and the welded steel base or between the base and the floor as recommended by the Manufacturer.

D. Engine:
1. The engine shall be a full compression ignition two-cycle unit or four-cycle unit.
2. Shall be of a design which has been in production for 5 years.
3. The rated net hp of the engine with the accessories, including radiator fan, shall not be less than that required to produce the minimum specified generator size at site altitude.
4. Equipped and designed as follows:
a. Spin-on type replaceable lube oil filter cartridges.
b. Heat-treated forged steel crankshaft: Dynamically balanced.
c. Forged steel connecting rods.
d. Crankshaft driven gear type lubricating pump.
e. Engine driven positive displacement fuel pump: Electrically driven fuel pumps are not acceptable.
f. Electric gas shut-off valve.
g. The engine air cleaner is to be a dry type replaceable filter.
h. 12 VDC or 24 VDC positive engagement solenoid shift-starting motor.

i. Oil level dip stick and oil drain pipe and valve with pipe plug: Oil drain pipe and valve shall extend 3 inches beyond the edge of engine base.
j. Dry electrical contacts to report: Engine running.
k. Engines requiring glow plugs will not be acceptable.
l. Governor:
    1) Isochronous type to maintain engine speed:
        a) Within 0.5% for steady state conditions.
        b) Within 5% for a no load to full load step with recovery to within 0.5% within 2 seconds of step load application.
    2) Equipped with means for manual operation and adjustment.
    3) Suitable for use on natural gas engines.
    4) Suitable for automatic, unattended starts.
    5) Electronic speed control matched and designed to control the actuator.
m. Personnel guards over exposed moving parts.

5. Gas system:
    a. Satisfactory performance on a natural gas as delivered by Xcel Energy at the site is a requirement. A heating value of 829 btu/cf and a specific gravity of 0.67 are typical for Denver. Confirm the heating value and specific gravity of the natural gas on-site.
    b. Flexible fuel lines rated for 300°F and 100 psi.
    c. Design natural gas pressure at the regulator shall be 13 inches of wc.
    d. Provide a natural gas inlet solenoid valve to engine.
    e. If required by the local fire district or the authority having jurisdiction, provide manual fire safe fuel shutoff valves:
        1) Three-piece ball valve.
        2) Carbon steel body and end caps.
        3) SST or hard chrome plated ball and stem.
        4) Reinforced teflon seats and seals.
        5) Socket welding ends.
        6) Firesafe design with secondary metal seating surfaces to ensure shutoff if primary seats are destroyed by fire.
6. Sensing elements:
    a. The engine shall be equipped with the devices necessary to allow it to be started and stopped remotely without manual adjustments to the engine controls.
    b. Automatic shutdown devices shall be included to protect against:
        1) Low oil pressure.
        2) High water temperature.
        3) Over speed.
        4) Overcrank.
7. Silencer and exhaust systems:
    a. The Equipment Supplier shall furnish an engine silencer with connections which match the engine exhaust outlet diameter:
        1) A SST exhaust flexible section shall be supplied at the engine to provide for vibration isolation.
        2) Hot surfaces on the engine, such as the exhaust manifold, shall have metal shields or high temperature blankets to prevent direct contact by operating personnel.
    b. Details of silencer location, supports, and bracing shall be shown and detailed on the Shop Drawings.
    c. The exhaust silencer shall be coated to be temperature and rust resistant and shall be rated for critical applications.
    d. Gas proof, seamless, SST, flexible exhaust connectors.
8. Insulation:
    a. Insulate the entire exhaust system, including the flex section at the engine, with 2 1/2 inch thick asbestos-free calcium silicate pipe insulation.
    b. Wired in place with 12 gauge dead soft annealed wire which has been twisted to lock tight enough to force the wire into the insulation.
    c. Wire remnants shall not be allowed to fall into the equipment.
    d. The insulated surface is to be covered with a 10 to 20 weave fiberglass covering which has been overlapped 2 inches:
        1) Cover surface with 0.016 inch thick smooth aluminum similar to Pabco Z-Lok Metal Jacketing:
            a) Use Z lock on longitudinal joints and overlap 3 inches on circumferential joints.
            b) No finish or caulking material will be necessary as the joints need not be weathertight.
            c) Metal jacket is to be held in place using banding straps.
9. Engine general operating requirements:
    a. The engine shall start, attain full speed, voltage, and assume full load within a maximum of 20 seconds, with jacket water at 85°F.
    b. The starting motor circuit is to be disconnected automatically after the engine starts.
    c. The engine shall be provided with an oil drain pipe and valve with pipe plug:
        1) Oil drain pipe and valve shall extend 3 inches beyond the edge of engine base.

d. The engine shall be equipped with an electric starting motor with starter solenoid, power shall be supplied from the engine control panel:
    1) The starting equipment shall include the necessary devices to prevent an overcrank and lockout if the starter pinion fails to engage the flywheel ring gear on the initial crank attempt.
e. The engine shall be equipped with gauges to indicate:
    1) Lube oil pressure.
    2) Gas pressure.
    3) Running time.
f. Gauges shall be mounted such that vibration will not cause premature failure.
g. The gauge system shall carry a full 3 year guarantee which provides for a no-charge visit to the site for replacement.
h. Engine coolant temperature shall be monitored by a thermometer with a thermometer well or a temperature gauge.

E. Generator (Alternator):
1. The alternator shall be:
    a. Brushless synchronous alternator.
    b. Self-ventilated.
    c. With full amortisseur windings.
    d. Skewed for smooth voltage waveform.
    e. With permanent magnet generator pilot exciter.
    f. With any other field forcing system which will provide 300% of full load current until the generator output breaker opens under overload or short-circuit conditions.
    g. Drip-proof protected.
    h. Protected against corrosion.
    i. Single bearing design.
    j. Insulated for continuous operation at 40°C ambient temperature.
    k. Temperature rise shall not exceed 105°C by resistance, consistent with a Class F rise: The winding insulation shall be Class H, 125°C rise by resistance.
    l. Capable of operating at 110% full load for 1 day.
    m. The insulation system shall be:
        1) Vacuum impregnated with epoxy varnish to be fungus-resistant in accordance with MIL I-24092.
        2) Multiply dipped and baked with a non-hygroscopic varnish with a final dip of epoxy.
    n. The alternator power leads shall be terminated using compression lugs.
    o. The alternator is to have a maximum balanced telephone interference factor not to exceed 50: To ensure that harmonics developed by the generator do not affect the other electrical equipment in the system.
    p. Designed to supply power to the non-linear loads as identified on the plans: Fluorescent lights.
2. The alternator voltage regulator shall be located in the engine control panel:
    a. Regulator is to:
        1) Provide constant voltage under all conditions.
        2) To maintain the steady state voltage within 1%:
            a) From 40°F to 120°F.
            b) From no load to full load conditions.
    b. Regulator is to have constant V per Hz characteristics.
    c. Static type.
    d. Maintain stable generator output voltage to within 1% for steady state loads from 0% to 100%.
    e. Regulator to be sized to match the power requirements at the permanent magnet generator pilot exciter.
    f. Include manual control to adjust voltage drop, voltage level, voltage gain.
    g. Regulator shall be sealed from the environment and isolated from the load to prevent tracking when connected to SCR loads.

F. Radiator and Cooling System:
1. The engine shall be cooled with a unit-mounted radiator cooling system complete with radiator, water pump, belt-driven fan, fan guard, thermostatic temperature control, high water temperature cutout, and accessories as required for proper operation. The radiator shall be sized to handle the cooling of the engine and other accessories required for proper operation. The fan shall draw air over the engine and discharge it through the radiator. The cooling system shall be sufficient to overcome the pressure and airflow losses associated with the engine generator enclosure and the generator and support equipment. If the Equipment Manufacturer offers a higher capacity radiator option instead of the standard radiator product in its written literature, this option shall be provided and installed as a part of the contract price.
2. The cooling system shall be filled with permanent antifreeze of the ethylene glycol type with rust inhibitor.
3. The engine shall be equipped with a three-phase electric jacket water heater(s) with the voltage indicated on the Drawings. The jacket water heater shall be sized to maintain jacket water at 90°F with a winter ambient temperature as specified. The jacket water heater shall be thermostatically controlled. Ball valves shall be installed on each side of the water jacket heaters for maintenance purposes.

G. Engine Wiring:
1. External wiring connection to and from the engine shall be made via engine-mounted junction boxes.
2. Wiring shall be enclosed in a NEC approved and recognized conduit system that is to be selected and sized by the Engine Generator Manufacturer and suitable for the temperatures, vibrations, and conditions on the engine driven generator skid.
3. Control wiring shall terminate on terminal blocks in the control junction box.
4. The wires shall be terminated using solderless compression type lugs.
5. The above wiring is to be coordinated with the engine control panel and the automatic transfer system equipment.
6. No wiring splices will be allowed and the connections shall be made at the terminal blocks in the control junction boxes.
7. Engine-mounted accessories shall be mounted so as to be readily removable for service.
8. Wiring on the engine shall terminate in a single terminal connection box:
    a. External connections shall be made to this single terminal connection box.
    b. Connections shall be made to terminal blocks:
        1) 600 V rated.
        2) Wires terminated on box with compression type ring type lugs, installed with proper tooling.
        3) Terminal blocks shall be numbered.
    c. Power connections to the alternator shall be made at the alternator box or the output circuit breaker and not at this terminal box.

H. Start Battery:
1. Start battery shall be installed on the engine driven generator skid.
2. Provide extra flexible cable to make the connection between the start battery and the engine: Proper compression lugs and tooling shall be used to terminate the cables.
3. Battery:
    a. The equipment supplier will supply a lead acid engine start battery system.
    b. Lead-acid recombination no maintenance type battery.
    c. Rated such that the 90 second cranking current to 1.0 V per cell exceeds the starter rolling current at 40°F:
        1) For the above ratings to be valid, the starter breakaway current shall not exceed the rolling current by a factor of more than 2.5.
        2) If the above battery selection will not meet these requirements for the engine being supplied, a larger battery shall be furnished.
    d. Truck type batteries or batteries with float voltage requirements above 2.27 V per cell will not be acceptable.
    e. Shall not require any additional air handling equipment to remove gases caused by constant battery charging.
    f. Battery system bolted electrical connections shall be made with heated NO-OX-ID grease and torqued as required by the Manufacturer and approved by the ENGINEER.
4. The start battery shall be mounted to the engine generator skid.
5. The charger shall be so sized as to be able to provide sufficient power to fully charge a drained battery.

I. Miscellaneous Items Engine Generator Skid:
1. The following items will also be supplied by the Equipment Supplier:
    a. Sectionalized drip pans.
    b. Vibration isolators shall be furnished to properly support the engine driven skid on its concrete base:
        1) The isolators shall be located for approximately equal load distribution and deflection per isolator.
        2) Isolators shall be spring type designed for the load and seismic conditions as identified for the site.
    c. Wall sleeves.

J. Automatic Standby Generator Control Equipment:
1. The unit-mounted controller shall incorporate the following items:
    a. Be set-mounted and capable of facing right, left, or rear.
    b. Vibration isolated on the generator enclosure.
    c. The microprocessor control board shall be moisture proof.
    d. Microprocessor control board shall be capable of operating from -40°C to 85°C.
    e. Relays will only be acceptable in high current circuits.
    f. Complete two-wire start/stop control which shall operate on closure of a remote contact:
        1) Contact located in automatic transfer switch.
    g. The starting system shall be designed for restarting in the event of a false engine start, by permitting the engine to completely stop and then re-engage the starter.
    h. Cranking cycler preset on and off cranking periods.
    i. Overcrank protection designed to open the cranking circuit if the engine fails to start.
    j. Circuitry to shut down the engine under the following conditions:
        1) High coolant temperature.
        2) Low oil pressure.
        3) Over speed.
    k. Engine cool down timer to permit unloaded running of the engine after transfer to the load to commercial power.

l. Three position off-manual-auto selector switch:
    1) In manual position the engine shall start and run regardless of the position on the remote starting contacts.
    2) In automatic position the engine shall start when the remote control circuit contact closes and stop after the cool down period expires.
    3) In the off position the engine shall not start even when signaled by the remote start contacts. Additionally, this position shall provide for immediate shutdown in case of an emergency.

m. The following indication lamps shall be included in the control panel:
    1) Not in auto.
    2) Overcrank.
    3) High engine temperature.
    4) Low coolant level.
    5) Over speed.
    6) Ready.

K. Instrument Panel:
1. Provide the following items on the skid-mount instrument panel:
    a. Vibration isolation.
    b. AC voltmeter.
    c. Ammeter.
    d. Voltmeter – ammeter phase selector switch.
    e. Direct reading pointer – type frequency meter.
    f. Oil pressure gauge.
    g. Run time meter.
    h. Voltage adjust rheostat.
    i. Elapsed time meter.
    j. Engine lock-out switch.
    k. Engine lock-out indicator.
    l. Emergency stop.
    m. DC voltmeter.
    n. Tachometer.

L. Generator Output Circuit Breaker:
1. Set-mounted and line side connected to alternator.
2. Manually resettable.
3. Line current sensing.
4. Inverse time versus current response.
5. Sized and coordinated to protect the generator from damage from overload and short-circuit.
6. Breakers shall be furnished as specified in SECTION 26 24 19.

M. Enclosure:
1. Weather protective enclosure with sound attenuation of 50 dBA at the property line.
2. Houses the generator equipment on the skid including the exhaust system.
3. Minimum 14 gauge steel with painted finish. Paint as specified in SECTION 09 90 00 System No. 5. Paint color to match existing.
4. SST hardware.
5. Cambered roof.
6. Keyed door accesses: Ensure easy access to the major generator and engine control components for servicing.
7. Limit switches on each door:
    a. Heavy duty metal body.
    b. Adjustable rocker arm.
    c. Wired in series on NC contactors when the doors are closed.
    d. Rating: 120 V 10 A continuous rating.
    e. Switches shall be the same Manufacturer.
8. Gravity outlet louver and actuated inlet louver openings.
9. Rodent/bird barriers on inlets and outlets.
10. Four point lifting system.
11. Vertical exhaust air discharge duct with SST screen.
12. Interior-mounted exhaust silencer.

2.3 OPERATION

A. To ensure the equipment has been designed and built to the highest reliability and quality standards, the Manufacturer shall be responsible for design prototype tests as follows:
1. Components of the system, such as the engine generator set, the automatic transfer switch, and accessories shall not be subjected to prototype testing because the tests are potentially damaging.
2. Similar design prototypes shall be used for testing, and not the actual equipment delivered to the site.
3. Tests shall include the requirements of NFPA and the following other items:
    a. Maximum power in kW.
    b. Maximum starting kVA at 35% instantaneous voltage dip.

c. Alternator temperature rise:
    1) By embedded thermocouple.
    2) By resistance method.
    3) In accordance with NEMA MG 1, 22.40 and NEMA MG 1, 16.40.
d. Governor speed regulation under steady-state and transient conditions.
e. Gas consumption at 1/4, 1/2, 3/4, and full load.
f. Harmonic analysis, voltage wave form deviation, and telephone influence factor.
g. Cooling air flow.
h. Torsional analysis testing to verify that the generator set is free of harmful torsional stresses.
i. Endurance testing.
j. A certified copy of the test results will be furnished to the OWNER.

PART 3 EXECUTION

3.1 PREPARATION

A. It is the sole responsibility of the Manufacturer to review the Drawings and furnish equipment suitable for the loads identified on the Drawings. The Specifications indicate a minimum size that the ENGINEER has determined based upon non-certified information. The Manufacturer shall furnish equipment sized to match the actual loads. No increase in Contract Price will be considered if the equipment size needs to be increased to meet the load requirements after bids have been submitted.

3.2 INSTALLATION

A. The equipment shall be installed as shown on the Drawings, and in accordance with the Shop Drawings, Manufacturer's recommendations, and applicable codes.

B. Field adjust protective device, relay, and control settings in accordance with the recommendations of the electrical system analysis studies as specified in SECTION 26 05 70.

C. Demonstration:
1. Upon completion of the Work, at a time to be designated by the OWNER's Representative, the Equipment Supplier shall demonstrate for the OWNER the operation of the engine installation, including special systems installed by it, or installed under its supervision.
2. Control functions will be tested, and the tests will be made in conjunction with the engine generator startup.
3. These tests will include the normal starting and stopping functions as outlined in the Contract Documents.

3.3 QUALITY CONTROL

A. Additional testing as specified in SECTION 26 08 00.

B. The authorized representative of the Engine Generator Manufacturer shall furnish the services of factory certified technicians during the startup and adjustment period to ensure that the items furnished are in proper operating condition.

C. An installation check shall be performed by the Manufacturer's Representative.

D. Gas, lubricating oil, and antifreeze shall be checked for conformity to the Manufacturer's recommendations under the environmental conditions present.

E. Accessories that normally function while the equipment is in standby mode shall be checked for proper operation prior to cranking the engine. These functions shall include, but not be limited to, the battery charger and engine starting system and engine starter lock-out system, block heater, fuel system heaters, and fuel gauge.

F. A visual and mechanical inspection shall be performed and shall include the following:
1. Proper grounding.
2. Blockage of ventilating passageways.
3. Proper operation of jacket water heaters.
4. Integrity of engine cooling systems.
5. Overheating of engine or generator.
6. Proper installation of vibration isolators.
7. Proper cooling liquid type and level.
8. Proper lubrication oil type and level.
9. Proper fuel type and level.

G. The engine-generator shall be started in the test mode and checked for the following items:
1. Excessive mechanical and electrical noise.
2. Exhaust leaks.
3. External path for exhaust gases.
4. Cooling air flow and overheating.
5. Check RTDs or embedded generator-alternator winding temperature detectors.
6. Movement during starting and stopping.
7. Vibration during running.
8. Normal and emergency line-to-line voltages and phase rotation.
9. Verify that voltage regulator and governor operation will cause unit speed and output voltage to stabilize at proper values within a reasonable length of time.
10. Compare the generator nameplate rating and connection with the one-line diagram.
11. Proper operation of meters and instruments.

H. Additional electrical and mechanical tests shall be performed as follows:
   1. Perform a minimum of three cold-start and three black-start tests by interrupting the normal power source with a test load consisting of the connected system loads to verify transfer switch operation, automatic starting operation, operating ability of the engine generator, overcurrent devices ability to withstand in-rush currents, and automatic shutdown. Continuously monitor and record the data as listed on the OWNER's standard generator load-bank test form available from the OWNER.
   2. Test and demonstrate the engine protective shutdown features and alarm features for low oil pressure, over temperature, and over speed.

I. Arrange for and make the adjustments both mechanically and electrically as needed or as directed by the ENGINEER to ensure a complete and operable system. Demonstrate that the control device/alarm features operate properly and start, stop, etc. the engine generator as intended.

J. Provide a combination resistive and reactive load bank test at the fully rated kW/KVA of the standby generator system and shall test the generator at 25%, 50%, 75% and at full capacity at 0.8 PF. The testing shall be for 30 minutes duration at each incremental step and the full load testing shall be for a minimum of 4 hours at 100% load. The Equipment Supplier shall follow the Manufacturer's recommendations for breaking in the engine prior to operating the engine at rated capacity. Fill out the OWNER's standard generator load-bank test form available from the OWNER and as listed as a supplement to this Section. This load bank testing shall occur at a time and date convenient to the OWNER during the months of July or August when the ambient temperature is above 90°F.

3.4 ADJUSTING

A. The Manufacturer's Representative shall make the adjustments both mechanically and electrically as needed and as directed by the ENGINEER to ensure a complete and operable system.

END OF SECTION

SECTION 26 32 19
SYNCHRONOUS GENERATORS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for synchronous generators.

B. Related Sections:
1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
4. SECTION 09 90 00 – PAINTING AND COATING
5. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
6. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
7. SECTION 26 32 20 – GENERATOR EXCITATION EQUIPMENT
8. SECTION 48 70 00 – GENERATOR STARTUP AND COMMISSIONING

1.2 REFERENCES

A. American Society for Non-Destructive Testing (ASNT):
1. SNT-TC-IA – Personnel Qualification and Certification in Non-destructive Testing

B. American Society of Mechanical Engineers (ASME):
1. Boiler and Pressure Vessel Code

A. ASTM International (ASTM):
1. A 36 – Specification for Carbon Structural Steel
2. A 345 – Standard Specification for Flat-Rolled Electrical Steels for Magnetic Applications
3. A 370 – Standard Test Methods and Definitions for Mechanical Testing of Steel Products
4. A 388 – Standard Practice for Ultrasonic Examination of Heavy Steel Forgings
5. A 609 – Standard Practice for Castings, Carbon, Low Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof
6. A 703 – Specification for Steel Castings, General Requirements, for Pressure Containing Parts

B. Institute of Electrical and Electronics Engineers (IEEE):
1. 115 – Guide for Test Procedures for Synchronous Machines Including Acceptance and Performance Testing and Parameter Determination for Dynamic Analysis
2. 141 – Recommended Practice for Electric Power Distribution for Industrial Plants
3. 421.1 – Standard Definitions for Excitation Systems for Synchronous Machines
4. 421.2 – Guide for Identification, Testing and Evaluation of the Dynamic Performance of Excitation Control Systems
5. 522 – Guide for Testing Turn Insulation on Form-Wound Stator Coils for Alternating-Current Electric Machines
6. C50.12 – Salient-Pole 50 Hz and 60 Hz Synchronous Generators and Generator/Motors for Hydraulic Turbine Applications Rated 5 MVA and Above

C. International Building Code (IBC)

D. International Electrotechnical Commission (IEC):
1. 60041 – Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps, and pump-turbines

1.3 COORDINATION

A. Selection, sizing, and design of equipment specified herein shall be coordinated with the Manufacturers and Suppliers of turbines.

B. Ensure proper interfacing and connection between components and systems, and eliminate adverse effects upon the operation or performance of turbine-generator equipment, as specified in the Contract Documents.

C. Coordination items include, but are not limited to, generator brake control, flywheel requirements, shaft requirements, bearing requirements, installation and assembly, manufacturing tolerances, static and dynamic balancing of rotating parts, and materials selection.

1.4 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt, unless otherwise specified. Resubmittals will be subject to the same review time.

C. Shop Drawings:
1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Use Contract Drawing equipment and device tags and abbreviations.
4. Dimensional drawings.
5. Conduit entrance locations.
6. Bus ratings, data, connection information, torque values, and drawings.
7. Protective devices: Copies of time-current characteristics.
8. Anchoring instructions and details.
9. Certified outline and clearance dimensions, weights, lifting locations, and arrangement Drawings for generator and major components.
10. Electrical and hydraulic (including water) interconnection diagrams showing required field wiring and connections (size, number, and type) to and from generator components and auxiliary devices.
11. Plan view and cross sections of generator.

12. Foundation and anchorage requirements for generator.
13. Generator outline indicating necessary clearances for assembly, disassembly, and maintenance.
14. Location and direction of maximum forces and torques transmitted by equipment to powerhouse structure.
    a. Design criteria and performance data summary in accordance with this Section.
15. Descriptive information for exciter, braking system, flywheel (if required), bearings, bearing lubrication and cooling, heaters, gauges, RTDs, and other thermal devices.
16. Bearing design calculations.
17. Detailed Shop Drawings of bearings and brakes.
18. Power terminal cubicle:
    a. Certified outline and clearance dimensions, weights, and lifting locations.
    b. Internal and external arrangement Drawings.
        1) Neutral grounding resistor information with sizing calculations.
    c. Surge protection device rating information.
    d. Bus data.
    e. Conduit entrance locations.
19. Submit a certified letter stating that the materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

D. Quality Control Submittals:
1. Factory acceptance test plan.
2. Final factory acceptance test data sheets and witness report.
3. Field test plan including functional and performance testing: Provide a narrative of the test plans and data to be recorded and analysis to be completed, including forms for recording data during the test.
4. Field test report: Provide a narrative and data summary of the tests discussing each element requiring testing, the tests performed, and the results. The field testing is not complete until this report is submitted and accepted by the ENGINEER.
5. Coating application and inspection qualifications as specified in SECTION 09 90 00.
6. Testing related Submittals.
7. O&M manuals:
    a. Provide preliminary and final manuals.
    b. As specified in SECTION 01 78 23.
    c. Shop Drawing Submittal information.

E. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
    a. Factory and field certified test reports.
    b. Software documentation: Updated version of software.
        1) Hardcopy and electronic version of installed programs in controllers and equipment.
    c. Calibration, startup, and commissioning reports.
        1) Include complete lists of equipment furnished, including the Manufacturer’s model numbers, correct settings, alarm points, and operating ranges.
    d. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
    e. Final As-Built Drawings:
        1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW’s current CAD Standards and shall include, but not be limited to, the Standards located online in DW’s CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer’s drawings shall be provided:
                (1) On a standard DW provided title block and border.
                (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
                (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
                (4) Titles: 0.2 inches.
    f. Warranty documentation.

F. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with Manufacturer’s name, description and part number, for shipment and long-term storage and deliver prior to 75% on the Final Completion date the following extra materials:
1. Fuses, 0 V to 600 V: A minimum of six of each type and each current rating installed.
2. Fuses and fuse links, 600 V and greater: A minimum of six of each type and each current rating installed.

1.5 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services: Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
1. Installation assistance, and inspection of installation: 1.
2. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

D. Design Criteria:
   1. Scope includes furnishing, delivering, testing, and commissioning the synchronous generator and auxiliaries in accordance with these Specifications.
   2. Generator:
      a. Type: Horizontal synchronous.
      b. Exciter: Brushless
      c. Number of phases: Three.
      d. Frequency: 60 Hz.
      e. Phase-to-phase voltage: 4160 V.
      f. Rated PF: 0.90 minimum.
      g. Speed: To match turbine.
      h. Efficiency at rated load: 95% guaranteed minimum.
      i. Insulation system: Minimum Class F with a machine design temperature rise consistent with Class B insulation.
      j. Stator winding connection: Star, suitable both for grounded and undergrounded operation.
      k. Net minimum capacity in kVA, continuous duty, at rated speed, frequency, voltage, and power factor, with maximum 80°C rise over 40°C ambient: To match or exceed turbine maximum output.
   3. Temperature rise:
      a. Maximum temperature rise, when delivering rated kVA continuously at 0.9 PF, rated voltage, and frequency, and with cooling air entering generator at not more than 40°C:
         1) Stator winding: 80°C.
         2) Field winding: 80°C.
         3) Stator core: 75°C.
      b. Stator winding temperature: Determined from the reading obtained at the hottest point by means of embedded RTDs, located in stator winding.
      c. Field winding temperature: Determined by resistance method.
      d. Stator core temperature: Determined by thermometer method or by thermocouples.
   4. Electrical characteristics:
      a. Short-circuit ratio: Not less than 1 to 1.
      b. Designed to withstand, without injury, a three-phase short-circuit at generator terminals, with machine initially at rated kVA, 0.9 PF, 105% armature voltage, and rated excitation, for not less than 30 seconds.
      c. Efficiency at rated kVA, 0.9 PF, including voltage regulator and excitation system losses: Not less than 96.0%.
      d. Calculated unsaturated (rated current) direct-axis transient reactance in accordance with IEEE 141 Table 4A.1.
      e. Telephone influence factor shall not exceed 150 (balanced) and 100 (residual), based on a weighing factor of 0.5 measured in accordance with IEEE 115.
      f. Suitable for operation over range of 90% to 105% of rated voltage at rated load.
   5. Guaranteed performance: Generator shall be designed and manufactured for continuous operation; site conditions as specified in SECTION 26 05 00.
   6. Mechanical characteristics:
      a. Flywheel effect (WR^2) of rotating parts of the generator, not less than: The Seller determines.
      b. Direction of rotation when viewed from opposite drive end: As shown on the Drawings.
      c. Maximum design runaway speed: Value determined by the Turbine Manufacturer.
      d. Maximum temperature of cooling water supply for bearing oil cooling system: 60°F.
      e. Designed for operation with a turbine having the following characteristics:
         1) Overspeed design characteristics:
            a) Each time a load rejection occurs, a temporary overspeed condition will occur.
            b) Generator and rotating parts shall be designed for periodic operation at runaway speed. Each such operation will include continuous operation at full runaway speed for a maximum duration of 1 hour.
            c) Generator shall be designed to safely withstand such operation without damage, excessive stress or vibration, deleterious deformation, or deterioration.

E. Materials of components furnished by the CONTRACTOR shall be new and of first-class quality, suitable for the purpose, free from defects and imperfections and of the classes and types listed in ASME Boiler and Pressure Vessel Code or the equivalent ASTM materials. Structural steel components and supports unless otherwise specified, shall be manufactured from steel in accordance with ASTM A 36.

F. Materials or parts used in the equipment shall be tested in accordance with the applicable Specifications and purchased with certified mechanical and chemical properties. Stocked materials may be used provided that the material when purchased required certification. Copies of certifications shall be supplied if requested by the ENGINEER.

G. The CONTRACTOR shall be responsible for using adequate factors of safety throughout the design of the equipment specified herein. Under the most severe conditions of loading expected under normal operation, stresses in the materials shall not exceed the lesser of 1/3 yield tensile strength or 1/5 ultimate tensile strength. Temporary emergency loadings, such as runaway speed conditions, shall not exceed 1/2 of the yield strength.

H. Welding:
   1. Testing personnel shall be qualified in accordance with ASNT SNT-TC-lA.
   2. Non-destructive testing procedures shall be in accordance with:
      a. ASTM A 370 (ferrous materials), ASTM A 609 (ultrasonic).
      b. ASTM A 388 (ultrasonic), ASME Boiler and Pressure Vessel Code (magnetic particle), liquid penetrant (non-ferrous and austenitic).

3. Welding procedures and welder qualifications shall be in accordance with the ASME Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications.

I. Castings: Castings, unless otherwise specified, shall be in accordance with ASTM A 703.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Shipping Splits: Established by the CONTRACTOR to facilitate the ingress of equipment to the final installation location within the building.

1.7 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.8 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the low-voltage motor control system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Generator:

1. Marathon
2. TECO-Westinghouse
3. WEG

B. Bearing Vibration:

1. Switches: Metrix, Model 440-DR-2-0-4-4-2-2-0-0

2.2 COMPONENTS

A. Generator Structure:

1. Stator frame:
   a. Supported on sole plates embedded in concrete foundation constructed as part of headworks structure.
   b. Provide with bolts and dowels for firmly fastening the stator frame to the sole plates and for preserving alignment between the generator frame and the sole plates.
   c. Provide an adequate number of suitably sized dowels to prevent movement of the stator frame on the sole plates when the generator is subject to stresses resulting from short-circuit conditions.
2. Sole plates and anchor bolts:
   a. Provide with suitable ears and jacking screws for leveling and alignment and necessary openings for grouting.
   b. Anchored to concrete foundations by SST anchor bolts furnished as part of this Contract.
   c. Baseplates, mounting bases, dowels, and bolts shall be provided in advance of other turbine-generator components for installation by the CONTRACTOR.
   d. The Seller shall provide anchor bolt templates at the time anchor bolts and other embedded parts are furnished.
3. Frame and mounting hardware:
   a. Designed to withstand forces resulting from faults, false synchronization, or unit runaway for the time indicated herein.
   b. In addition to the normal static and dynamic horizontal and vertical support and anchoring forces, equipment bases and anchor bolts shall be capable of withstanding short-circuit forces of the generator acting simultaneously with horizontal and vertical earthquake forces prescribed in the latest edition of the ICC IBC.
4. Provision shall be made for conveniently handling parts during assembly or disassembly of a unit. Adequate provisions shall be made for attaching lifting devices, slings, and eyebolts.
5. Provide grounding plates, suitable for bonding with bolted type grounding lugs on the stator frame and the generator housing at two locations diagonally opposite each other.
6. Suitable working space around, and access to, the generator and field windings shall be provided for routine inspection and maintenance of coils, coil ends, wedges, coil bracing, ring bus, external electrical connections, and other components.
7. Housing shall be equipped with suitable covers to provide winding and other internal access. Covers shall permit proper ventilation. Provide covers in sections, with lifting means and fasteners, to provide convenient removal and installation.

B. Stator:

1. Core:
   a. Built up with high-grade, nonaging thin-laminated silicon steel of at least ASTM A 345 C 5 quality.
   b. Laminations:
      1) Each lamination shall be coated on both sides with an insulating varnish or other suitable material to minimize core losses.
      2) Frame and laminations shall be completely factory-assembled.
      3) Laminations shall be stacked to counteract any taper introduced in rolling process.
      4) Laminations shall be clamped and securely held in place within the stator frame via keying, dovetailing, through-rods, or welding.
      5) To ensure uniform tightness of laminations, full and final clamping pressure shall be applied to successive layers of laminations while being stacked. Layers shall not exceed more than 18 inches in depth.
      6) There shall be no perceptible buzzing of laminations during operation.
   c. Air ducts: Arranged to make flow of air smooth and quiet and to minimize air friction losses.
   d. Coil installation:
      1) To ensure against buckling and shrinkage, coil slot wedges shall be of a glass reinforced polyester material or other suitable Class F material as defined by ANSI standards.
      2) Coils shall be installed, wedged, tied, and connections made before the stator is shipped from the factory.

2. Winding:
   a. Star-connected.
   b. Copper and assembled using form-wound coils of the same size and shape.
   c. Type that will minimize losses and heating due to circulating currents. Strands shall be of annealed copper, free from splinters, flaws, rough spots, or sharp corners.
   d. Connections shall be made in a neat, secure, and proper manner.
   e. If multi-turn coils are used, they shall be connected to provide parallel paths as nearly equal as feasible, with neutral leads of each path and common main lead brought out at suitable locations.
   f. If single-turn coils are used, they shall be completely transposed by Roebel or other method, with both ends of each phase winding brought out within the generator housing at suitable locations.
   g. With type of winding having neutral of two or more parallel paths brought out, location and connections of individual coils in each of the parallel paths shall be such that circulating currents between the parallel paths, in the event of misalignment of rotor with respect to the stator, shall not adversely affect differential protection provided for winding.
   h. Circuit rings shall be located in the area behind coils and shall be solid bar type.
3. Winding insulation:
   a. Minimum Class F insulation, as defined by NEMA standards, with the machine designed for a maximum hot spot temperature of 130ºC, at an ambient of 40ºC, temperature rise of 80ºC, and a 10ºC hot-spot allowance.
   b. Designed to provide high resistance to moisture and other contaminants.
   c. Coils shall be wound with copper wire covered with strand insulation consisting of glass, dacron, mica, or other high temperature flexible insulating film.
   d. Turn-to-turn insulation shall be adequate to withstand test voltages in accordance with IEEE 522 and shall be applied to ensure coils withstand switching or other electrical surges well in excess of normal turn-to-turn voltage.
   e. Insulation shall consist of mica tape and shall be applied to end turns, as well as to the slot portion of coil, to ensure that parts of coils are fully insulated to ground for voltage class of generator and for corona suppression.
   f. After insertion of the coils in the stator slots, end connections shall be brazed and insulated. The end bracing system shall be capable of completely supporting each coil and the entire assembly, and shall prevent coil vibration and distortion under stresses caused by the most severe short-circuit conditions to which the generator may be subjected, as specified herein. After the coils are properly wedged, end-turns braced, and moisture removed, the entire stator assembly shall be vacuum pressure impregnated with thermo setting epoxy resin. The complete stator shall then be heat-cured.

C. Generator:
1. Capable of withstanding sudden three-phase short-circuits at its terminals without injury to the stator winding, provided duration of such short-circuits is not sufficient to cause injurious heating in accordance with ANSI C 50.10. Line-to-ground fault currents shall be limited to a value not exceeding that obtained with a three-phase fault at terminals of generator.
2. A minimum of six 100 ohm platinum, three-wire, RTDs shall be installed two per phase with leads in a terminal box.

D. Rotor:
1. General:
   a. Designed and manufactured in accordance with the best modern practice.
   b. Construction shall permit removal of rotor and shaft assembly as a unit when the generator is disassembled.
   c. The rotor core shall be solidly attached to the shaft and cast, forged, or fabricated of steel.
2. Pole pieces and rotor core:
   a. Built up of thin steel laminations fastened to the rotor core by means of accurately machined or punched dovetails, matching similar slots in the rotor core, and secured in place by means of tapered keys. Keys shall be locked in place on both sides of the rotor core to prevent their coming out if they become loose.
   b. Alternatively, rotor poles may be secured to the rotor core by an approved system of high-strength threaded studs and fasteners.

E. Coils:
1. Material used in coil insulation system shall be Class H material, in accordance with ANSI standards, or better.
2. Field coils and connections between coils shall be copper and shall be supported or braced to prevent distortion or damage due to vibration, thermal expansion or contraction, or rotational stresses throughout normal and overspeed speed conditions.

F. Amortisseur Windings:
1. Low resistance and rugged construction.
2. Shall not be susceptible to resonant mechanical vibration.
3. Capable of withstanding unbalanced short-circuits in accordance with ANSI C 50.10.

G. Shaft:
1. Material: Fabricated of forged, open-hearth carbon or alloy steel, properly heat treated.
2. Design:
   a. Designed to operate safely at any speed up to and including maximum runaway speed without detrimental vibration or distortion and to carry generator loads specified in this Section without exceeding unit stresses.
   b. Designed and manufactured to avoid, or to reduce to a safe minimum, stress concentrations due to fillets, holes, keyways, or other discontinuities of shaft section.
   c. Critical speeds and natural periods of vibration of the combined turbine and generator rotating parts in bending and in torsion shall be checked. Lowest critical speed shall be at least 25% above runaway speed.
3. Arrangement and construction:
   a. Proper length and construction to accommodate overhung mounting of turbine runner, generator rotor, brake disc, and flywheel (if provided).

b. Coordinate shaft dimensions and machining with type and location of turbine shaft seal components.
c. Machined all over and polished at bearing surfaces and at accessible points below or above guide bearing for alignment checks.
d. Runout tolerances: In accordance with IEEE C50.12.

H. Flywheel:
1. The rotating inertia of each turbine-generator in relation to that required to ensure adequate stability during synchronization, operation, and runaway and shall thereby determine the need for a flywheel. A penstock transient analysis shall be performed to inform this evaluation.
2. Design:
a. If it is determined that a flywheel is required, it shall be designed to operate safely at speeds up to 110% of maximum turbine runaway speed.
b. Provision shall be made for securely integrating flywheels with turbine-generator shafting.
c. The method used for attaching the flywheel to turbine-generator shafting shall not result in high stress concentrations in the shaft which may cause shaft failure due to fatigue or overstress.
d. The flywheel may incorporate brake disc function.

I. Bearings:
1. General:
a. Provide drive end and non-drive end bearing assemblies.
b. Generator bearings may be sleeve Babbitt type or anti-friction type.
c. Each bearing assembly shall be complete and self-contained, including any integral oil cooler heat exchangers.
d. Bearing assemblies relying upon external, electric motor-driven, pump operated, forced-lubrication systems, for oil circulation or cooling, are not acceptable.
e. Loads:
1) For anti-friction bearings, designed for B10 operating life of 150,000 hours at rated load.
2) Withstand forces caused by faults, false synchronizing, or overspeed for time specified without damage or loss of lubricant.
3) In addition to generator loads, bearings shall carry all loads as may be imposed on them by the turbine.
4) The Generator Manufacturer shall design the generator bearings to meet the requirements of the Turbine Manufacturer with respect to loads, including normal radial loads imposed by the turbine runner, normal hydraulic thrust, and transient reverse hydraulic thrust.
5) If thrust loads are encountered, provide suitable thrust bearing. Thrust bearings shall be adjustable shoe, self-equalizing type.
f. Turbine runner shall be supported by generator bearings. Bearings shall be designed to control runout and end play within vendor specified limits, including during overspeed operation for the time specified. Rotor end play limits shall be stamped on the generator shaft.
g. Bearing housings shall be sealed to prevent entry of foreign material or release of lubricant into the generator.
h. Oil cooler:
1) If necessary for proper bearing operation, provide bearings with integral and self-contained oil cooler heat exchangers.
2) If required, a source of cooling water shall be available from penstock serving each unit. The cooling water supply shall be filtered. The Manufacturer shall specify the required water temperature and associated flow rates to maintain proper bearing cooling.
3) Provide components necessary for control and monitoring cooling water system of each bearing, including flow switch, flow indicator, temperature indicators (supply and return), strainer, pressure switch, and pressure regulating or flow control valves.
4) Interconnecting piping and isolation valves shall be furnished by others under separate Contract.
i. RTDs shall be provided in each bearing, wired to a terminal box, and as specified in this Section.
j. Provide bearing pedestals or supports with grounding pads.
k. Bearings and their housings shall include provisions for bonding and insulation, configured as required to prevent the flow of circulating currents.
2. Sleeve bearings:
a. Ring-oil lubricated and horizontally split, to permit easy inspection and replacement.
b. The bearing oil reservoir shall be sized to keep oil cool and arranged to accommodate settling of foreign material and have a convenient drain plug and oil level indicator.
3. Antifriction bearings:
a. Oil or grease lubricated.
b. The lubrication system shall be designed to remove contaminants from bearing and to prevent over-lubrication.
4. Main guide/thrust bearings:
a. Bearings shall have sufficient capacity, without overheating, to support the combined load of the generator and turbine rotating parts at any speed from rest to maximum runaway speed of the turbine. The bearings shall be capable of operating continuously without failure at the maximum runaway speed for 1 hour.
b. The guide and thrust bearings shall be Babbitt lined oil lubricated type. The thrust bearing shall be a Kingsbury self-equalizing shoe type.
c. The bearing housing shall be designed to allow removal of the guide or thrust bearing assemblies without removal of the bearing bracket, generator stator, or rotor. Suitable lifting eyes shall be provided for installing and removing the bearing assemblies. Any seals on the housing shall be accessible for replacement without removing the housing. The bearing housing shall be doweled to the mounting surface.

d. If needed, a self-contained, skid-mounted oil lubricating system shall be furnished including oil reservoir, oil heaters, socket welded piping system, filters, pumps and motors, cooling coils, valves, instruments and other necessary appurtenances. Parts in contact with water shall be SST. Cooling coils using water shall be double walled SST heat exchangers. Components and assemblies shall be designed to be oil tight or leak free. Avoid the use of threaded fittings where possible. Pump motors shall be TEFC, rated for the site conditions, provided with a 1.15 SF and Class F insulation. Instrument contacts shall be rated for a minimum 0.5 A at 480 VAC. The lube oil system shall be provided with a 480 VAC three-phase oil reservoir tank heater and reservoir tank heater thermostatic control. The tank heater location and removal procedure shall be approved by the ENGINEER. The lube oil system skid shall be provided with mounting channel for a lube oil system control panel, provided by others. Equipment location shall be approved by the ENGINEER.
e. 100 ohm platinum, three-wire, RTDs shall be installed in guide and thrust bearings with leads in a terminal box.

J. Brake System:
1. General:
a. Provide a disc, securely mounted on generator shaft, and an electrically operated, caliper type brake operator. Brake disc shall incorporate ports, studs, or other suitable features whereby leverage can be applied for manual rotation of the unit.
b. Alternatively, flywheel, if furnished, may incorporate braking surfaces.
c. Sufficient capacity to bring rotating parts of generator and turbine to a stop from 10% of normal operating speed within 1 minute after brakes are applied.
d. Designed to make at least 1,000 stops from 10% speed between normal maintenance intervals.
2. Brake operator:
a. Electrically operated.
b. Equipped with adjustable and replaceable brake pads.

K. Generator Power Terminal Cubicle:
1. Provide a single, metal-enclosed cubicle housing with the following:
a. Terminations for generator phase and neutral leads.
b. Provisions for terminating outgoing power cables.
c. Surge protection.
d. Excitation system power transformer.
e. Excitation system paralleling current transformer.
f. Neutral-side differential current transformers as specified in DIVISION 26.
g. Neutral connection bus.
h. Neutral grounding transformer as needed in coordination with DIVISION 26.
i. High resistance grounding system as specified in DIVISION 26.
j. Provision for station ground connection.
k. Core-balance current transformer for generator protection relay.
2. Features:
a. Sheet-steel enclosure.
b. Doors: Full-height, gasketed with key-locking three-point latches and concealed hinges.
c. Louvers:
1) As necessary for adequate ventilation.
2) Screened to prevent entrance of insects.
d. Electric heater:
1) Adjustable thermostatic control.
2) Rated for 240 VAC and suitable for operation on single-phase, 120 V, 60 Hz power.
e. Low voltage, instrument transformer, and relaying circuits shall be prewired to terminal blocks as specified in this Section.
3. Generator phase and neutral leads shall be routed to the generator power terminal cubicle via a metal-enclosed throat or duct, containing suitable means of cable support. Coordinate relative elevations of duct interfaces at the generator and the power terminal cubicle to accommodate installation of the power terminal cubicle on 3 1/2 inch high housekeeping pad. Cubicle shall be adequately sized to accommodate components. Outgoing cables will be routed in multiple raceways entering the bottom of the power terminal cubicle. Cubicle shall be partitioned into phase and neutral grounding sections.
4. Surge protection.
5. Provide necessary buswork, conductors, connectors, terminals, supports, standoffs, insulators, and other materials. Bolted bus connections shall be tin-plated.
6. Current transformers as specified in DIVISION 26.
7. Secondary resistor as specified in DIVISION 26.
8. Excitation power transformer:
a. Type: Insulated dry, indoor.
b. Rating:
1) 480 V, three-phase.
2) kVA Rating: As required. Coordinate with automatic voltage regulator input requirements.
c. Fixed-mounted.
d. Primary protection: Two current-limiting fuses.
e. Secondary protection: Fuses or molded case circuit breaker.

L. Exciter/Voltage Regulator as specified in SECTION 26 32 20.

M. Heaters:
1. Provide electric heaters within generator and exciter as required to prevent condensation of moisture.
2. Heaters shall be suitable for operation on single-phase, rated for operation at 240 VAC and operated at 120 V, 60 Hz power.
3. Provide wiring, in rigid conduit, between individual heaters and terminal box, as specified in this Section.
4. Provide thermostatic control. Where heater load ampere rating or voltage rating exceeds thermostat capability, provide control contactors.

N. Accessory Leads and Auxiliary Terminal Boxes:
1. General:
   a. Provide leads and wiring within the generator or exciter for controls, heaters, temperature detectors, and other accessories. Exciter circuits shall be routed in rigid galvanized steel conduits where practicable.
   b. Circuits that extend beyond the generator, except main generator leads and exciter field leads, shall terminate in terminal boxes, as specified herein.
   c. Conduits shall be arranged to make removal unnecessary when the generator is dismantled.
2. Auxiliary terminal boxes:
   a. Provide one or more mounted at suitable locations on outside of generator housing.
   b. Segregate AC, DC, temperature detector, and current transformer terminal areas.
   c. Provide NEMA 12 enclosure with back plane.
   d. Enclosures shall be arranged for conduit entrance from bottom or either side.
3. Terminal blocks:
   a. Molded barrier type, rated not less than 600 V.
   b. Shorting type terminal blocks shall be provided for current transformer circuits.
   c. Marking:
      1) White or other light-colored marking strips, fastened by screws to molded sections at each block for circuit designation.
      2) Each connected terminal of each block shall have circuit designation or wire number permanently placed on marking strip.
      3) Spare marking strips shall be provided with each block. Provide at least 20% spare terminals.
   d. Power, potential transformer, or current transformer circuits: Provide GE; Type EB-25 or EB-27.
4. Wiring:
   a. Except for temperature detectors, shall be stranded copper, 600 V minimum, with 90°C thermosetting type insulation.
   b. #14 AWG minimum, except for current transformer leads, which shall be #10 AWG minimum.
   c. Wiring for temperature detectors may, except as otherwise specified in this Section, be in accordance with the Seller's standard practice for such leads.
   d. Control cable conductors shall be color-coded.
   e. Each wire shall be clearly identified by a code stating its destination stamped on sleeve type tags located at each end of the wire.
   f. Suitable attention shall be given to wiring and terminal arrangement to permit conductors to be conveniently and neatly grouped for connection to a minimum number of external cables.
   g. Insulate generator components to prevent stray currents that may result from the field of the generator and that may damage generator bearings.
   h. Oil level gauge and low level switch:
      1) One for each bearing oil reservoir, with scale of sufficient length to indicate oil level at room and operating temperatures, and at rest and operating conditions.
      2) Locate near or on reservoirs, in an approved, accessible location where they can be clearly read.
      3) Provide discrete level switch for each bearing for remote indication of low bearing oil level.
   i. Generator speed sensing:
      1) Tachometer functions and requirements, including speed sensing, speed sensor cabling, and speed switch functions.
      2) Provide and install the tachometer in the GCP. Separately mount a pushbutton on the GCP interior to verify function. Provide four SPDT programmable relay outputs for speed switch functions, minimum. Provide 4 mA to 20 mA DC isolated analog current output proportional to generator speed in rpm.
      3) Mount toothed gear on generator shaft.
      4) Provide active Hall-Effect sensor for speed sensing, including 0 rpm.
      5) Provide mounting bracket and other accessories as required to install the sensor in a secure location on the synchronous generator assembly, protected from damage, contamination, or tampering.
   j. Bearing vibration:
      1) Monitoring:
         a) The generator and turbine shall be equipped with vibration detection sensors suitably affixed to the structural steel base frame of the generator and turbine assemblies at right angles to each other to measure and transmit vibration levels in the X and Y axis of operation.
         b) Provide two proximity sensors for each bearing, and one for thrust. Mount sensors 90 degrees apart (X-Y). Each proximity sensor shall have a dedicated channel.
         c) Monitors shall be installed in the GCP.
      2) Switches:
         a) The generator and turbine shall be equipped with vibration switches with two SPs. One for alarm and one for shutdown.

b) The switches shall have an adjustable trip delay and adjustable startup delay.

O. Enclosures:
1. The generator’s enclosure shall be weather protect Type I (WPI) as defined by NEMA.
2. The circulation of air shall be by means of the fan action of the generator rotor.

2.3 FINISHES

A. Finish requirements for generator in accordance with the Manufacturer’s standard and as specified in SECTION 09 90 00.

PART 3 EXECUTION

3.1 INSTALLATION

A. Equipment shall be installed by the CONTRACTOR under separate Contract.

B. The Seller shall provide assistance and direction to install equipment as specified in SECTION 01 44 33, these Specifications, and the Manufacturer’s instructions and requirements.

3.2 REPAIRS

A. Field Finishing:
1. Products shall be delivered with prime and finish coats applied.
   a. Touch up or repair damage to coatings resulting from unloading, storage, installation, testing, and startup.
   b. If finish coats are damaged extensively after delivery, completely repaint.
   c. Touch up, repair, or complete repainting shall match the color of the original paint, and shall be fully compatible with applied primers and finish.

3.3 QUALITY CONTROL

A. Factory Assembly and Tests:
1. Equipment shall be completely assembled, wired, and adjusted at the factory.
2. Equipment shall be given the Manufacturer’s routine shop tests and other electrical and operation tests, as specified herein, to ensure reliable operation of equipment.
3. Consult the Manufacturers of specialty devices and materials to ensure their proper application, installation, and adjustment, as required.
4. If required, parts shall be properly marked and identified for ease of assembly in the field.
5. Testing format shall be unwitnessed by the OWNER. Provide itemized and certified test documentation.
6. Inspection: Devices, including mounted and unmounted devices and spare parts shall be tested for proper operation. Device markings, nameplate markings, conductor identifications, terminal block wire designations, and scales and calibration of meters and instruments shall be checked against approved Drawings. Completed assembly shall be checked for alignment of panels, doors, and equipment, for rigidity of assembly, and for adequacy of fasteners and supports.
7. The following tests shall be completed on each generator at the factory, in accordance with the IEEE 115:
   a. Dielectric test of armature and field windings.
   b. Resistance test of armature and field windings.
   c. Mechanical balance of generator rotor.
   d. No-load saturation test.
   e. Synchronous impedance curve.
   f. Check of bearing temperatures during no-load saturation test.
   g. Bearing insulation test.
   h. Efficiency.
   i. Telephone influence factor.
8. The excitation system shall be factory tested in accordance with IEEE 421.1 and IEEE 421.2.
9. Bearing oil coolers shall be subjected to a static water pressure of 175 psi for a period of not less than 1 hour without showing leaks. Provide certified test reports.
10. Operation tests: Completed assembly shall be connected to proper control and supply voltage and, as far as practical, a mockup of simulated control signals and controlled devices shall be systematically applied to check equipment for specified functions and proper operation.

B. Supervisory Services During Installation: Perform supervisory services during installation of the Work as needed.
1. Qualifications of supervisor: Minimum 15 years of experience in erecting hydroelectric equipment.
2. Duties: Observe and document activities of the CONTRACTOR. Advise the ENGINEER of correct installation procedures during the installation of Work. Provide the ENGINEER with a written and illustrated report of Work observed and recommendations made.
3. Duration: As determined by the OWNER.

3.4 STARTUP

A. Startup procedures requirements for the equipment specified herein as specified in SECTION 01 91 00 and SECTION 48 70 00.

B. Commissioning procedures requirements for the equipment specified herein shall include the activities as specified in SECTION 01 91 00 and SECTION 48 70 00.

C. Manufacturer's Services: As specified in SECTION 01 44 33 and SECTION 48 70 00.

D. Field Testing:
1. Provide technical direction of functional and performance testing in accordance with the following:
   a. Provide functional and performance testing in accordance with NETA Acceptance Testing Specifications and Manufacturer’s standard procedures.
   b. Provide step-by-step test procedures to systematically demonstrate functions. Prior to generating unit operational tests, demonstrate functions to the extent possible. Complete demonstration during operational testing phase.
   c. Field test reports shall document test procedures, results, and pass/fail status on the Seller’s standard forms.

2. Testing format: Witnessed by the OWNER and the ENGINEER.
3. Check proper connection of power, control, and instrument circuits.
4. Functional testing: Equipment shall be inspected and tested during and after installation for proper alignment and adjustment, quiet operation, proper timing, absence of excessive vibration, rotation, and proper connection.

E. Provide technical direction for the following tests:
1. During plant startup and upon availability of adequate Project flow, equipment shall be tested by the CONTRACTOR for specified guaranteed performance.
2. Witnessed by the OWNER, the ENGINEER, and the Manufacturer's Representative, as necessary to resolve malfunction problems attributable to, or associated with, equipment specified herein.
3. If required by the OWNER, test the generator to determine whether guarantees and requirements of these Specifications have been fulfilled and furnish information that may be needed in using the generator as a dynamometer during testing of the turbine.
4. Perform tests in accordance with applicable requirements of ANSI standards, IEEE 115, and IEC 60041 except as specified otherwise herein.
5. Test equipment and personnel will be furnished at the expense of OWNER.
6. Performance tests shall be performed within 2 years after delivery of equipment.
7. After bearing oil coolers have been completely assembled, subject to a static water pressure of 175 psi for a period of not less than 1 hour without showing leaks or drop in pressure.
8. The generator shall be subjected to the following routine tests:
   a. Alignment, rotational, runout, and bearing checks.
   b. Megger test for insulation resistance.
   c. Stator and field windings dielectric tests:
      1) Test at not less than 75°C.
      2) Test in accordance with ANSI standards, one phase at a time, with other windings grounded.
      3) Field winding shall be given a dielectric test of 1,500 V for 1 minute connected through field leads and generator collector rings, or on stator and rotor of a brushless exciter, with solid-state devices disconnected and grounded.
   d. Resistance test of armature and field windings.
   e. Operation tests and adjustment of entire excitation system to show compliance with operating requirements of these Specifications.
   f. Test for determination of time for brakes to stop the machine safely from 10% to 0 speed with turbine wicket gates fully closed.
   g. No-load saturation test.
   h. Short-circuit saturation test.
9. In addition to the listed tests herein, the Buyer may perform other tests required to establish conformance of equipment with guarantees and Specifications and to obtain data needed in testing the turbine.
10. Overspeed test:
    a. Perform on the generator to demonstrate that parts of generator will successfully withstand stresses incident to its operation at unit runaway speed.
    b. If the overspeed test shows deficiencies in the generator, deficiencies shall be corrected, and the overspeed test shall be repeated.

F. Special Services:
1. As specified herein, in SECTION 48 70 00, at such times as requested by the OWNER, and as follows:
   a. The Manufacturer's Representative shall provide technical direction and the checking of the following:
      1) Setting and grouting of anchor bolts.
      2) Grouting of sole plates.
      3) Erecting generator parts and appurtenances.
      4) Alignment of the generator with reference to the turbine.
      5) Dynamic balancing of the generator rotor and making required adjustments so the generator will operate satisfactorily under any load within its specified capacity without detrimental vibration or objectionable noise.
      6) Excitation system operation and making required adjustments so systems will operate satisfactorily under specified conditions.
   b. Provide assistance during testing and startup of equipment.
   c. Monitor, direct, and assist the CONTRACTOR's personnel during the Work.
   d. Provide step-by-step test procedures to systematically demonstrate functions.

END OF SECTION

SECTION 26 32 20
GENERATOR EXCITATION EQUIPMENT

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for generator excitation equipment.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER’S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
4. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
5. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
6. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):

1. 421.2 – Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control Systems
2. 421.3 – Standard for High-Potential Test Requirements for Excitation Systems for Synchronous Machines
3. C 57.12.01 – Standard General Requirements for Dry-Type Distribution and Power

B. National Electrical Manufacturers Association (NEMA):

1. ICS 2.3 – Instructions for the Handling, Installation, Operation and Maintenance of Motor Control Centers Rated Not More than 600 V

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Brushless exciter:
   a. I/O amperage curve.
   b. Open circuit output saturation curve.
   c. IEEE excitation system model constants.
   d. Detailed drawings of brushless exciter schematic and converter assembly layout drawing with numbered references to individual components in the Bill of Material.
4. Eternal power and signal connections.
5. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
6. Dimensional drawings, including outline diagrams, lifting eye locations and size of eye bolt, maximum weight, cabinet mounting hole sizes and location, size and location for ventilation.
7. Calculations including: Exciter loading (on exciter power transformer and transformer power source), CT, and PT burden calculations.
8. Protective devices:
   a. Copies of time-current characteristics.
   b. Protective device trip settings.
9. Anchoring instructions and details.
10. One-line and three-line diagrams.
11. Schematic/interconnect diagrams with wiring number identification and wiring list.
12. Internal layout drawing.
13. Power requirements and heat dissipation: Maximum heat dissipations Btu/hour.
14. Conduit entry/exit locations.
15. SPs, wiring diagrams, etc.
16. Installation details: Include modifications or further details required.
17. Spares, expendables, and test equipment.

D. Quality Control Submittals:

1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
   e. Factory and field certified test reports.
   f. Software documentation: Updated version of software.
      1) Hardcopy and electronic version of installed programs in controllers and equipment.
   g. Calibration, startup, and commissioning reports.
      1) Include complete lists of equipment furnished, including the Manufacturer’s model numbers, correct settings, alarm points, and operating ranges.
   h. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.

i. Final As-Built Drawings:
1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
a) Drawings shall be on a standard DW provided title block and border.
b) As-Builts and Manufacturer's drawings shall be provided:
(1) On a standard DW provided title block and border.
(2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
(3) Text: Minimum 0.1 inches, maximum 0.2 inches.
(4) Titles: 0.2 inches.
j. Warranty documentation.

E. Extra Materials:
1. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
a. Fuses: A minimum of six of each type and each current rating installed.

1.4 QUALITY ASSURANCE
A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.
C. Manufacturer's Services:
1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
a. Installation assistance, and inspection of installation: 1.
b. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.5 SITE CONDITIONS
A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY
A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the generator excitation equipment system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
A. Brushless Exciter:
1. Electric Machinery Company – WEG Group
2. ENGINEER approved Manufacturer
B. Control System:
1. Basler Electric Company, Model DECS-250 Generator Excitation System
2. ENGINEER approved Manufacturer

2.2 COMPONENTS
A. Voltage Regulator Control:
1. The digital voltage regulator shall provide ±1/4% voltage regulation from no load to full load. The minimum control range of the automatic voltage regulator shall be -15% to +10% of the nominal generator terminal voltage. The temperature drift shall not exceed 0.5% for slow changes in ambient temperatures ranging from 59°F to 104°F. The digital voltage regulator shall be equipped with a voltage limited/V per Hz circuit to reduce the generator terminal voltage as prime mover frequency reduces. The threshold frequency shall be adjustable via a Windows based PC software program provided with the excitation system for setup. An alarm shall be provided on the controller to indicate under-frequency operation. Voltage sensing shall be 120 VAC, three-phase.
2. Paralleling provisions shall be included to provide reactive load sharing between generators. The droop setting shall be adjustable from –30% to +30% at rated PF, rated load. The negative droop setting shall provide line drop compensation to counteract line or transformer impedance voltage drops to maintain a constant load voltage at a remote point in an isolated power system.
a. The automatic voltage regulator shall utilize field tunable PID gain settings to provide a means to optimize generator voltage response and minimize voltage overshoot. A software setup program shall be provided to assist in the selection of the PID values to help optimize system performance.
b. Manual control of field current shall be provided, standby to the automatic voltage regulator, to maintain constant field current with 1% regulation for 10% changes in generator terminal voltage. The minimum control range shall be 0% to +120% of rated field current.
B. Power Stepdown Transformer: A three-phase dry-type control power isolation transformer shall be supplied to provide acceptable voltage to the excitation system. The transformer shall be designed with a 185°C insulation system, 115°C rise at a 40°C ambient. Transformer shall be convection cooled, Type AA, having open frame construction. Primary fusing shall be provided at the input of the power PT.
C. Power Interrupt: An AC Subcontractor shall be provided to interrupt the AC power.

D. Voltage Softstart: The digital controller shall be equipped with voltage softstart feature to minimize generator overvoltage at buildup. The digital controller shall include a means to program the time interval for the generator to buildup to rated terminal voltage. Voltage softstart shall be active in both automatic voltage regulator and field current regulator mode. The generator voltage shall follow a V/Hz characteristic during voltage buildup.

E. Automatic Field Flash: The excitation shall be supplied with field flashing provisions to build generator voltage from station battery. Field flashing shall disable when generator voltage builds to a specific value of machine voltage. If generator voltage does not buildup, field flashing shall be disabled after a designated time limit that shall be field programmable.

F. System Control Provisions:
   1. The excitation system shall be equipped with the ability to provide local control of the generator at the excitation cubicle using a keypad type control and at the GCP using control switches including:
      a. Auto/manual transfer.
      b. Raise/lower for AVR, FCR (manual), var/PF mode.
      c. Excitation on/off.
   2. Remote control is provided using external switches wired back to the digital excitation system and Ethernet communication using a Modbus protocol to allow the operation of the functions below from a remote computer including:
      a. Auto/manual transfer.
      b. Raise/lower for AVR, FCR, var/PF mode.
      c. Excitation on/off.
      d. Shaft voltage suppression.
   3. Shaft voltage suppression shall be supplied across the exciter field to prevent bearing deterioration caused by switching power rectifiers.

G. Protective Functions:
   1. The excitation system shall be equipped with the following protective features:
      a. Generator over-voltage. Adjustable from 100% to125% with adjustable time delay.
      b. Generator under-voltage. Adjustable from 50% to100% with adjustable time delay.
      c. Loss of Voltage sensing. Adjustable time delay of 0 seconds to 10 seconds.
      d. Field over-voltage. Adjustable from 100% to 170% with adjustable time delay.
      e. Field over-current. Adjustable from 100% to 170% with an adjustable inverse time curve.
      f. Watchdog timer: A watchdog function shall monitor the microprocessors and provide a contact to trip in the event of a fault within the microprocessors.
      g. Alarms annunciation shall be provided via the RS 485 communication serial link and user-settable contacts for hardwire annunciation.
      h. Field ground protection device 64. Device 64 field ground protection relay shall be provided, which shall alarm upon detection of an exciter field ground. Contact shall be provided for annunciation. A target is provided on the relay to record a relay trip.

H. Excitation Cubicle:
   1. Components of the excitation system shall be mounted in a formed 11 gauge sheet steel NEMA 1 enclosure. The cubicle shall be rigid and self-supporting with enclosed panels on rear.
   2. A full-length door equipped with a three-point latch assembly and locking handle, shall be provided for access to inside mounted equipment. Openings shall be provided as necessary for adequate ventilation. The enclosure shall include a separate compartment in the upper section for low-voltage controls and the annunciator panel as shown on the Drawings.
   3. Digital controller shall be equipped with an LCD. The user shall have the means to define the three metering quantities desired on the LCD. Options shall include:
      a. Generator voltage.
      b. Bus voltage.
      c. Generator line current.
      d. Generator frequency.
      e. Bus frequency.
      f. Generator kW.
      g. Generator vars.
      h. PF.
      i. Apparent power.
      j. Field voltage.
      k. Field amperes.
   4. Cabinet LCD shall provide the following additional indication:
      a. In auto/FCR mode.
      b. Excitation on/off.
      c. Position indication.
      d. Alarm status.
      e. Generator voltage SP.
   5. Additional annunciation shall be provided on the cabinet to include:
      a. Raise/lower limits.
      b. Autotrack enabled.
      c. Null indication.

d. Preposition.

I. Alarm Annunciation: Alarms shall be provided to indicate limiting or protective functions active. Alarms shall be available by the RS485 serial and Ethernet communication links using Modbus protocol or field settable customer contacts. A maximum of four contacts shall be provided to the user for general alarm annunciation. Alarms may include:
   1. Under-excitation limiting.
   2. Over-excitation limiting.
   3. Under-frequency operation.
   4. Raise/lower limits.
   5. Generator over-voltage.
   6. Generator under-voltage.
   7. Field overvoltage.
   8. Field overcurrent.
   9. Loss of voltage sensing.
   10. Null indication.

J. Communications: Ethernet – Modbus TCP/IP for remote communications. A RS 232 front panel port shall be provided for calibration and setup. The communications shall provide means to control start/stop functions, raise/lower SP of any active mode including the voltage regulator, field current regulator, var/PF mode, transfer between operating modes, annunciate alarms including limiters, and protective functions active.

K. Cubicle Accessories:
   1. LED light fixture assembly, with door-activated switch and convenience outlet.
   2. Space heater with thermostat.

L. CT Shorting Terminal Block: A safety shorting block shall be provided for the connection of the remote parallel CT.

M. Control Power: 125 VDC and 120 VAC shall be provided for electronic circuits. In the event of loss of one of the control power sources, the other source shall be used to keep the excitation system operating.

N. Protective Finishes: Fabricated metal parts shall have a protective finish. The finish process shall include metal cleaning and preparation followed by one coat of ANSI No. 61 gray for the cabinet enclosure. Subpanels shall have a color white finish process.

PART 3 EXECUTION

3.1 GENERAL

A. This Section describes a digital excitation system, for use on a brushless exciter type synchronous generator. The digital excitation system shall be designed to work with the brushless exciter and shall be complete with controls, limiters, and protection to safeguard the generator. The generator excitation system shall be provided with a user-friendly Windows-based software program for easy setup and commissioning of the excitation system, as well as Ethernet communications using Modbus protocol for control, metering and annunciation.

B. The rating information, to be verified with the Generator Manufacturer:
   1. Generator rating: 1976 kVA, 4,000 VAC, 60 Hz, 0.9 PF, 514 rpm.
   2. Exciter field rating:
      a. Field amperes at rated load: 4.8 ADC.
      b. Rated excitation volts: 92.0 VDC.
      c. Minimum field amperes: 1.5 ADC.
      d. Minimum field volts, cold: 21.0 VDC.
      e. Resistance at 25°C: 14.3 ohms.
      f. Minimum field flashing amperes: 1.2 ADC.
      g. Maximum field flashing amperes: 1.8 ADC.
      h. Maximum current during forcing: 14 ADC.
   3. Generator prime mover type: Hydro turbine.

C. A digital voltage regulator shall be designed, provided, and installed to supply the VA requirements of the exciter field. The excitation system shall be a high initial response design in accordance with IEEE 421.2.

3.2 INSTALLATION

A. Install equipment in accordance with NEMA ICS 2.3, Submittal Drawings, and the Manufacturer's instructions and recommendations.

B. Install equipment plumb and in longitudinal alignment with pad or wall.

C. Coordinate terminal connections with installation of feeders.

D. Grout mounting channels into floor or mounting pads.

E. Retighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.

F. Field adjust protective device, relay and control settings in accordance with the recommendations of the electrical system analysis studies as specified in SECTION 26 05 70.

3.3 QUALITY CONTROL

A. Verify wiring, layout, installation, and identification.

B. Inspect excitation system interconnection wiring, generator collector ring, and grounding connection.

C. Verify proper system operation and other system settings.

D. Provide installation certification.

E. Testing:
   1. Factory tests:

a. Prior to mounting, devices shall be individually tested in accordance with the acceptance test procedure for that device.
b. The excitation system shall be thoroughly factory tested to determine compliance with the specification and the functional design of the system.
c. Electrical dielectric test shall be performed on the excitation cabinet in accordance with IEEE 421.3.
d. The power PT test shall include the following in accordance with IEEE C57.12.01, Table 7 – Routine Test:
    1) No load core loss.
    2) Exciting current at rated voltage.
    3) Turns ratio.
    4) Applied dielectric hipot.
    5) Open circuit voltage test.
    6) Polarity check.

2. Field tests:
    a. The excitation system shall be operated at 0.95 PF lag, 1.0 PF, 0.95 PF lead by use of the var/PF controller. PF shall be maintained at 1.0 for 30 minutes with the unit synchronized to the system to demonstrate that the var/PF controller is capable of maintaining the unit PF.
    b. Measurement of excitation system voltage response time and maximum exciter voltage in per unit.
    c. Load rejection of rated load at rated voltage and rated PF.
    d. Determination of the excitation system frequency response, phase and gain, for on-load and no-load conditions. For the on-load condition this shall be done from measurements of generator power and voltage.
    e. Overall response of machine and excitation system to power system voltage changes.
    f. Test to demonstrate that the excitation system is able to protect itself against excessive current.
    g. Field current at rated kVA, PF and 105% voltage.
    h. Field current at rated kVA, PF and 100% voltage.
    i. Operational test to demonstrate that protective relays shall operate satisfactorily to provide protection for the generator. In conjunction with this test, relays shall be set as recommended by the CONTRACTOR and as approved by the Utility and the ENGINEER.
    j. Establish proper adjustment for the excitation system during load rejection tests and demonstrate effectiveness of voltage regulator forcing action in demagnetizing the main generator field.
    k. Additional tests, startup, and commissioning as specified in SECTION 01 91 00 and SECTION 26 08 00.

F. Performance Features:
1. The following features shall be provided with the excitation system to modify the operating characteristics of the solid-state automatic voltage regulator:
    a. A UEL shall be provided to prevent a loss of generator synchronism due to under-excitation. The UEL shall utilize a circular characteristic that approximately matches the generator's under excited capability curve. The digital excitation system shall be provided with indication via the RS 485 serial communication link when the limiter is active and a contact closure shall indicate the activation of the UEL.
    b. Both offline and online OEL shall be provided to prevent generator overvoltage offline and rotor field heating due to excessive current in the exciter field when the generator is online. The offline field current limiter shall have a minimum of one adjustable instantaneous limit with adjustable time delay when the generator circuit breaker is open. The online OEL with be a three-stage current limiter with the following characteristics:
        1) Instantaneous current limit with adjustable time delay.
        2) Intermediate current limit with adjustable time delay.
        3) Final current limit: The online and offline OELs shall be active in the event of loss of voltage sensing at the voltage regulator input. The digital excitation system shall provide indication via the RS 485 serial communication link when the limiter is active with an alarm contact.
    c. Var/PF control shall be provided as a supplementary control to the automatic voltage regulator. The var/PF control shall utilize an adjustable proportional and integral network to provide either fast or slow response into the voltage regulator control loop. The var/PF controller shall maintain a constant vars or PF over the operating range of the generator.
    d. Bumpless transfer shall be provided from the active to non-active mode, including automatic voltage regulator, field current regulator, var/PF. Autotracking shall be enabled at all times to ensure match levels during transfer.
    e. Automatic transfer to field current mode shall take place when loss of voltage sensing at the voltage regulator input occurs.
    f. The excitation system shall be equipped with generator to bus voltage matching when paralleling to the utility bus. Adjustable compensation shall be provided to match differences between generator and bus voltage instrument transformers.

G. Software Setup Program: A Windows-based software program shall be provided with the equipment for use with a PC to provide means for setup and commissioning the excitation system via the RS 232 or Ethernet port. The software programs shall include user-friendly screens to adjust PID values required for the various control loops, to provide performance step responses for the automatic voltage regulator, field current regulator, or var/PF modes, and to provide metering information of measured generator and field quantities. Control of start/stop, raise/lower SP, transfer between operating modes, annunciation of limiters, and protective functions active, plus configurable functions for setup shall be provided through the PC setup software.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products and execution for hydroelectric generator maintenance.

B. Related Sections:
   1. SECTION 01 32 00 – CONSTRUCTION PROGRESS DOCUMENTATION
   2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
   5. SECTION 26 32 20 – GENERATOR EXCITATION EQUIPMENT
   6. SECTION 28 46 00 – FIRE ALARM SYSTEM
   7. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS
   8. SECTION 48 13 13.01 – HYDROELECTRIC WATER TURBINE MAINTENANCE
   9. SECTION 48 70 00 – GENERATION STARTUP AND COMMISSIONING

1.2 REFERENCES

A. American National Standards Institute/International Electrical Testing Association (ANSI/NETA):
   1. MTS – Standard for Maintenance Testing Specifications for Electrical Power Equipment and Systems

B. American Petroleum Institute (API)
   1. 686 – Recommended Practice for Machinery Installation and Installation Design

C. ASTM International (ASTM):
   1. E 165 – Standard Practice for Liquid Penetrant Testing for General Industry

D. Institute of Electrical and Electronics Engineers, Inc. (IEEE):
   1. 43 – Recommended Practice for Testing Insulation Resistance of Electric Machinery

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. Shop Drawings:
   1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
   2. Catalog, descriptive and specification information for equipment, components, and devices.
   3. Dimensioned equipment and layout drawings.
   4. Complete sizing calculations and ratings.
   5. Conduit entrance and connection locations.
   6. Conductor and cable interface drawings.
   7. Enclosure, support and mounting details.
   8. Maintenance:
      a. Submittals shall be approved prior to performing maintenance, inspections or tests.
      b. Testing technician resume(s).
      c. Schedule for performing maintenance, inspections, and tests.
      d. Standards references and procedures for each test.
      e. Equipment, materials and methods to be used for each test.
      f. Test form to be used and submitted.

C. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing Submittal information.
      d. Manufacturer's installation, operation, maintenance, troubleshooting and calibration instructions. Include internal wiring and schematic diagrams.
      e. Certified test or inspection reports.
      f. Testing, inspection, commissioning and startup reports and forms.
      g. Final As-Built Drawings:
         1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
               (1) On a standard DW provided title block and border.
               (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
               (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
               (4) Titles: 0.2 inches.
   3. Rotor assembly natural frequency:
      a. Submit an analysis of the turbine and generator rotating assembly's critical speed. Include calculations, graphs, and write up covering procedures, assumptions, conclusion, and recommendations in a report.
      b. Identify any excitation to the unit from low flow instabilities, cavitation, and runaway.

c. If rotor natural frequencies are found around the normal operating point or at runaway speed, provide recommendations, other than change in rpm, that will move rotor natural frequencies away from the normal and runaway operating points.
d. Analysis shall include generator modifications and the new runner.

D. Warranty Documentation.

1.4 QUALITY ASSURANCE

A. Qualifications: The Subcontractor performing the Work on the generator shall have a minimum of 10 years of experience performing similar work on similar machines. A resume of past projects similar in nature shall be submitted before work begins.

B. A detailed data log shall be kept by the Subcontractor performing the Work. It shall show the activities performed and measurements taken. Submit the log to the ENGINEER upon completion of the generator work, and include it with the submission of the Daily Log Book as specified in SECTION 01 32 00.

1.5 DELIVERY, STORAGE, AND HANDLING

A. The generator equipment and components shall be stored in an indoor, temperature controlled and moisture free environment. The generator shaft shall be protected from the elements during transport, and shall not be transported if there is any chance of inclement weather expected for the day. The generator equipment and components shall not be exposed to large temperature variations that might allow moisture to condense on the exposed metal and windings.

B. The generator stator shall be cleaned on-site and temporary room shall be constructed to prevent debris and cleaning solvent from contaminating the powerhouse. Clean the powerhouse to the approved level of the ENGINEER.

1.6 WARRANTY

A. The Subcontractor performing the Work shall warrant the work to be free from defects and poor workmanship for a period of 1 year after commissioning of the generator.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Electric Machinery Company – WEG Group:
1. 6655 Sugarloaf Parkway Duluth, GA 30097-4907
2. Telephone number: 612-378-8000

B. ABB Inc.:
1. 4900 Kingston St. Denver, CO 80239
2. Telephone number: 303-329-2300

C. Speed Sensing Equipment:
1. Al-TeK Instruments

D. ENGINEER-Approved Manufacturer

PART 3 EXECUTION

3.1 GENERAL

A. As part of this Contract, the generator shall be professionally cleaned and tested.
1. The CONTRACTOR and the Hydroelectric Generator Maintenance Subcontractor shall coordinate, schedule, and plan the turbine and generator maintenance with the Mechanical Millwright Subcontractor as specified in SECTION 48 13 13.01, including but not limited to, ancillary instruments and systems associated with turbine, generator, governor, inboard thrust and guide bearing, outboard guide bearing, new brushless exciter, new speed gear and tach magnetic pickups, new brake system, lube oil system, generator cooling water system, RTDs, vibration sensors, etc. The Hydroelectric Generator Maintenance Subcontractor’s tasks shall be coordinated with the CONTRACTOR to provide complete hydroelectric unit refurbishment and enhancements in accordance with the Contract Documents. The I&C system shall coordinate as specified in SECTION 40 50 00.
2. CONTRACTOR and Hydroelectric Generator Maintenance Subcontractor shall coordinate, schedule, and plan all aspects of the generator maintenance with Generator Excitation Equipment Manufacturer as specified in SECTION 26 32 20 for new brushless exciter conversion, new speed gear and tach magnetic pickups. Hydroelectric Generator Maintenance Subcontractor tasks shall be coordinated with the CONTRACTOR to provide complete hydroelectric unit refurbishment and enhancements in accordance with the Contract Documents. The I&C system shall be coordinate as specified in SECTION 40 50 00.

B. The original generator information shall be provided to the CONTRACTOR for use in the refurbishment.

C. Generator Description:

Make	**Type**	**Serial Number**	**Capacity**	**Voltage**
Toshiba	Horizontal Synchronous Generator	A9298	6,111 kVA	12.46kV

D. The generator is normally configured as voltage following machine with VAR/PF controller:
1. (Nameplate) Type: GAST.
2. (Nameplate) Form: RCCP.
3. (Nameplate) Poles: 16.
4. (Nameplate) kVA: 6111.
5. (Nameplate) RPM: 450.
6. (Nameplate) Volts: 12460.
7. (Nameplate) Ampere: 283.

8. (Nameplate) Hz: 60.
9. (Nameplate) PF: 0.9.
10. Rating: Continuous (9000 feet).
11. Direct axis transient reactance X’d = 31.3%.
12. Quad axis transient reactance X’q = NA.
13. Direct axis subtransient X’’d = 28.2%.
14. Quad axis subtransient reactance X’’q = 31.2%.
15. Zero sequence reactance.

E. Generator disassembly and shaft removal:
1. The generator shall be disassembled, inspected, cleaned, tested, modified and started-up in accordance with the Manufacturer’s instructions. The existing overhead crane may be used to disassemble the generator and assemblies.
2. Coordinate the generator cooling water, halon, lube oil, electrical and control disconnection, reconnection, and identification with other Contractors and the OWNER.
3. Removal of the generator shaft requires the removal of the sound booth. Removable roof access hatch shall be properly removed and reinstalled for transporting equipment over 2 tons in and out of the powerhouse.

3.2 INSTALLATION

A. Reassemble and install generator in accordance with the Manufacturer’s instructions. Coordinate the generator cooling water, halon, lube oil, electrical and control disconnection, reconnection, and identification with other Contractors and the OWNER. The halon system shall be demolished as specified in SECTION 28 46 00.

B. Perform final quality inspection.

3.3 RESTORATION

A. General: The following scope of work is required, as a minimum for the electric generator refurbishment.
1. Visual and mechanical inspection, before disassembly and after reassembling:
   a. Perform vibration test.
   b. Inspect physical and mechanical condition.
   c. Inspect anchorage, alignment, and grounding. Check for soft-foot in accordance with API 686, Section 5.4.4. Electrical insulation tests shall be in accordance with IEEE 43.
   d. Confirm correct application of appropriate lubricants.
   e. Check mechanical components including the shaft and lower bearing assembly for burrs, or damaged areas.
   f. Visually inspect original leads.
      1) Air gap spacing and machine alignment measurements: The air gap shall be measured and recorded with a feeler gauge at four locations on top of the generator and four locations on the bottom, locations shall be as approximately 90 degrees apart.
   g. The position of the magnetic center line on the rotor shaft shall be measured and recorded with respect to the generator and turbine frame.
   h. Inspect bolted electrical connections for high resistance using the following methods:
      1) Use of low-resistance ohmmeter in accordance with ANSI/NETA MTS, section 7.15.3.2.
      2) Verify tightness of accessible bolted electrical connections by calibrated torque-wrench method in accordance with Manufacturer’s published data or ANSI/NETA MTS table, 10.12.
   i. Stator core, blocking, wedges, lashing, end windings, main leads.
   j. Auxiliary equipment.
   k. Main terminal box and installed components.
2. Perform electrical testing on the stator windings and rotor:
   a. Polarization index test.
   b. Insulation leakage current test with DC hi-pot to the Manufacturer’s recommended voltage level.
   c. Disconnect generator leads for testing and reconnect them after testing is complete.
   d. Re-tape connections with varnished cambric, high-voltage insulating tape and Scotch 33.
3. Air cooler radiators:
   a. Remove radiators for a full inspection.
   b. Inspect exterior surfaces for defects, rust, dents, etc.
   c. Pressure test radiators to 40 psi for 60 minutes. Investigate any leakage or drop in pressure and correct any leaks.
   d. Report findings to the ENGINEER.

B. Scope of Work for Generator Rotor:
1. Pretest electrically prior to performing scope of Work:
   a. Measure resistance using a digital low ohm resistance meter.
   b. Perform a megger and PI test.
   c. AC voltage drop test rotating field coils.
   d. Verify the correct resistance of the RTD at various temperatures.
2. Clean rotor with steam. Visually inspect the pole pieces.
3. Touch up varnish in required areas.
4. Paint rotor windings with red insulating Glyptol.
5. Measure drive end and front-end journal bearing clearances on for four quadrants. Rotate the shaft in 90 degree increments to obtain four sets of measurements. Record measurements and submit to the ENGINEER for review.
6. Replace oil in the generator bearings with Manufacturer recommended and ENGINEER-approved new oil test electrically after completing scope of Work and check to prior baseline.

7. Test electrically after completing scope of Work and compare to prior baseline. Provide a report of test results.

C. Scope of Work for Generator Stator:
   1. Pretest electrically prior to performing scope of Work:
      a. Measure resistance using a digital low ohm resistance meter.
      b. Perform a megger and PI test.
      c. Perform generator capacitance testing. Actual tested capacitance shall be used for the high resistance grounding sizing calculations as specified in SECTION 26 05 10.
   2. Remove space heaters from mountings and lay in the bottom of the stator.
   3. Clean the back side of upper and lower end turns with Karcher SDS#K803789 or ENGINEER-approved degreaser.
   4. Clean the section windings and stator iron with Karcher SDS#K803789 or ENGINEER-approved degreaser.
   5. Clean the outside of iron through cooling ports with Karcher SDS#K803789 or ENGINEER-approved degreaser. Vacuum materials removed from the stator.
   6. Complete final stator visual inspection: Paint the stator core and windings with red insulating Glyptol.
   7. Test electrically after completing scope of Work and check to prior baseline.
   8. Repaint the stator exterior as needed.

D. Scope of Work for Generator Brake and Speed Sensing Equipment:
   1. Design, provide and install new generator brake and speed sensing equipment.
   2. Test electrically after completing scope of work and check to prior baseline.
   3. The brake system shall be designed to actuate off 90 psi or less compressed air. Coordinate air demand with OWNER-furnished air compressor (AC1).
   4. Provide weights, dimensioned general arrangement drawings, installation drawings, and other information for the brake system and speed sensing equipment.
   5. Perform a natural frequency critical speed analysis. Include new brake, brushless exciter, and runner in analysis.
   6. Speed sensing equipment shall be as specified in SECTION 40 50 00, Contract Drawings, and as required.
   7. Equipment shall be completely enclosed in a NEMA 1 type enclosure.

E. Scope of Work Generator Bearings:
   1. Thrust and guide bearings (two bearing housings):
      a. Drain, dispose, and refill generator bearings with fresh filtered oil.
      b. Inspect and document the babbitt and general condition of the bearings journal pads.
      c. Inspect and document the babbitt and general condition of the thrust bearing pads.
      d. Measure and record the as-found I.D. of the generator guide bearing journal pads with an inside micrometer at four locations spaced 45 degrees apart around the circumference of the bearing journal. These measurements shall be taken and recorded along three equally spaced planes along the journal bearing surface that are normal to the axis of the bearing.
      e. Polish the journal pads and thrust pads on both bearings.
      f. Repeat and record the I.D. measurements of the journal bearing pads after polishing. The I.D. of the journal bearing pads shall be within the tolerances.
      g. The final surface finish of the journal bearing pads shall be 32 microinches.
      h. Clean the bearing housing and oil passages to remove built up debris or blockage.
      i. Apply room temperature vulcanizing sealant to the joints of the generator bearing housing, inner oil well and outer oil well to ensure the bearing housing does not leak oil.
      j. Replace the bearing shaft seal with new felt rings.
      k. Reassemble bearing and measure clearances to verify that clearances are within the Manufacturer’s specifications.
      l. Provide and install bearing RTDs and vibration transducers as specified SECTION 40 50 00, and in accordance with the Contract Documents.

F. Approved Companies for Refurbishment Work:
   1. Re-babbitting is not required in the Contract. However, if inspection shows a need to re-babbitt the bearings, the following companies shall be used and the work performed by change order:
      a. Kingsbury, Inc. 209 Burns Dr. Yuba City, CA 95993 Telephone: (530) 673-6262
      b. PME Babbitt Bearings 2551 Nowlin Rd. Minden, NV 89423 Telephone: (800) 535-1388
      c. American Babbitt Bearing 80 Co Rd 2/19 Huntington, WV 25702 Telephone: (800) 343-3933

G. Scope of Work for Generator Shaft:
   1. Perform a visual inspection of the generator shaft to check for deformation and other defects. Record results of the visual inspection and submit to the ENGINEER.
   2. Perform non-destructive testing inspection of the entire generator shaft utilizing a liquid dye penetrant test to check the shaft for cracks in accordance with ASTM E 165, witnessed by the ENGINEER. Submit results of the inspection to the ENGINEER.
   3. Measure and verify the features of the generator shaft to check if the shaft meets the Manufacturer’s tolerances. Measurements shall be recorded and submitted to the ENGINEER.
   4. Measure and record runout. Report to ENGINEER for acceptance prior to continuing.
   5. Measure and record the OD of the generator shaft bearing surfaces with an outside micrometer at four locations spaced 45 degrees apart around the circumference of the shaft bearing surfaces. These measurements shall be taken and recorded along three equally spaced planes along the generator shaft bearing surfaces that are normal to the shaft axis. If the diameter of this surface deviates from the tolerance, notify the ENGINEER.
   6. Verify the surface finish of the generator shaft bearing surfaces meets the Manufacturer specification of 32 microinches. Polish bearing surfaces to the required level if found to be out of specification.

7. If defects are found that require repair to bring the shaft back into the Manufacturer specified tolerances, notify the ENGINEER and submit repair procedures to the ENGINEER for review and approval prior to performing repairs.
8. Shaft protecting sleeve: Furnish and install in accordance with ASTM A 743 CA15 SST shaft sleeve to replace the existing sleeve.

3.4 STARTUP

A. Witness operation of the generator during startup.

B. The CONTRACTOR, Hydroelectric Generator Maintenance Subcontractor, Mechanical Millwright Subcontractor, and I&C System Subcontractor shall coordinate, schedule, and plan the generator startup and commissioning as specified in SECTION 48 70 00, SECTION 48 13 13.01, and SECTION 40 50 00.

END OF SECTION

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SECTION 26 33 00
DC POWER SYSTEM

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for DC power systems.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 10 – BASIC ELECTRICAL MATERIALS AND METHODS
5. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
6. SECTION 26 09 00 – CONTROL AND PROTECTION EQUIPMENT
7. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES

A. National Electrical Manufacturers Association (NEMA):

1. ICS 2.3 – Instructions for the Handling, Installation, Operation and Maintenance of Motor Control Centers Rated Not More than 600 V

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Eternal power and signal connections.
4. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
5. Dimensional drawings including, but not limited to:
   a. A full drawing list with revision levels.
   b. A data nameplate detail featuring electrical ratings and the Manufacturer's model number and serial number.
   c. An outline drawing featuring dimensions, external components (labeled), and unit shipping weight.
   d. An internal component layout drawing featuring major internal components and customer connection specifications.
   e. An instrument panel detail featuring indicator lights, switches, meters, and timers.
   f. A full schematic, featuring charger components and electrical ratings of major components.
   g. A full connection diagram featuring charger components and individual number/color-coded wires.
   h. Revision levels and dates listed on individual sheets.
   i. Factory internal job numbers listed on each sheet.
   j. Provisions for end-user tag numbers.
6. Provide DC power system calculations for equipment including load study, battery duty-cycle diagram, cell sizing, charger sizing, and final voltage scenarios using S-curve presentation.
7. Short-circuit current available at 125 VDC distribution and utilization equipment including, but not limited to, disconnects, panelboards, switchgear, lighting control cabinets, and actuators.
8. Protective devices:
   a. Copies of time-current characteristics.
   b. Protective device trip settings.
9. Anchoring instructions and details.
10. One-line diagrams.
11. Schematic (elementary) diagrams.
12. Outline diagrams.
13. Wireless unit connection diagrams.
14. Interconnection diagrams.
15. Charger power requirements and heat dissipation: Maximum heat dissipations Btu/hour.
16. Charger conduit entry/exit locations.
17. Charger SPs, wiring diagrams, etc.
18. Installation details: Include details including, but not limited to, bolted connection torque values, heated NO-OX-ID grease application, battery handling, etc.
19. Spares, expendables, and test equipment.

D. Quality Control Submittals:

1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
   e. Factory and field certified test reports.

f. Calibration, startup, and commissioning reports.
    1) Include complete lists of equipment furnished, including the Manufacturer's model numbers, correct settings, alarm points, and operating ranges.
g. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
h. Final As-Built Drawings:
    1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
        a) Drawings shall be on a standard DW provided title block and border.
        b) As-Builts and Manufacturer's drawings shall be provided:
            (1) On a standard DW provided title block and border.
            (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
            (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
            (4) Titles: 0.2 inches.
i. Warranty documentation.

E. Extra Materials:
1. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
    a. Fuses: Provide four of each type and each current rating.

1.4 QUALITY ASSURANCE

A. Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services:
1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
    a. Installation assistance and inspection of installation: 1.
    b. Functional and performance testing: 1.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the DC power system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Batteries:
1. C&D Technologies

B. Battery Chargers:
1. Hoppecke
2. HindlePower

C. Battery Rack:
1. C&D Technologies

2.2 COMPONENTS

A. Batteries:
1. Low maintenance lead-acid type. A flame arrestor shall be provided with each cell.
2. 8-hour discharge rate of not less than 100 A to an end voltage of 1.75 V per cell at 104ºF. A minimum of sixty cells shall be furnished.
3. The batteries shall be sized for the actual continuous current of equipment for 8 hours followed by a loss of utility trip with equipment operating at full capacity.
4. Battery loads shall be verified with actual equipment being furnished before the final battery size is selected. The battery size shall be approved by the ENGINEER.

B. Battery Rack:
1. The batteries shall be arranged for installation in two-tier, powder coated "painted", battery racks. Connections between cells shall be provided.
    a. The racks shall meet UBC seismic requirements for Zone 1.
    b. The battery racks shall stand alone, requiring only floor anchoring. The racks shall have two coats of acid-resistant paint.

C. Battery Chargers:
1. Two full size battery chargers shall be furnished and connected to operate in parallel. Each shall be furnished with the accessories required for parallel operation. Each charger shall be solid-state float type with indicating voltmeter and ammeter, 24-hour equalizing timer, high/low DC voltage alarm relay, loss of current alarm relay, power on indicating light, and ground detection lights.

2. Verify the size of the battery chargers and submit the calculations with the Shop Drawing Submittal. The minimum size chargers provided shall be not less than 300 A each. Each charger shall be completely self-contained in a NEMA Type 1 cabinet. The cabinet shall have a hinged front cover containing the indicating meters, AC and DC circuit breakers, float voltage adjustment, and AC “power on” indicating light. SPDs, rectifiers and required supply voltage transformers shall be contained within the charger cabinet. Overvoltage/undervoltage alarm contact shall be furnished for wiring to the generator control panel.

D. The DC distribution panelboards shall be dead-front, circuit breaker, two-wire 250 VDC, panelboard type as shown on the Drawings and in accordance with:
   1. The panelboards shall be mounted as shown on the Drawings. A directory inside the switchgear door shall have a panel and the circuit identities neatly typewritten at the completion of the Contract.
   2. Circuit breakers shall be thermal-magnetic, bolt-on, individually front replaceable, and shall indicate on, off, and tripped. Breakers shall be two-pole common trip, rated 14,000 AIC at 125 VDC.
   3. The panel shall have two-phase buses and an equipment ground bus. Buses shall be tin-plated copper. The DC panelboards shall be furnished with a main breaker, as shown on the Drawings.

E. The DC disconnect shall be heavy duty, fused two-wire 250 VDC, NEMA Type 1 as shown on the Drawings and in accordance with the following:
   1. Verify this is adequate for the short-circuit current available at the disconnect, including the battery chargers contribution.
   2. Terminations shall be done and tightened to specifications. Conductors shall be tested and retagged.

F. Basic electrical materials and methods including, but not limited to, panelboards, disconnects, CTs, PTs, pushbuttons, indicating lights, selector switches, control relays, elapsed time meters, and time delay relays, as specified in SECTION 26 05 10.

G. Control and protective equipment including, but not limited to, control switches, lockout relays, test blocks and plugs, protective relays, as specified in SECTION 26 09 00.

H. I&C systems including, but not limited to, terminal blocks, hydrogen gas detector, isolators, limit switches, digital meters, analog meters, as specified in SECTION 40 50 00.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install and rework equipment in accordance with NEMA ICS 2.3, Submittal Drawings, and the Manufacturer's instructions and recommendations.

B. Coordinate terminal connections with installation of feeders.

C. Battery system bolted electrical connections shall be done with heated NO-OX-ID grease and torqued as required by the Manufacturer and approved by the ENGINEER.

D. Provide torque values and mark torque position.

E. Tighten current-carrying bolted connections and enclosure support framing and panels to the Manufacturer's recommendations.

F. Field adjust trip settings of protective devices and SPs.

3.2 QUALITY CONTROL

A. Verify wiring, cell layout, installation, and identification.

B. Inspect racking, support, and grounding connection.

C. Verify proper system operation: Verify battery cell voltage, connection torque and resistance values, power system alarm, rectifier, converter, and other system settings.

D. Measure VRLA impedance to detect low voltage without load testing.

E. Inspect safety devices for neutralizing electrolyte spills, safety station supplies, and spill containment systems.

F. Provide installation certification.

G. As specified in SECTION 26 08 00.

END OF SECTION

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SECTION 26 33 53
THREE-PHASE UNINTERRUPTIBLE POWER SUPPLY SYSTEM

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for a three-phase uninterruptible power supply system.

B. Related Sections:
   1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   4. SECTION 26 05 70 – ELECTRICAL SYSTEMS ANALYSIS
   5. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):
   1. C62.41 – Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
   1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
   2. Catalog, descriptive and specification information for equipment, components, and devices.
   3. External power and signal connections.
   4. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
   5. Dimensional drawings, including outline diagrams, lifting eye locations and size of eye bolt, maximum weight, cabinet mounting hole sizes and location, size and location for ventilation.
   6. Protective devices:
      a. Copies of time-current characteristics.
      b. Protective device trip settings.
   7. Anchoring instructions and details.
   8. One-line diagrams.
   9. Schematic/interconnect diagrams with wiring number identification and wiring list.
   10. Internal layout drawing.
   11. Power requirements and heat dissipation: Maximum heat dissipations Btu/hour.
   12. Conduit entry/exit locations.
   13. SPs, wiring diagrams, etc.
   14. Installation details: Include modifications or further details required.
   15. Spares, expendables, and test equipment.
   16. The Equipment Manufacturer shall submit a certified letter stating that materials and equipment provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site environmental conditions. The Equipment Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve equipment derated values.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Include Shop Drawing Submittal information.
      d. Software: Provide complete licensed copy of software including interface cables. Software provided shall allow modification of settings and logic. Provide electronic files of final programs/settings.
      e. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
      f. Factory and field certified test reports.
      g. Hardcopy and electronic version of installed programs.
      h. Calibration, start-up, and commissioning reports.
      i. Complete lists of equipment furnished, including the Manufacturer's model numbers, correct settings, alarm points, and operating ranges.
      j. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustments.
      k. Final As-Built Drawings:
         1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction- information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
               (1) On a standard DW provided title block and border.

(2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
(3) Text: Minimum 0.1 inches, maximum 0.2 inches.
(4) Titles: 0.2 inches.

I. Warranty documentation.

1.4 QUALITY ASSURANCE

A. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

B. Service:
1. Reliability: System mission reliability, including bypass, shall be in excess of 200,000 MTBF hours based upon reliability information of previous installations. Demonstrated equipment reliability is 3 years minimum.
2. Maintainability: Calculated and demonstrated MTTR shall be 1 hour including time to diagnose the problem and replace subassembly.

C. Manufacturer's Services:
1. Furnish a Manufacturer's Representative as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
   a. Installation assistance, inspection, and factory-authorized startup: 1.
   b. Functional and performance testing and completion of the Manufacturer's certificate of proper installation: 1.
   c. Post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

D. Mechanical Design:
1. UPS enclosure: The UPS shall be in a freestanding, NEMA 1 enclosure equipped with casters and leveling feet.
2. Matching battery enclosures: Battery cabinets shall be provided consisting of a freestanding, matching NEMA 1 enclosure equipped with casters and leveling feet.
3. Cable entry: The UPS shall be provided with cable entry from the rear of the UPS enclosure (top or bottom input).
4. Ventilation and maintenance requirements: The UPS shall require the following space for ventilation and maintenance:
   a. Front: 6 inches.
   b. Top: 6 inches.
   c. Rear: 28 inches.
   d. Side: 20 inches.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 3 years from the Substantial Completion date for the satisfactory performance and installation of the uninterruptible power system and associated appurtenances.
1. Typical on-site response time shall be 4 hours, 1 day maximum.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Toshiba, 4400 Series

B. APC Gutor PXC

2.2 COMPONENTS

A. The UPS shall consist of the following components:
1. Rectifier.
2. Chopper/charger.
3. PWM inverter.
4. Static bypass switch.
5. Microprocessor controlled logic and control panel.
6. Input circuit breaker.
7. Battery banks.
8. Input/output EMI/RFI filters.

2.3 FABRICATION

A. System Parameters:
1. UPS input:
   a. Voltage input: 208 VAC.
   b. Input voltage requirements: three-phase, four-wire, and ground.
   c. Voltage variation: 10% to -15%, to -30% with reduction of output capacity.
   d. Rated frequency: 50/60 Hz.
   e. Frequency range: 45 Hz to 65 Hz.
   f. PF: Greater than 0.98 lagging at full load.
   g. Input capacity: 110% of UPS output capacity.
   h. Walk-in function: From 20% to 100% over 5 seconds, adjustable.

i. Input current limit: 125% of nominal capacity.
j. Inrush current: Less than 600% under synchronous condition.
k. Input current THD: Less than 5%THD.
l. Surge withstandability: In accordance with IEEE C62.41.
m. Input phase rotation protection/detection: Standard front-panel alarm panel shall notify the user that the unit has been supplied with incorrect phase rotation on input to allow for correct installation. The UPS shall be fully protected to prevent damage from the event.

2. UPS output:
   a. Voltage output: 208 VAC.
   b. Output voltage configuration: three-phase, four-wire, and ground.
   c. Output capacity: 30 kVA. Rated load PF: 0.9 lagging.
   d. Voltage regulation:
      1) Balanced load: ±2% nominal.
      2) Unbalanced load: ±3% nominal.
   e. Voltage adjustable range: ±5% manually, by front panel user interface.
   f. Phase displacement:
      1) Balanced load: ±2 degrees.
      2) 100% unbalanced load: ±4 degrees.
   g. Rated frequency: 50/60 Hz, jumper selectable.
   h. Frequency regulation: ±0.01% at free running.
   i. Frequency synchronized range, user selectable: ±0.5/1.0/1.5 Hz, ±1.0 Hz standard.
   j. Frequency slew rate: Less than 1.0 Hz/second.
   k. Voltage transients:
      1) 100% step load change: ±5%.
      2) Loss or return of input power: ±3%.
      3) Bypass to inverter: ±8%.
   l. Transient voltage recovery: 50 ms maximum to within 2% of nominal.
   m. Overload capacity, on inverter: 125% for 90 seconds, 150% for 30 seconds.
   n. Overload capacity, on bypass: 1,000% for 10 ms, 125% for 10 minutes.
   o. Crest factor: 3.0, 2.5 with less than 5% voltage THD.
   p. Harmonic voltage distortion: 1.5% THD maximum, 1% maximum for any single harmonic, linear load.
   q. Inrush current protection: Automatic transfer to bypass, then auto return to inverter, retransfer may be inhibited by jumper.
   r. Output overcurrent protection: Hall-effect CT and fusing.
3. Batteries:
   a. Battery type: Sealed, maintenance-free, lead acid cells.
   b. Protection time:
      1) Standard matching battery pack(s) shall provide the minimum run-time:
         a) 40 minutes back-up time on 15 kVA, 50% full load.
   c. 20 minutes back-up time on 30 kVA, full load. DC voltage range: 216 V shutdown, 288 V nominal.
   d. Ripple voltage: Less than 0.5% rms maximum.
   e. Recharge time: 8 hours to 90% full capacity.
   f. Battery circuit breaker: A molded case circuit breaker shall be provided for battery short-circuit protection and as a means of manual disconnect for battery maintenance. The breaker shall be mounted on the rear section of each battery cabinet and shall provide breaker status information as well as the capability to be shunt tripped when the UPS is being shutdown or the battery life has completely expired.
4. Environmental:
   a. Efficiency:
      1) AC/DC/AC: 8%.
      2) DC/AC: 90%.
   b. Operating temperature:
      1) UPS: 14°F to 122°F.
      2) Battery: 68°F to 77°F.
   c. Storage temperature:
      1) UPS: -4°F to 140°F.
      2) Battery: Prolonged storage above 104°F causes rapid battery degradation.
   d. Relative humidity: 95%, non-condensing.
   e. Audible noise: 63 dB, A scale at 1 meter.

B. Standard Features:
   1. In addition to the features listed previously, the UPS shall have the following standard features at a minimum:
      a. EPO terminals which trip open the UPS and battery circuit breakers.
      b. RS232 and Ethernet communication interface: Communications link which enables the UPS to interface with a computer to provide power status and diagnostic information. Additionally, the communications ports shall be used to adjust vital parameters within the UPS.

c. The following normally open dry contacts shall be provided through a located on the rear of the UPS enclosure:
   1) UPS on.
   2) Bypass active.
   3) Input power loss.
   4) Battery voltage low.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install in accordance with the Manufacturer's instructions.

B. Field adjust protective device, relay, and control settings in accordance with the recommendations of the electrical system analysis studies as specified in SECTION 26 05 70.

3.2 QUALITY CONTROL

A. Factory Inspections: Inspect control panels for required construction, electrical connection, and intended function.

B. Functional Test: Perform the Manufacturer's standard tests.

C. Additional testing as specified in SECTION 26 08 00.

D. System Operation:

1. The UPS shall operate as an online, fully automatic, reverse-transfer system in the following modes:
   a. Normal: Incoming AC power is converted into DC power and boosted using a chopper circuit. The DC power is then used to charge the battery bank while at the same time providing clean DC power to the inverter circuitry. The inverter converts DC power to regulated AC power which feeds the load.
   b. Emergency: Upon failure of commercial AC power, the UPS shall derive power from the battery bank and continue feeding the load with clean, regulated AC power. There is no interruption to the critical load upon failure or restoration of commercial AC power.
   c. Recharge: Upon restoration of the commercial AC source, the rectifier/chopper powers the inverter while simultaneously recharging the battery bank. The UPS shall have the following recharge process:
      1) A constant level of current is used to recharge the batteries, the process shall utilize a current-limit function to prevent overcharging batteries, thus extending the life of the batteries.
      2) As the batteries reach the normal charge level, a constant-voltage control shall begin which causes the battery recharge current to gradually decrease.
      3) Under normal operation, the UPS battery bank floats at the nominal DC level to stay fully charged and ready for the next discharge.
   d. Bypass mode: Upon detection of an internal fault or output overload, the UPS shall automatically switch from inverter power to an internal bypass via the static switch. Transfer shall be within 4 milliseconds, causing no interruption to the critical load. The transfer shall be in phase and in synchronization with the commercial AC source, causing no interruption to the critical load. Return from bypass mode shall be an automatic function, causing no interruption of power to the critical load. Transfer to bypass may also be performed as a manual operation via the UPS front panel.

E. Functional Description:

1. Rectifier/charger/DC chopper:
   a. Description: The rectifier/charger shall consist of a solid-state three-phase rectifier, DC to DC converter, chopper, output filter, and transient suppresser network to regulate and maintain DC power to the inverter.
      1) Transient suppresser: The incoming AC utility shall first be connected to a molded case circuit breaker as a means of disconnecting power to the UPS. Power shall flow through a surge absorber to prevent large transients from passing through to the load or damaging the batteries. The input shall be in accordance with IEEE C62.41. Power shall then flow through a line filter to prevent sags or surges from passing to the load.
      2) Rectifier/charger: The rectifier shall serve to convert incoming AC power to DC, which shall be supplied to the DC chopper. From this point, DC power is used to recharge the battery bank while simultaneously providing power to the inverter.
         a) Input frequency range: 45 Hz to 65 Hz, continuous, without battery operation.
         b) Capacity: Battery recharge shall be to within 90% of nominal from a fully discharged state within 8 hours.
      3) DC chopper: The chopper circuit shall consist of inductors, capacitors, diodes, and IGBT. The chopper shall have the function of providing start-up protection, by checking phase rotation of incoming utility power, boosting the DC to the inverter, during low AC input voltage conditions, providing PF correction, and reducing reflected harmonics to incoming utility power.
2. PWM inverter:
   a. Description: The PWM inverter shall incorporate an advanced IGBT design and output overcurrent protection for clean, regulated output power to the critical load.
      1) Inverter: The inverter network shall consist of a high-speed IGBT switching network designed to supply nonlinear loads with a clean and steady voltage waveform. The inverter switching speed shall be fast enough to limit audible noise to 63 dB at 1 meter, measured on A scale.
      2) Overcurrent protection: The output circuitry shall be equipped with a hall-effect CT and fusing to detect and protect the inverter from excessively high currents.

3. Static bypass switch:
    a. Transfer: The static bypass switch shall consist of thyristor switches in conjunction with an output contactor to permit manual switching from bypass to UPS and UPS to bypass without power interruption. The UPS shall instantaneously transfer to bypass if a component fails during normal operation, provided the UPS and bypass are in synchronization. Auto-retransfer to UPS after an overload condition shall be completed within 1 second after the bus has dropped to 100% of nominal.
    b. Remote run/stop: A set of normally open dry contacts shall be provided to remotely transfer the UPS online and offline. When the UPS is in this mode of operation, the UPS front control panel shall be disabled to provide a secured configuration.
4. Microprocessor control system:
    a. Description: The UPS system shall be provided with a highly reliable microprocessor internal control system to perform startup, transfers, monitoring, and battery recharging. The microprocessor shall provide important information to the user, via a LCD, such as system status, fault messages, and input and output parameters.
    b. LED indicators: The following LED indicators shall be provided on the UPS front panel display which mimic power flow through the UPS:
        1) AC input present.
        2) Inverter operating.
        3) UPS on bypass.
        4) UPS on battery.
        5) Fault.
    c. System metering: The UPS shall be provided with a single readout display which displays, upon request, the following information:
        1) Input voltage.
        2) Output voltage.
        3) Output current.
        4) Battery voltage.
        5) Input frequency.
        6) Output frequency.
    d. UPS operating status: The UPS shall display the current operating state of the UPS, described as yes or no:
        1) Utility power ok.
        2) Low battery voltage detected.
        3) UPS in bypass mode.
        4) UPS in normal mode.
        5) Input and output frequency synchronized.
        6) UPS fault occurred.
    e. System diagnostics: The following diagnostic information shall be provided to troubleshoot the UPS if a fault occurs:
        1) DC bus overcurrent.
        2) DC bus overvoltage.
        3) DC bus undervoltage.
        4) Input overcurrent.
        5) Overheat.
        6) Overload being timed.
        7) Overload, allowable time exceeded.
        8) Output overvoltage, during normal mode.
        9) Output undervoltage, during normal mode.

END OF SECTION

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SECTION 26 41 00
LIGHTNING PROTECTION SYSTEM

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for lightning protection systems.
- B. Related sections:
  1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
  2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
  3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
  4. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES
- A. American Association of State Highway and transportation Officials (AASHTO):
  1. LTS-6 – Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals
- B. Française de Normalisation (NF):
  1. C17-102 – Protection Against Lightning – Early Streamer Emission Lightning Protection Systems

1.3 SUBMITTALS
- A. As specified in SECTION 26 05 00.
- B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.
- C. Shop Drawings:
  1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
     - a. Catalog, descriptive and specification information for equipment, components, and devices.
  2. External power and signal connections.
  3. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
  4. Location of ESE air terminal, conductors, bonding connections, and grounding equipment. Drawings shall include sizes for conductors, ground electrodes, and connection/termination details. Drawings shall include a verifiable phone number and address of the ESE Manufacturer or Supplier.
  5. Submit for approval detailed mast support calculations and the ability of it to support the mast in 110 mph winds.
  6. Submit detailed product data sheets showing application, dimensions, and material of each component utilized in the lightning protection system installation.
- D. Accurately record actual locations of air terminals, bonding/grounding equipment, and conductors:
  1. Dimensional drawings.
  2. Anchoring instructions and details.
  3. One-line diagrams.
  4. Schematic (elementary) diagrams.
  5. Outline diagrams.
  6. Interconnection diagrams.
  7. Installation details, include modifications or further details required.
- E. Quality Control Submittals:
  1. Testing related Submittals.
  2. Submit proof of installer's approval or certification by the ESE System Manufacturer.
  3. O&M manuals:
     - a. Provide preliminary and final manuals.
     - b. As specified in SECTION 01 78 23.
     - c. Shop Drawing Submittal information.
     - d. Supplement A – Form ESE-1-90.
     - e. Legend abbreviation lists.
       - 1) Final As-Built Drawings and wiring diagrams in hardcopy and electronic, AutoCAD format.
       - 2) Factory and field certified test reports.
     - f. Device O&M manuals for components, electrical devices, and mechanical devices shall include:
       - 1) Operations procedures.
       - 2) Installation requirements and procedures.
       - 3) Maintenance requirements and procedures.
       - 4) Troubleshooting procedures.
       - 5) Internal schematic and wiring diagrams.
     - g. List of spares and expendables required and recommended.
     - h. Final As-Built Drawings:
       - 1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         - a) Drawings shall be on a standard DW provided title block and border.
         - b) As-Builts and Manufacturer's drawings shall be provided:
           - (1) On a standard DW provided title block and border.
           - (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
           - (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
           - (4) Titles: 0.2 inches.

F. Warranty Documentation.
G. Supplements listed in this Section.
H. Extra Materials:
1. Furnish, box, tag and clearly mark on exterior, identify each item with the Manufacturer's name, description and part number, for shipment and long-term storage and deliver prior to 75% of the Final Completion date the following extra materials:
a. Fuses: A minimum of three of each type and each current rating installed.

1.4 QUALITY ASSURANCE
A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
B. UL Compliance: Materials manufactured within the scope of UL shall be in accordance with UL standards and have an applied UL listing mark.
C. Manufacturer's Services: Furnish a Manufacturer's Representative as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
1. Installation shall be supervised, inspected, and tested by the System Equipment Manufacturer: 1.
2. Functional and performance testing and completion of the Manufacturer's certificate of proper installation: 1.
D. Complete Form ESE-1-90, found at the end of this Section, and return it to the ESE Manufacturer for certification, verification, archiving, and system documentation.
E. NRTL inspection of the completed lightning protection system installation.

1.5 SITE CONDITIONS
A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY
A. Warranty for 5 years from the Substantial Completion date for the satisfactory performance and installation of the lightning protection system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
A. National Lightning Protection Corporation:
1. Prevectron 3 ESE Air Terminal, US-1543TC (Prevectron 3560)
2. Digital Lightning Strike Counter, US-8011-P4
3. Lightning Protection Mast, NLP HB Series
4. Prevectron 3 Remote Test Unit for Self-Testing Air Terminals US-1591
B. Valmont:
1. Concrete-embedded, two-piece tapered aluminum pole
C. Grounded Systems Connections:
1. Burndy HYGROUND compression fittings

2.2 MATERIALS
A. ESE Air Terminal:
1. Complete ESE air terminal assembly:
a. Type 316 SST 3/4 inch diameter air terminal.
b. Sensing mechanism.
c. Early streamer initiator.
d. Triggering mechanism.
e. Sealed SST housing.
f. Threaded base for connection to mast.
g. The air terminal shall be fitted with a remote test device to verify operational status without direct access to the air terminal.
h. The air terminal shall be UL certified to NF C17-102.
i. Air terminal test module.
2. Plate indicating the name and phone number of the ESE Air Terminal Manufacturer.
B. Conductors:
1. Copper conductors shall be twenty-eight strands of 14 gauge copper wire in a rope lay configuration with a net weight of 380 lbs/1,000 ft, minimum. Copper strip of equivalent capacity may be substituted.
2. The structural steel may be utilized as the main down conductor.
3. Structural steel shall be electrically continuous or made so.
4. Every other column shall be grounded or at intervals not exceeding an average of 60 feet o.c.
5. Conductors shall be securely fastened to the structure at every 36 inches o.c. utilizing fasteners with corrosion resistance equal to that of the conductor.
6. Metal objects of induction situated within 15 feet of a lightning protection conductor or bonded metal body shall be interconnected to the lightning protection system.
a. Grounded metal bodies shall be interconnected to the lightning protection system via a conductor sized in accordance with the main lightning mast's ground grid down leads.
b. Ungrounded metal bodies shall be interconnected to the lightning protection system via a secondary conductor no smaller than #6 AWG copper.
7. No copper materials shall be installed upon a dissimilar metal. Tin-coated copper and bronze equipment shall be installed where these conditions exist.

8. Tin-coated or lead-coated copper and bronze equipment shall be utilized where corrosive atmospheres are present.
9. Lightning protection conductors shall maintain a downward or horizontal path to ground avoiding U and V pockets with the following exception.
    a. A conductor may rise no more than 3 inches for every 12 inches of run.
10. No bend of conductor shall form a final included angle of less than 90 degrees nor shall have a radius of less than 8 inches. Exceptions are through roof, through wall, and T connections.
11. Each ESE air terminal shall be provided with two paths to ground from the base plate of the mast, with the exception of an elevated mast that may have a single conductor run for a maximum of 16 feet before two down conductors are implemented.

C. Lightning Protection Mast:
1. Aluminum or galvanized steel masts.
2. Height as required by application.
3. Threaded connection for acceptance of ESE air terminal.
4. Bonding plate for cable connection.
5. Mast shall be structured as required by wind and safety factors inherent to the geographic location of the installation.
6. Anchor base and direct burial masts shall provide the following effective projected area data based in accordance with AASHTO LTS-6:
    a. Wind velocity based upon safety factors inherent to the geographic location.
    b. Moment of inertia.
    c. Section modulus.
    d. Allowable stress at base.
    e. Bending allowable stress.
    f. Shear allowable stress.
    g. Longitudinal moment.
    h. Longitudinal shear.
    i. Transverse moment.
    j. Transverse shear.
    k. Torsion moment.
    l. Combined moment.
    m. Combined shear.
    n. Axial load.
    o. Maximum overturn moment.
    p. Combined stress ratio.
    q. As shown on the lightning protection Drawing(s).
    r. Certified or accepted by the ESE System Manufacturer.

2.3 COMPONENTS

A. Grounding System:
1. The ground system shall have no more than 10 ohms of resistance.
2. Ground terminations:
    a. Ground rods: 3/4 inch by 10 foot copper-clad, three per down lead.
    b. Ground plates: 20 gauge copper 2 sf in area, three per down lead, encased in San-Earth(r) conductive concrete.
    c. Electrolytic ground electrodes, one per down lead, may be used in lieu of or in combination with ground rods and plates to achieve the 10 ohm resistance requirement.
    d. Ground loop: 4/0 nineteen strand copper encased in San-Earth(r) conductive concrete.
3. Ground connections shall be accomplished via exothermic cadweld type connections.
4. Connections to ground rods, ground plates, electrolytic ground electrodes, or ground loop conductors shall be made at a point not less than 24 inches away from foundation walls and 18 inches below grade.
5. Ground terminations shall be spaced as evenly as possible around the building perimeter.
6. Grounded systems shall be bonded together via main size conductor to achieve equal potential of the grounded systems.

B. Connectors, Fasteners, and Hardware:
1. Provide connectors, fittings, fasteners, clamps, guards, lugs, exothermic connections, etc., as required to install the parts of the lightning protection system. Material shall be listed where applicable. Equipment shall be fabricated from copper and bronze material for the use intended.
2. Connections between dissimilar metals shall be executed with tinned copper or tinned bronze equipment.

C. Strike Counter: Provide and install a parallel digital lightning strike counter, unless otherwise approved by the ENGINEER.

PART 3 EXECUTION

3.1 GENERAL

A. Furnish and install the lightning protection system having the ratings, features/accessories, and enclosures in accordance with the Contract Documents.

B. The lightning protection system shall include equipment and devices necessary for a complete lightning protection system in accordance with the Contract Documents. The lightning protection system shall include, but not be limited to: ESE lightning protection air terminal, mast, base, supports, down conductors, grounding terminations, strike counter, and transient voltage surge suppression.

3.2 PREPARATION

A. Verify that surfaces are ready to receive Work.

B. Verify and compare dimensions and measurements shown on the Drawings with field conditions.

C. Verify that systems that may influence the lightning protection system design are included or referenced as shown on the Drawings.

3.3 INSTALLATION

A. Install the ESE lightning protection system in accordance with the Manufacturer's instructions.

B. Installation shall be accomplished in a neat and orderly manner by an installer approved or certified by the ESE System Manufacturer.

C. Work inside the building shall be concealed.

D. Wall, roof, and other penetrations shall be sealed as required and performed by the appropriate trade.

E. Structural applications shall be coordinated with the Project structural ENGINEER and other applicable trades.

F. Protect elements under other sections from damage or disfiguration during work under this Section.

G. Adhesive lightning protection components shall be installed with an adhesive approved by the Roof Manufacturer.

H. Work installed in accessible areas shall be properly guarded and protected from damage.

I. Material shall be installed in a manner to protect against electrolytic couple in the presence of moisture.

3.4 QUALITY CONTROL

A. Testing as specified in SECTION 26 08 00.

B. Field inspections will be held and documented for the following:

1. Ground system testing and inspection of down conductors shall be made prior to being covered by interior, exterior, or other installations.
2. Inspection and testing of the lightning protection system shall be made prior to burial.
3. Inspection of air terminal operational status shall be accomplished via remote testing after a line of sight has been established.

C. Obtain services of NRTL to provide the inspection and certification of the lightning protection system.

3.5 SUPPLEMENTS

A. Supplement A – Form ESE-1-90

END OF SECTION

SUPPLEMENT A – FORM ESE-1-90

Project Information			
Project Name:			
Project Address:			
City:			
State:		Zip:	
Telephone Number:			
Contact Name:			

Owner Information			
Owner Name:			
Owner Address:			
City:			
State:		Zip:	
Telephone Number:			
Contact Name:			

Installer Information			
Installer Name:			
Installer Address:			
City:			
State:		Zip:	
Telephone Number:			
Contact Name:			

Structural Information			
Roof Structure		Support Structure	
Steel		Steel	
Concrete		Concrete	
Wood		Wood	
Other (specify)		Other (specify)	

Structure Occupancy and Contents			
Occupancy		Contents	
Unoccupied		Flammable	
Commonly Occupied		Explosives	
Large Occupancy (specify)		Irreplaceable Items (specify)	

LIGHTNING PROTECTION SYSTEM

Air Terminals			
Total number on structure			
Air Terminal Type		Serial Number	
1		1	
2		2	
3		3	
4		4	
5		5	
6		6	

Lightning Protection Mast			
	Hinged Base	Size(s)	
	Shoe Base	Size(s)	
	Aluminum Side Mount	Size(s)	
	Steel Side Mount	Size(s)	
	Embedded	Size(s)	
Height of tallest object on roof			
Height of mast above tallest object			
Distance from mast to tallest object			

Lightning Protection Mast Mounting Method	
Welded to Structure (specify)	
Bolted To Structure (specify)	
Gravity Mounting (specify)	
Embedded (off structure)	
Caisson Mounted (off structure)	

LIGHTNING PROTECTION CONDUCTORS

Exposed Horizontal/Roof Lightning Protection Conductors	
What size conductor is utilized as the main conductor? *(Indicate size in box at right)*	
Are all exposed conductors fastened at every 36 inches o.c.? *(Indicate yes or no in box at right)*	
Are all conductor bends greater than 90 degrees with a minimum radius of 8 inches? *(Indicate yes or no in box at right)*	
Do all exposed roof conductors maintain a horizontal or downward path to ground? *(Indicate yes or no in box at right)*	

Concealed Horizontal/Roof Lightning Protection Conductors	
Conduit Type	
Conduit Size	
What size conductor is utilized as the main conductor (indicate size at right)?	
Are metallic conduits bonded to the conductor at the top and bottom of each continuous run? *(Indicate yes or no in box at right)*	
Are all conductor bends greater than 90 degrees with a minimum radius of 8 inches? *(Indicate yes or no in box at right)*	
Do all concealed roof conductors maintain a horizontal or downward path to ground? *(Indicate yes or no in box at right)*	

Embedded Horizontal/Roof Lightning Protection Conductors	
What size conductor is utilized as the main conductor? *(Indicate size in box at right)*	
Are all embedded conductors bonded to the reinforcing steel at 60 foot intervals? *(Indicate yes or no in box at right)*	
Are all conductor bends greater than 90 degrees with a minimum radius of 8 inches? *(Indicate yes or no in box at right))*	
Do all embedded roof conductors maintain a horizontal or downward path to ground? *(Indicate yes or no in box at right)*	

DOWN CONDUCTORS

Exposed Down Conductors	
Total Number of Down Conductors (indicate number at right)	
What size conductor is utilized as the down conductor? (indicate size at right)	
Are all exposed conductors fastened at every 36 inches o.c.? *(Indicate yes or no in box at right)*	
Are all conductor bends greater than 90 degrees with a minimum radius of 8 inches? *(Indicate yes or no in box at right)*	
Do all exposed roof conductors maintain a horizontal or downward path to ground? *(Indicate yes or no in box at right)*	

Concealed Down Conductors	
Conduit Type	
Conduit Size	
Total Number of Down Conductors *(Indicate number at right)*	
What size conductor is utilized as the down conductor? *(Indicate size at right)*	
Are metallic conduits bonded to the conductor at the top and bottom of each continuous run? *(Indicate yes or no in box at right)*	
Are all conductor bends greater than 90 degrees with a minimum radius of 8 inches? *(Indicate yes or no in box at right)*	
Do all concealed down conductors maintain a horizontal or downward path to ground? *(Indicate yes or no in box at right)*	

Embedded Down Conductors	
Total Number of Down Conductors (indicate number at right)	
What size conductor is utilized as the down conductor (indicate size at right)?	
Are all embedded conductors bonded to the reinforcing steel at 60 foot intervals? *(Indicate yes or no in box at right)?*	
Are all conductor bends greater than 90 degrees with a minimum radius of 8 inches? *(Indicate yes or no in box at right)*	
Do all embedded down conductors maintain a horizontal or downward path to ground *(Indicate yes or no in box at right)?*	

Structural Steel Used as Down Conductor			
Perimeter of Structure		Number of Columns Grounded	
Connection at Roof		Connection at Ground	
Conductor Type and Size		Conductor Type and Size	
Connection Type and Size		Connection Type and Size	

GROUND SYSTEM

Soil Type					
	Sandy Loam		Sandy Clay Loam		Sandy Clay
	Silty Loam		Silty Clay Loam		Silty Clay
	Loam		Clay Loam		Clay
			Sand		Loamy Sand

Soil Condition					
	Dry		Damp		Wet

Last precipitation within (circle one)					
24 hours	48 hours	1 week	2 weeks	1 month	Unknown

Facility Ground Loop			
Conductor type and size		Depth of conductor	
Ground rod or ground plate type and size		Number of ground rods or ground plates	

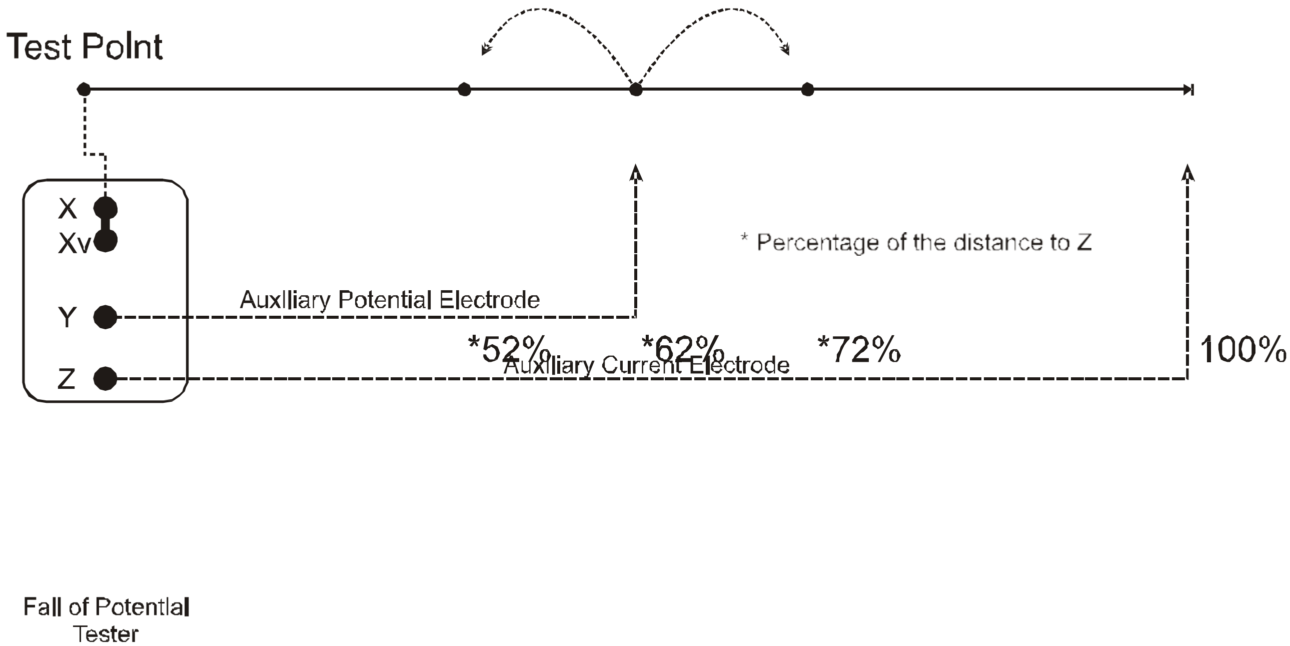
Ground Array			
Conductor type and size		Depth of conductor	
Ground rod or ground plate type and size		Distance between ground terminations	

Chemical Ground Rods (C-Rod)			
Conductor type and size		Depth of C-Rod	
C-Rod type and size		Number of C-rods per	

Connection Type					
	Mechanical		High Compression		Exothermic
	Other (specify)				

GROUND RESISTANCE

Ground Resistance Tester	
Manufacturer	
Model	



Ground Resistance Test Procedure			
Approximate Distances to Auxiliary Current Electrode		**Test Properties**	
Driven Depth	Distance to Z	Driven Depth	
6 feet	72 feet	Distance to Z	
8 feet	80 feet	Distance to Y at 52% of Z	
10 feet	88 feet	Distance to Y at 62% of Z	
12 feet	96 feet	Distance to Y at 72% of Z	
18 feet	115 feet	**Test Parameters**	
20 feet	120 feet	Test Range (ohms)	
30 feet	140 feet	Test Current (mA)	

Ground Resistance *(Required for Each Down Conductor)*		
Auxiliary Potential Electrode Readings		Average Resistance
Resistance at Y(52%Z)		
Resistance at Y(62%Z)		
Resistance at Y(72%Z)		

BONDING

Roof Level Bonding

Are all metal bodies of conductance within 15 feet of an exposed lightning protection conductor bonded to the lightning protection system with main size conductor? *(Indicate yes or no in box at right)*	
Are all metal bodies of inductance within 15 feet of an exposed lightning protection conductor bonded to the lightning protection system with secondary conductor? *(Indicate yes or no in box at right)*	
There are no metal bodies of conductance or inductance within 15 feet of an exposed lightning protection conductor? *(check box at right)*	
There are no exposed roof conductors? *(check box at right)*	

Potential Equalization Bonding		
Ground System	How is Continuity Attained	Where is the Connection made
Electrical Service		
Telecommunication Systems		
Incoming Water Line		
Structure		

SURGE SUPPRESSION

Secondary Surge Arrestor	
Manufacturer	
Model number	
Main Electrical Panel Transient Voltage Surge Suppression	
Manufacturer	
Model number	
Sub-Panel Transient Voltage Surge Suppression	
Manufacturer	
Model number	
Telephone System Transient Voltage Surge Suppression	
Manufacturer	
Model number	
Security System Transient Voltage Surge Suppression	
Manufacturer	
Model number	
Fire Alarm System Transient Voltage Surge Suppression	
Manufacturer	
Model number	

SUPPLEMENTAL INFORMATION

PHOTO REQUIREMENTS

Ground System Photos	
Show ground system at each down conductor prior to back fill	Show connection of down conductor to ground system
Show distance between ground rods	Show ground system connections

Ground Resistance	
Show connection to test point	Show auxiliary current electrode (z) with tape to show distance
Show auxiliary potential electrode (y) with tape to show distances	Show resistance readings at 52% Z, 62% Z, and 72% Z for each down conductor
Potential Equalization	
Show bond to electrical ground	Show bond to water system
Show bond to telecommunication system ground(s)	Show bond to structure
Down Conductors	
Show connection to mast (for concealed installations)	show connection to roof conductor (when exposed)
Show horizontal runs or provide diagram	Show vertical runs or provide diagram
Show horizontal to vertical transitions	Show bond connections at top and bottom of metallic conduit runs (when used)
Roof Conductors	
Overall picture of each roof run to a down conductor	Show connection to lightning protection mast
Show all bond connections to metal objects within 15 feet of a conductor	Provide photo that demonstrates proper fastening of exposed conductors
Lightning Protection Mast	
Show properly installed mounting bolts	Show level installation of pole base
Show properly installed hinge retaining bolts	Show properly installed upper and lower mounting brackets (for side mounted poles)
Air Terminal	
Show properly installed electrodes	Show properly seated jam nut and set screw

Note: Failure to provide photos may result in denial of the application.

Supplemental Information (continued)

1. Attach red-lined drawing of installation indicating all deviations from NLP design OR attach drawing marked "No-Deviations" with the system highlighted and the inspector's signature.
2. Attach warranty registration card(s) to application.
3. Attach photos. Photos shall be original prints or digital photos on a CD.

INSPECTOR'S STATEMENT

I certify that I have personally made a site visit for the acquisition of all information contained in this report and certify that all information contained herein is true.

Inspectors Name (print):________________________ Signed: _____________________________ Date: _________

SECTION 26 43 00
LOW-VOLTAGE SURGE PROTECTIVE DEVICES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for low-voltage surge protective devices.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):

1. C62.11 – Approved Draft Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV)
2. C62.33 – Standard for Test Methods and Performance Values for Metal-Oxide Varistor Surge Protective Components
3. C62.41.1 – Guide on the Surge Environment in Low-Voltage (1000 V and less) AC Power Circuits
4. C62.41.2 – Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits
5. National Fire Protection Association (NFPA):
6. 70 – National Electrical Code (NEC), Section 285.6

B. Underwriters Laboratories, Inc. (UL):

1. 67 – Panelboards
2. 96A – Installation Requirements for Lightning Protection Systems
3. 497A – Standard for Secondary Protectors for Communications Circuits
4. 497B – Standard for Data Communications and Fire-Alarm Circuits
5. 1283 – Standard for Electromagnetic Interference Filters
6. 1449 – Standard for Surge Protective Devices

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.
Shop Drawings:

1. Itemized Bill of Material including the Manufacturer, the complete model number, and the options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. External power and signal connections.
4. Each suppressor type indicating component values, part numbers, and conductor sizes; include a dimensional drawing for each, showing mounting arrangements.
5. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
6. Manufacturer's UL certified test data and nameplate data for each surge protective device (SPD).
7. Electrical single-line diagram showing the location of each SPD.
8. Dimensional drawings.
9. Anchoring instructions and details.
10. Schematic, elementary, diagrams.
11. Outline diagrams.
12. Interconnection diagrams.
13. Include installation modifications or further details required.

C. Quality Control Submittals:

1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. Final As-Built Drawings and wiring diagrams.
   e. Factory and field certified test reports.
   f. Device O&M manuals for components, electrical devices, and mechanical devices shall include:
      1) Operations procedures.
      2) Installation requirements and procedures.
      3) Maintenance requirements and procedures.
      4) Troubleshooting procedures.
      5) Internal schematic and wiring diagrams.
   g. List of spares and expendables required.
   h. Final As-Built Drawings:
      1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         a) Drawings shall be on a standard DW provided title block and border.

b) As-Builts and Manufacturer's drawings shall be provided:
(1) On a standard DW provided title block and border.
(2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
(3) Text: Minimum 0.1 inches, maximum 0.2 inches.
(4) Titles: 0.2 inches.

D. Warranty Documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Final Completion date the following extra materials:
1. Fuses, 0 V to 600 V: A minimum of six of each type and each current rating installed.
2. Lamps and LEDs for indicating lights: Two of each type and each current rating installed.
3. QUALITY ASSURANCE

F. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

G. UL Compliance and Labeling: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.
1. For power and signal circuits, SPD devices in accordance with UL 1449 and UL 1283 as an EMI filter. Provide units listed and labeled by UL.
2. For telephone circuit protection, SPD devices in accordance with UL 497A.

H. Installation shall be supervised and tested by the System Equipment Manufacturer. The supervisory and testing Work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly trained and qualified for the Work.

I. Use SPD devices in accordance with IEEE C62.41.2 and IEEE C62.33.

J. Provide a SPD system that is suitable for application in IEEE C62.41.2 Category A, B, and C3 environments as tested by IEEE C62.11.

1.4 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.5 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the SPD system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Cooper Bussman
B. Eaton
C. National Lightning Protection Corp.
D. Square D
E. Vigitron

2.2 MATERIALS

A. SPD Devices:
1. SPD devices for power circuits, provided under this Section, shall be the product of a single Manufacturer and shall be of modular construction designed for field replacement.
2. SPD devices shall be capable of performance at ambient temperatures between -15°F and 140°F, at relative humidity ranging from 0% to 95%, and at altitudes ranging from sea level to Project elevation.
3. SPD devices shall be fused to disconnect the suppressor from the electrical source if the suppressor fails. The fusing shall allow full surge handling capabilities and afford safety protection from thermal overloads and short-circuits.
4. Design SPD devices for the specific type and voltage of the electrical service. Single-phase and three-phase wye-configured systems shall have L-N, L-G, and N-G protection. Grounded delta-configured systems shall have L-L and L-G protection.
5. Power filter: The SPD shall include a high frequency extended range power filter and shall be UL 1283 listed as an EMI. Provide minimum noise attenuation as follows:

Attenuation Frequency	**100 KHz**	**1 MHz**	**10 MHz**	**100 MHz**
Insertion loss (ratio)	50 to 1	350 to 1	500 to 1	250 to 1
Insertion loss (dB)	34	51	54	48

B. Service Entrance Suppressors:
1. SPDs: In accordance with UL 1449 UL 67, IEEE C62.41.1, and IEEE C62.41.2.
a. SPDs installed on the line side of the service entrance overcurrent protective device shall be Type 1 SPDs. SPDs installed on the load side of the service entrance overcurrent protective device shall be either Type 1 or Type 2 SPDs.
b. Type 2 SPDs shall also be in accordance with UL 1283.
2. Features and accessories: SPDs shall provide the following features and accessories:
a. An internal fusing design capable of disconnecting the SPD before any damaging external effects to the suppressor or surroundings occur.
b. Indicator light(s) display for power and protection status with push-to-test capabilities.
c. Audible alarm with silencing switch.

d. One normally open and one normally closed for remote monitoring of protection status. Contacts shall reverse on failure of any surge diversion module or on opening of any current-limiting device. Coordinate with building power monitoring and control system.
e. Surge counter with reset switch.
f. Optional integral disconnect switch for externally mounted SPDs. SPDs integrated into factory supplied equipment shall have an input disconnect switch or circuit breaker unless indicated on the equipment drawings/data sheets.

3. Surge current rating: The surge current rating of the SPD shall be dependent of its category/location, as follows:

Category/Location	Application	Per Phase	Per Mode
C	Service Entrance	240 kA	120 kA
B	Distribution	160 kA	80 kA

4. Protection modes:
   a. UL 1449 voltage protection rating for grounded wye configured circuits shall not exceed the following:

Modes	208Y/120	480Y/277
L-N; L-G; N-G	800 V	1200 V
L-L	1200 V	2000 V

   b. UL 1449 voltage protection rating for Delta configured circuits shall not exceed the following:

Modes	208Y/120	480Y/277
L-N; L-G; N-G	800 V	1200 V
L-L	1200 V	2000 V

5. SCCR: In accordance with NFPA 70, Section 285.6, the short circuit current rating of the SPD shall be equal to or greater than the available short circuit current at the point on the system where installed.
6. Nominal discharge current rating: 20 kA $I_{(n)}$.
   a. Surge protective devices located at service entrance locations shall carry a minimum nominal discharge current rating of 20 kA in accordance with UL 96A.

C. Distribution/ Branch Panelboard Suppressors:
1. SPDs: In accordance with UL 1449.
   a. Type 1 or Type 2 SPDs.
   b. Type 2 SPDs shall also be in accordance with UL 1283.
2. Features and accessories: SPDs shall provide the following features and accessories:
   a. An internal fusing design capable of disconnecting the SPD before any damaging external effects to the suppressor or surroundings occur.
   b. Indicator light(s) display for power and protection status.
   c. Surge counter with reset switch.
   d. Optional integral disconnect switch for externally mounted SPDs. SPDs integrated into factory supplied equipment shall have an input disconnect switch or circuit breaker unless indicated on the equipment drawings/data sheets.
3. Surge current rating: The surge current rating of the SPD shall be dependent of its category/location, as follows:

Category/Location	Application	Per Phase	Per Mode
B	Distribution	160 kA	80 kA
B	Branch	120 kA	60 kA

4. Protection modes:
   a. UL 1449 voltage protection rating for grounded wye configured circuits shall not exceed the following:

Modes	208Y/120	480Y/277
L-N; L-G; N-G	800 V	1200 V
L-L	1200 V	2000 V

   b. UL 1449 voltage protection rating for Delta configured circuits shall not exceed the following:

Modes	240D	480D
L-G; N-G	1200 V	2000 V

5. SCCR: In accordance with NFPA 70, Section 285.6, the short circuit current rating of the SPD shall be equal to or greater than the available short circuit current at the point on the system where installed.
6. Nominal discharge current rating: 10 kA $I_{(n)}$.

D. Data Communications:
   1. SPDs: In accordance with UL 497B.
      a. Ethernet data cable, panel-mounted.
         1) RJ45 socket connection.
         2) Power over Ethernet (PoE+) up to 48 VDC.
         3) 10/100/1000 Base T.
         4) Surge current rating of 2.0 kA (minimum).
         5) VPR shall not exceed 600 V.
      b. Ethernet data cable, line port plugin module.
         1) RJ45 plug and socket in-line connection.
         2) Power over Ethernet (PoE+) up to 48 VDC.
         3) 10/100/1000 Base T.

E. Annunciation: Provide unit or separately mounted LED type indication lights to show the normal and failed status of each module. Provide one normally open contact and one normally closed contact that operate when the unit fails.

F. Surge Counter: Provide each SPD rated above 100 kA with a counter displaying the number of voltage transients that have occurred on the unit input. The counter shall be battery-backed and retain the count through system power outages.

G. Paired Cable Dataline Interior Suppressors:
   1. Provide units in accordance with IEEE C62.41.2, Location Category A.
   2. Use bi-polar 1,500 W SADs between the protected conductor and earth ground.
   3. Provide units with a maximum single impulse current rating of 80 A, 10 by 1,000 microsecond–waveform.
   4. Breakdown voltage shall not exceed 36 V.

H. Paired Cable Dataline Exterior Suppressors:
   1. Provide units in accordance with IEEE C62.41.2, Location Category A.
   2. Suppressors shall be a hybrid design with a minimum of three stages, utilizing solid-state components and operating bi-directionally.
   3. Meet or exceed the following criteria:
      a. Maximum single impulse current rating of 10,000 A, 8 microsecond by 20 microsecond–waveform.
      b. Pulse life rating: 3,000 A, 8 by 20 microsecond–waveform: 2,000 occurrences.
      c. Maximum clamping voltage at 10,000 A: 8 microsecond current waveform by 20 microsecond current waveform; shall not exceed the peak of the normal applied signal voltage by 200%.

PART 3 EXECUTION

3.1 INSTALLATION

A. Application Requirements:
   1. As a minimum, provide and install SPD on the following:
      a. New panelboards and MCCs.
      b. Power and data supply to LCPs, ECPs, communications cabinets, and security control cabinets.
   2. Electronic equipment paired cable conductors: Install dataline suppressors at the low voltage input and output of each piece of equipment, including telephone cable entrance and utility meter data pulse cabling.
      a. Use secondary protectors on lines that do not exit the structure.
      b. Use primary protectors on lines that exit and enter the structure.

B. General Requirements:
   1. Install suppressors in accordance with the Manufacturer's recommendations.
   2. Install suppressors directly to the cabinet that houses the circuit to be protected so that suppressor leads are straight and short, with conductors laced, running directly to the point of connection within the panel, without loops or bends. No bend may exceed 90 degrees and the bending radius may not be less than 6 inches.
   3. Provide at least 3 inches of separation between line-side and load-side connecting wires. Do not bundle line-side and load-side conductors together nor run them in the same raceway.
   4. Field-installed conductors shall be the same as specified for building wire, no smaller than #8 AWG and no larger than #4 AWG. Device leads shall not be longer than the length recommended by the Manufacturer, unless specifically reviewed and approved by the Manufacturer.
   5. Provide dedicated circuit breakers and number of poles as required as disconnecting means for SPD devices installed in panelboards. The interrupting capacity of the circuit breakers shall be that specified for the other breakers at that location.

C. Field Testing: As specified in SECTION 26 08 00.

END OF SECTION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for lighting.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL

1.2 REFERENCES

A. American National Standards Institute (ANSI):

1. C78.389 – Electric Lamps – High Intensity Discharge – Methods of Measuring Characteristics

B. Federal Communications Commission (FCC):

1. 47 CFR – Telecommunication

C. International Code Council (ICC):

1. International Building Code (IBC)

D. Underwriters Laboratories, Inc. (UL):

1. 924 – Emergency Lighting and Power Equipment
2. 935 – Standard for Fluorescent-Lamp Ballasts

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Luminaires:
   a. Catalog literature for each luminaire specified, cross-referenced to the luminaire type in the luminaire schedule shown on the Drawings.
   b. Provide for each luminaire type:
      1) Materials.
      2) Type of diffuser.
      3) Mounting or suspension details and hardware.
      4) Gasketing.
      5) Reflector: Lens material, pattern, and thickness.
      6) Chassis including metal gauge.
      7) Finish and color.
      8) Electronic ies files for each luminaire.
      9) Ballast and LED driver:
         a) Type.
         b) Protection.
         c) Wiring diagram.
         d) Nominal wattage, input wattage, and lamp wattage.
         e) Input voltage and PF.
         f) Starting current, operating line current, and restrike current.
         g) Sound rating.
         h) BF.
         i) Starting temperature and temperature rating.
         j) Efficiency ratings.
      10) Lamp and LED:
         a) Type.
         b) Wattage.
         c) Voltage.
         d) Approximate life, in hours.
         e) Lumen output:
            (1) Initial.
            (2) Mean.
            (3) CCT.
            (4) Lamp lumen depreciation.
            (5) Efficacy.
            (6) Base.
      11) Picture of luminaire.
      12) Detailed dimensioned Drawings including luminaire total weight and support method.
      13) Effective projected area for pole-mounted luminaires.
      14) Photometric data:
         a) Coefficient of utilization tables based on the IES Zonal Cavity System by an approved testing laboratory.
         b) Luminaire dirt depreciation factor.

c) Candlepower distribution curves.
d) Average luminaire brightness.
e) Lumen output charts.
f) IES file in standard ies format.
g) Power requirements in watts and VA.

4. Accessories:
   a. Photocell:
      1) Photocell type.
      2) Switching capacity.
      3) Means of adjusting the lighting pickup level.
      4) Enclosure type.
      5) Mounting method.
   b. Luminaire poles:
      1) Material.
      2) Finish and color.
      3) Handholes.
      4) Anchoring.
      5) Luminaire attachment methods and fittings.
      6) Pole height.
      7) Pole dimensions.
      8) Bolthole circle layout and hardware.
      9) Accessories.
      10) Maximum total effective projected area, total weight-mounted on pole and maxium total rated pole weight.
      11) Complete design calculations and installation documents for pole mounting piers and poles mounted from structures; include in the calculations the wind and seismic requirements at the Work site.
5. Provide lighting calculations and layouts of lighting systems including:
   a. Lighting layout of the equipment spaces and rooms with equipment, walls, and obstructions shown on the Drawings.
   b. Lighting renderings, calculations, and layouts showing equipment, obstructions, and walls. Use surface reflectance values and luminaire light loss factors approved by the ENGINEER to perform calculations.
   c. Software generated calculations showing illuminance levels in FC and power usage in watts per sf for each of the areas.
   d. Layouts and calculations in AGI32 software; provide an electronic copy of the AGI32 software file generated for layouts and calculations.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing Submittal information.
      d. Complete final As-Built information including AGI32 software file showing as-installed fixture locations.
      e. Factory and field certified test reports.
      f. List of spare and expendable parts and accessories required and recommended.
      g. Final As-Built Drawings:
         1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW provided title block and border.
            b) As-Builts and Manufacturer's drawings shall be provided:
               (1) On a standard DW provided title block and border.
               (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
               (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
               (4) Titles: 0.2 inches.

E. Warranty Documentation.

F. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Final Completion date the following extra materials:
   1. Fuses, 0 V to 600 V: A minimum of six of each type and each current rating installed.
   2. Lamps and LEDs for indicating lights: Two of each type and each current rating installed. For each type of programmable LED: One remote programmer.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

1.5 SITE CONDITIONS
   A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.
1.6 WARRANTY
   A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the lighting system and associated appurtenances.
   B. Warranty for 5 years from the Substantial Completion date for the satisfactory performance and installation of the fluorescent ballast system and associated appurtenances.
   C. Warranty for 5 years from the Substantial Completion date for the satisfactory performance and installation of the LED lighting system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
   A. Ballasts:
      1. Advance Transformer
      2. MagneTek Jefferson
      3. Sylvania
      4. Universal
   B. Florescent Ballasts:
      1. Advance/Philips
      2. MagneTek/Universal
      3. Motorola/Sylvania
   C. Photocell:
      1. MagneTek Intermatic
      2. Paragon Electrical Products
      3. Tork
   D. Lamps:
      1. General Electric
      2. North American Philips
      3. Sylvania
   E. LED Light Engines:
      1. Columbia Lighting
      2. Hubbell Industrial Lighting
      3. Lithonia/Acuity Brands
   F. LED Drivers:
      1. Columbia Lighting
      2. Hubbell Industrial Lighting
      3. Lithonia/Acuity Brands
   G. LED Standby Light Unit:
      1. Barron Exitronix
      2. Lithonia
   H. Illuminated Exit Sign:
      1. Dual-Lite
      2. Lithonia
   I. Fluorescent Emergency Ballast:
      1. The Bodine Co., Inc.
      2. Lithonia
      3. MagneTek Lighting Products
2.2 MATERIALS
   A. Luminaires:
      1. Specific requirements relative to the execution of Work of this Section are located in the luminaire schedule shown on the Drawings.
      2. Feed-through type or separate junction box.
      3. Ballasts: Two-lamp when possible.
      4. Tandem wired for two-lamp or three-lamp, fluorescent fixtures.
      5. Wire leads: Minimum #18 AWG.
      6. Component access: Accessible and replaceable without removing the luminaire from the ceiling.
      7. Soffit installations:
         a. UL labeled: SUITABLE FOR DAMP LOCATIONS.
         b. Ballast: Removable, prewired.
      8. Exterior installations:
         a. UL labeled: SUITABLE FOR WET LOCATIONS.
         b. Ballast: Removable, prewired.
         c. Luminaires in combination with their mounting pole and bracket shall be capable of withstanding:
            1) Wind levels at the Work site without damage.
            2) Seismic levels at the Work site in accordance with ICC IBC.
         d. Corrosion-resistant hardware and hinged doors or lens retainer.

e. Luminaires furnished with integral photoelectrical control shall be of the Luminaire Manufacturer's standard design.

B. Lamp and LED:
1. Provide as indicated in the Luminaire Schedule shown on the Drawings.
2. Shall meet or exceed the requirements of the Energy Policy Act of 1992.
3. Fluorescent lamps: F32T8 rapid start type, cool white.
4. HID:
   a. Type: Metal Halide.
   b. Color: Clear.
5. Incandescent: Standard filaments, Halogen PAR, or linear quartz as applicable, rough service type, 125 V, of the type and wattage indicated in the Luminaire Schedule shown on the Drawings.
6. Metal halide: Suitable for burning position as required for the light fixture, in accordance with ANSI C78.389. Average rated life in the vertical burning position shall be 10,000 hours minimum for 250 W and smaller lamps and 20,000 hours minimum for 400 W and larger lamps. Mean lumens shall be 75% of initial lumens minimum; color temperatures shall be 3600K minimum; re-strike time after momentary interruption shall not be more than 4 minutes; warm-up time to full brightness shall be within 15 minutes. Pulse start unless otherwise indicated in the Luminaire Schedule shown on the Drawings.

C. Ballasts:
1. General:
   a. Meet requirements for fixture light output, reliable starting, radio interference, THD, EMI, and dielectric rating.
   b. Certified by electrical testing laboratories to conform to the certified Ballast Manufacturer's specifications.
   c. For use in exterior located ballasts to produce reliable starting of lamps over the entire temperature range at 90% of nominal line voltage.
   d. Energy saving type suitable for use with energy saving lamps where available.
   e. Meet FCC standard, Class A for EMI/RFI, FCC 47 CFR Part 18 non-consumer equipment.
   f. In accordance with ANSI/IEEE standards/guidelines for THD and line voltage transient protection.
2. Fluorescent:
   a. Type: Premium low heat high frequency electronic ballast with a maximum THD of 10%.
   b. In accordance with UL 935.
   c. Operate with no visible flicker.
   d. Tolerate sustained voltage variations of ±10% with no damage to the ballast.
   e. 0.98 PF or above.
   f. Sound rating of A or better.
   g. Comply with EMI and RFI limits set by the FCC 47 CFR, Part 18 for non-consumer equipment.
   h. cf of 1.7 or less.
3. Metal halide: Ballasts shall be single lamp. Volts and watts shall be as shown on the Drawings. At any lamp voltage, from nominal through life, lamp wattage regulation spread at that lamp voltage shall not exceed 5% for ±10% line voltage variation. Ballasts shall have a minimum PF of 0.98 and shall be suitable for low-temperature operation.
4. Photocell:
   a. Photocells for control of multiple luminaires:
      1) Self-contained.
      2) Weatherproof.
      3) Provided with time-delay features.
      4) Sized to meet switching capacity of the circuit: Based on ballast VA and lighting circuit load as shown on the Drawings.
   b. Photoelectric cell for control of a single luminaire: Integral to the luminaire.

D. LED Light Engines:
1. Solid-state, high output light emitting diode arrays.
2. Field removable and replaceable using pre-wired plug wiring harness.

E. LED Drivers:
1. Drive current: 350 mA or 700 mA as indicated in the Luminaire Schedule.
2. Field removable and replaceable using pre-wired plug wiring harness.
3. Integrated surge protection.
4. Projected lumen maintenance: Minimum L80 at 50,000 hours.

F. LED Fixtures:
1. Optics: As indicated in the Luminaire Schedule
2. Thermal management: Aluminum alloy heat sink integrated into luminaire housing.
3. Finish: Polyester baked powder coat or baked enamel paint.

G. LED Standby Light Unit:
1. Power pack: Self-contained, 120 V/277 V, dual voltage transformer, inverter/charger, sealed nickel cadmium battery, and indicator switch in accordance with UL 924.
2. Lighted, push-to-test indicator.
3. Capable of providing illumination for 1 1/2 hours in emergency mode.
4. Capable of full recharge in 1 day, automatically upon resumption of normal line voltage.
5. Capable of protecting against excess charging and discharging.

6. Self-diagnostics:
    a. Continuous monitoring operating conditions of the source power, battery supply voltage, emergency lamp continuity, and charging circuit.
    b. Charger and battery fault indicating LEDs. Indicators to remain illuminated until the fault condition is corrected.
    c. Automatic, monthly 30-second discharge and self-test.
    d. Automatic, bi-annually 90-minute discharge and self-test.

H. Illuminated Exit Sign:
1. Power pack: Self-contained, 120 V/277 V, dual voltage transformer, transient/surge protection, solid-state inverter/charger, sealed nickel cadmium battery, and indicator switch in accordance with UL 924.
2. Single or dual face, LED illuminated green lettering with snap-in directional chevrons.
3. Impact and scratch resistant, white thermoplastic housing.
4. Push-to-test switch and AC-ON indicator.
5. Universal mounting to standard octagon or square electrical outlet boxes.
6. Capable of providing illumination for 2 hours in emergency mode.
7. Capable of full recharge in 1 day, automatically upon resumption of normal line voltage.
8. Capable of protecting against excess charging and discharging.
9. Self-diagnostics: Continuous monitoring of operating conditions of the source power, battery supply voltage, emergency lamp continuity, and charging circuit.

I. Fluorescent Emergency Ballast:
1. In accordance with UL 924.
2. Nickel cadmium battery, charger, and electronic circuitry in metal case plus AC ballast.
3. Solid-state charging indicator for monitoring lighting and double-pole test switch.
4. Capable of operating one fluorescent lamp for a period of 90 minutes with output of 1,100 to 1,200 lumens.

PART 3 EXECUTION

3.1 INSTALLATION

A. Luminaires:
1. General:
    a. Install luminaires in accordance with the Manufacturer's instructions.
    b. Provide proper hangers, pendants, and canopies as necessary for complete installation.
    c. Provide additional ceiling bracing, hanger supports, and other structural reinforcements to the building and to concrete pole bases required to safely mount luminaires.
    d. Install luminaires plumb and level.
    e. Mounting heights shown on the Drawings for wall-mounted or pendant-mounted luminaires are measured from the bottom of the luminaire to finished floor or finished grade, whichever is applicable.
    f. Install each luminaire outlet box with galvanized stud.
    g. Pendant fixtures shall have swivel type box covers and threaded conduit pendants.
    h. Fixtures in rows shall be aligned both vertically and horizontally.
    i. The drawings indicate the general location and arrangement of the fixtures desired. The actual location and arrangement of the fixtures shall be clear of pipes, mechanical equipment, structural openings, and other obstructions. The actual location and arrangement of the fixtures shall be approved by the ENGINEER.
    j. Coordinate luminaire locations with Work of other trades to prevent the obstruction of light from the fixtures.
    k. Individual luminaire types in the luminaire schedule shown on the Drawings.
2. Wall-mounted metal halide:
    a. Surface mount the fixture over a concealed or embedded box and provide an opening in the back of the fixture suitable to provide access to the wiring in the box.
    b. Ground and bond the fixture and the box to each other with a minimum of a #12 AWG conductor.
    c. Support the fixture utilizing SST anchors and hardware. Provide caulking with a non-hardening sealer around the fixture.
3. Pendant-mounted:
    a. Provide swivel type hangers and canopies to match luminaires, unless otherwise shown on the Drawings.
    b. Space single-stem hangers on continuous-row fluorescent luminaires nominally 48 inches apart.
    c. Provide twin-stem hangers on single luminaires.
4. Pole-mounted: Provide a cast-in-place concrete base as shown on the Drawings.
5. Swinging type: Provide, at each support, safety cable capable of supporting four times the vertical load from the structure to the luminaire.
6. Unfinished areas: Locate luminaires to avoid either conflict with other building systems or blockage of luminaire light output.
    a. Fixture suspension: As approved or shown on the Drawings.
7. Illuminated exit sign:
    a. Install in accordance with the Manufacturer’s recommendations.
    b. Provide separate, un-switched circuit wiring to luminaire.
    c. Mount 8 feet above finished floor.
8. LED standby light unit:
    a. Install in accordance with the Manufacturer’s recommendations.
    b. Provide separate, un-switched circuit wiring to luminaire.
    c. Mount 8 feet, 6 inches above finished floor.

B. Lamps and LEDs: For each fixture, provide the number and type for which the fixture is designed.
C. Ballasts:
1. Install ballasts in accordance with the Manufacturer's instructions.
2. Utilize ballast mounting holes to fasten securely within the luminaire.
3. Replace noisy or defective ballasts.

3.2 CLEANING

A. Remove labels and other markings, except UL listing mark.
B. Wipe luminaires inside and outside to remove construction dust.
C. Clean luminaire plastic lenses with anti-static cleaners.
D. Touch up painted surfaces of luminaires and poles with matching paint ordered from the Manufacturer.
E. Replace defective lamps prior to the Substantial Completion date.

END OF SECTION

SECTION 26 70 00
MOTORS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for AC induction motors.

B. Related Sections:
   1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   4. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. American Bearing Manufacturers Association (ABMA):
   1. 9 – Load Ratings and Fatigue Life for Ball Bearings
   2. 11 – Load Ratings and Fatigue Life for Roller Bearings

B. Institute of Electrical and Electronics Engineers (IEEE):
   1. 112 – Standard Test Procedure for Polyphase Induction Motors and Generators

C. National Electrical Manufacturers Association (NEMA):
   1. MG 1 – Motors and Generators
   2. 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)

D. National Fire Protection Association (NFPA):
   1. 70 – National Electrical Code (NEC)

E. Underwriters Laboratories, Inc. (UL):
   1. 1 – Standard for Flexible Metal Conduit
   2. 674 – Electric Motors and Generators for Use in Hazardous (Classified) Locations

1.3 DEFINITIONS

A. Motor Nameplate HP: That rating after any derating required to allow for extra heating caused by the harmonic content in the voltage applied to the motor by its controller.

1.4 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
   1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
   2. Catalog, descriptive and specification information for equipment, components, and devices.
   3. Conduit entrance locations and connection information.
   4. Anchoring instructions and details.
   5. Typed tabulation:
      a. Motor name; tag (equipment) numbers as shown on the Drawings.
      b. Motor hp.
      c. Nameplate information.
      d. Currents and voltages.
      e. Weight.
      f. Inertia.
   6. Certified drawings of the equipment, including but not limited to: Dimensional, electrical drawings showing the equipment dimensions, size, mounting requirements, and locations of connections for equipment, detailed base drawing showing dimensions and materials used in fabrication, driven equipment shaft interface, including couplings, keyway, bolts, and shaft dimensions.
   7. Motor bearing life calculations.
   8. Power and control wiring diagrams, including terminals and numbers.
   9. Complete motor data sheets shall include, but not be limited to:
      a. Manufacturer's name and the date manufactured.
      b. Model number.
      c. Serial number.
      d. Descriptive information.
      e. Nameplate data in accordance with NEMA MG 1.
      f. Additional rating information:
         1) SF.
         2) Locked rotor current.
         3) No load current.
         4) Safe stall time: Stall time/thermal limit curve.
         5) Performance data curves showing speed, slip, torque, current, kW input, PF, and percent efficiency from shutoff to maximum capacity.
         6) X/R ratio, reactances, resistances, short-circuit time constants, open circuit time constants, rotor inertia, etc.
         7) Complete motor model/equivalent circuit.
      g. Enclosure type and mounting.
      h. Conduit box dimensions and usable volume in accordance with NEMA MG 1 and NFPA 70.

i. Motor interconnection boxes.
j. Dimensions and total weight.
k. Bearing type, lubrication and life.
l. Description and rating of motor thermal protection.
m. Motor sound power level in accordance with NEMA MG 1.
n. Maximum brake hp required by the equipment driven by the motor.
o. Space heater wattage and voltage.
p. The Motor Manufacturer shall submit a certified letter stating that the motor provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site conditions. The Motor Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve motor derated values.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
a. Provide preliminary and final manuals.
b. As specified in SECTION 01 78 23.
c. Shop Drawing Submittal information.
d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
e. Factory functional and performance test reports.
f. Factory and field test reports.
g. Shipping, storage, protection, and handling instructions.
h. Manuals shall include, but not be limited to the following:
1) Standard motor operational manuals normally furnished by the Manufacturer.
2) A motor shop manual equivalent to the manual used by factory-authorized shop repair personnel.
3) A motor repair parts manuals normally furnished by the Manufacturer.
4) Details of parts and subassemblies available as repair parts.
i. Manufacturer's certificate of proper installation (after the motor has been installed).
j. Suggested spare parts list to maintain the equipment in service for a period of 5 years. Include a list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
k. Tabulated data for operating drive motors at design points:
1) Rated hp.
2) Full load speed, rpm.
3) PF.
4) Efficiency curves at 1/2, 3/4, and full load.
5) Service factor.
6) kW input.
3. Final As-Built Drawings.
a. Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW’s current CAD Standards and shall include, but not be limited to, the Standards located online in DW’s CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
1) Drawings shall be on a standard DW provided title block and border.
2) As-Builts and Manufacturer’s drawings shall be provided:
a) On a standard DW provided title block and border.
b) With the drawing graphics and text, assigned to a pen 2 color (yellow).
c) Text: Minimum 0.1 inches, maximum 0.2 inches.
d) Titles: 0.2 inches.

E. Warranty Documentation.
F. Supplements listed in this Section.

1.5 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.
C. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
a. Installation assistance, and inspection of installation: 1.

1.6 SITE CONDITIONS

A. Environmental Requirements: Materials and equipment shall be designed and constructed for continuous operation, at rated current and voltage, at 6,000 feet above mean sea level, -30°F (exterior and non-environmentally controlled areas) to 104°F ambient temperature and 95% relative humidity. The Equipment Manufacturer shall submit a certified letter in the Shop Drawing Submittal stating the equipment provided meets this requirement.

1.7 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the AC induction motors system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. AC Induction Motors:
   1. TECO-Westinghouse
   2. WEG
B. Connecting Head:
   1. Pyromation, Inc., Series 904-905
C. Motor Lead Connections:
   1. 1,000 V and less:
      a. 3M Series 5300-5304
   2. Medium voltage:
      a. 3M Series 5321-5324

2.2 MATERIALS

A. General:
   1. For multiple units of the same type of equipment, furnish identical motors and accessories of a single Manufacturer.
   2. Frame assignments in accordance with NEMA MG 1.
   3. Motors shall be specifically designed for the use and conditions intended with a NEMA design letter classification to fit the application.
   4. Lifting lugs on motors weighing 100 lbs or more.
   5. Operating conditions:
      a. Maximum ambient temperature not greater than 104°F.
      b. Motors shall be suitable for operating conditions without any reduction being required in the nameplate rated hp or exceeding the rated temperature rise.
      c. Overspeed in either direction in accordance with NEMA MG 1.
      d. Motors shall be derated for operation at site conditions.
   6. Induction premium efficiency type motor.
   7. Horizontal mounting.
   8. The motors shall be continuous duty.
   9. Stator windings shall be made of copper only.
B. HP Rating:
   1. As designated in motor-driven equipment specifications and as shown on the Drawings.
   2. Brake hp of the driven equipment at any operating condition not to exceed motor nameplate hp rating at site conditions, excluding any SF.
C. SF:
   1. Motors shall be provided with 1.15 minimum at rated ambient temperature. SF shall not be used in normal equipment loading or in derating for altitude.
   2. The full load rating of each motor shall be as required to meet the brake hp as specified at 1.00 SF, (without using 15% additional SF rating).
   3. Variable frequency, adjustable speed applications: Driven equipment brake hp at any operating condition not to exceed motor nameplate hp rating, excluding any SF.
D. Voltage and Frequency Rating:
   1. System frequency: 60 Hz.
   2. Voltage rating, as indicated.
   3. Suitable for full voltage starting.
   4. Suitable for reduced voltage starting with 65% or 80% voltage tap settings on reduced inrush motor starters. Provide thermal damage curves/information for reduced voltage starting applications.
   5. Suitable for reduced voltage starting with VFDs, solid-state reduced voltage starters, or autotransformers. Provide thermal damage curves/information for reduced voltage starting applications.
   6. Suitable for accelerating the connected load with supply voltage at motor starter supply terminals dipping to 90% of motor rated voltage.
E. Efficiency and PF:
   1. For motors, including motors for HVAC equipment, except single-phase, under 1 hp, multispeed, short-time rated and submersible motors, or motors driving gates, valves, elevators, cranes, trolleys, and hoists:
      a. Efficiency: Premium efficient. Exceed efficiency values in accordance with NEMA MG 1, Part 12.60 and Table 12-12 to be classified as premium efficient.
   2. PF: Manufacturer’s standard.
   3. Medium voltage motors.
      a. 95% efficiency or better, guaranteed minimum.
      b. 0.80 PF before PFCCs, minimum.
F. PFCCs:
   1. The motor controllers shall be provided with PFCCs. Size and provide the correct PFCC rating based on the new induction motor design/ratings.
   2. The PFCCs shall be provided with the following:
      a. NEMA three-terminal compartment.
      b. Three-phase fusing with 50 KAIC rating and pop-up button visual-indication of blown fuse.
      c. Discharge resistors to reduce residual voltage to 50 V or less within 5 minutes of de-energization.

d. PFCCs shall be mounted in the motor controllers.

G. Locked Rotor Ratings:
1. Locked rotor kVA Code F or lower if the motor hp is not covered by NEMA MG 1 tables.
2. Safe stall time 15 seconds or greater.

H. Insulation Systems:
1. Single-phase, fractional hp motors: Manufacturer's standard winding insulation system.
2. Three-phase and integral hp motors: Class F with Class B temperature rise at nameplate hp and designated operating conditions.
3. The temperature rise shall not exceed the 1.00 SF Class B NEMA MG 1 temperature rise requirements of 80°C for resistance method of temperature determination and 90°C for embedded detector method of temperature determination, minus a reduction for altitude in accordance with NEMA MG 1. The altitude temperature reduction shall be 1% for every 330 feet above 3,300 feet. If the motors do not meet the temperature rise requirements of both methods of temperature determination, the motors shall be rejected.

I. Enclosures:
1. Enclosures shall be in accordance with NEMA MG 1.
2. TEFC and TENV: Furnish with a drain hole with porous drain/weather plug.
3. Submersible: As specified in this Section.

J. Terminal (Conduit) Boxes:
1. Oversize main terminal boxes for motors within reason to allow adequate room to make terminations.
2. Diagonally split, rotatable to each of four, 90 degree positions. Threaded hubs for conduit attachment.
3. Except ODP, furnish gaskets between box halves and between box and motor frame.
4. Terminal for connection of equipment grounding wire in each terminal box, two servit posts on frame.
5. Separate power feed conduit and RTD terminal boxes shall be mounted on the motor arranged as shown on the Drawings or TBD during Submittals.
6. The configurations detailed herein shall be followed unless otherwise changed by the ENGINEER during the Submittal process.

K. Bearings and Lubrication:
1. Horizontal motors:
   a. 3/4 hp and smaller: Permanently lubricated and sealed ball bearings or regreasable ball bearings in labyrinth sealed end bells with removable grease relief plugs.
   b. 1 hp through 400 hp: Regreasable ball bearings in labyrinth sealed end bells with removable grease relief plugs.
   c. Minimum 100,000 hours L-10 bearing life for ball and roller bearings in accordance with ABMA 9 and ABMA 11. Dynamically balanced in accordance with NEMA MG 1, Part 7, maximum amplitude, inches peak to peak 0.0025.
      1) The motor bearings shall be shipped from the Manufacturer with sufficient grease for a long operating period.
      2) Re-lubrication procedures supplied by the Motor Manufacturer shall be provided in the instruction tag shipped with the motors.
2. Vertical motors:
   a. Thrust bearings:
      1) Anti-friction bearing.
      2) Manufacturer's standard lubrication 100 hp and smaller.
      3) Oil lubricated 125 hp and smaller.
      4) Minimum 50,000 hours L-10 bearing life.
   b. Guide bearings:
      1) Manufacturer's standard bearing type.
      2) Manufacturer's standard lubrication 200 hp and smaller.
      3) Oil lubricated 250 hp and smaller.
      4) Minimum 100,000 hours L-10 bearing life.
3. Regreasable anti-friction bearings:
   a. Readily accessible, grease injection fittings.
   b. Readily accessible, removable grease relief plugs.
4. Oil lubrication systems:
   a. Oil reservoirs with sight level gauge.
   b. Oil fill and drain openings with opening plugs.
   c. Provisions for necessary oil circulation and cooling.

L. Special Features and Accessories:
1. Screen over air openings: Corrosion-resistant on motors with ODP, WPI, and WPII enclosures meeting the requirements for guarded machine in NEMA MG 1.
2. Winding thermal protection:
   a. RTDs:
      1) Motor shall have the following RTD thermal protection.
      2) Six 100 ohm platinum three-wire RTD temperature sensors shall be provided in the stator winding; two embedded in each stator phase winding; terminated in a motor-mounted NEMA 4 terminal box.
      3) A three-wire 100 ohm, platinum RTD shall be provided for each motor bearing.
      4) RTDs shall be designed for 100 ohms at 0°C, with a temperature coefficient of 0.385 ohms per °C.

5) Each bearing RTD shall be installed utilizing a Pyromation, Inc. connecting head, Series 904-905. Twisted shielded triad conductors shall be routed to the motor-mounted NEMA 4 terminal box with LFMC and terminated on an approved terminal strip.

b. Thermistors:
1) Only when approved by the ENGINEER or shown on the Drawings.
2) Thermistor embedded in each stator phase winding before winding dip and bake process.
3) In intimate contact with winding conductors.
4) Epoxy-potted, solid-state thermistor control module mounted in NEMA 250, Type 4X box on motor by the Motor Manufacturer.
5) Individual thermistor circuits factory-wired to control module.
6) Control module rated for 120 VAC power supply.
7) Control module automatically reset contact for external use rated 120 VAC, 5 A minimum, opening on abnormally high winding temperature. Manual reset shall be provided at the motor controller.

3. Nameplates:
a. Raised or stamped letters on SST.
b. Provide large SST motor identification tag number, 2 inches by 4 inches minimum, on the motor.
c. Display motor data required by NEMA MG 1 in addition to bearing numbers for both bearings.
d. Premium efficiency motor nameplates shall also display NEMA nominal efficiency, full load PF, and maximum allowable kVAR for PFCC.
e. Guaranteed minimum efficiency and altitude rating shall be shown.
f. Do not include motor winding and bearing alarm and trip temperature values on the nameplate.

M. Special Motors:
1. Requirements in this paragraph take precedence over conflicting features specified elsewhere in this Section.
2. Multispeed: Meet requirements for speeds, number of windings, and load torque classification specified in the motor-driven equipment specifications.
3. Submersible pump motors:
a. Efficiency:
1) Premium efficiency.
2) Equal or exceed efficiency values in accordance with NEMA MG 1, Part 12.60 to be classified as premium efficiency.

b. At 100% load: 82 guaranteed minimum PF.
c. Insulation system: Class F.
d. Motor capable of running dry continuously.
e. Enclosure:
1) Hermetically sealed, watertight, for continuous submergence up to 65 foot depth.
2) Listed in accordance with UL 674 and NFPA 70 for Class 1, Division 1, Group D, hazardous atmosphere for the sanitary sewer pumps.
3) Seals: Tandem mechanical.

f. Bearing and lubrication:
1) Permanently sealed and lubricated, replaceable anti-friction guide and thrust bearings.
2) Minimum 15,000 hours L-10 bearing life.

g. Inrush kVA/hp no greater than NEMA MG 1 and NFPA 70, Code F.
h. Protection:
1) Incorporate thermal switches in series in stators to monitor the temperature of each phase winding and stop the motor and activate an alarm.
2) Install a leakage sensor to detect water in the stator chamber and activate an alarm.
3) Provide a solid-state sensing relay to detect pump motor high temperature and pump leak to the Motor Starter Manufacturer for installation in the motor control cabinet.

i. Connecting cables:
1) One cable containing power, control, and grounding conductors.
2) Each cable suitable for hard service, submersible duty with watertight seal where cable enters motor.
3) Length: 40 feet minimum.
4) UL 1 listed and sized in accordance with NFPA 70.

4. Inverter duty motors:
a. 600 VAC and lower induction motors supplied for use with VFDs shall be rated for inverter duty and shall include a SST nameplate showing inverter duty motor.
b. The nameplate shall also show that the motor is suitable for variable torque, or constant torque if progressive cavity pump; operation on VFD power from 6 Hz to 60 Hz; and rated torque in pounds per foot on inverter power in addition to the standard nameplate data specified in NEMA standards.
c. Motor insulation shall be an inverter grade system designed to meet the voltage spike limits in accordance with NEMA MG 1, Part 31.4.4.2. Insulation systems shall use triple layer magnet wire or magnet wire with a PEI greater than 50. Insulation systems utilizing heavy film and two film wire with a PEI less than 50 are not acceptable. Complete insulation of the slot, cell, and phase groups is required. The system shall be rated for Class F rise or better, rated to operate at a maximum ambient temperature of 104°F and at site conditions with temperature rise limited to Class B.

d. Inverter duty stator core designs shall be of high rigidity type with reinforced end turn construction to minimize mechanical fatigue of the winding and to reduce resonant noise. Single dip and bake cycles are not acceptable.
e. The Motor Manufacturer shall supply certification with Submittals that the motor is constructed in accordance with NEMA MG 1, Part 31; the compliance shall be stamped on the motor nameplate.

2.3 FABRICATION

A. Noise:
1. Measured in accordance with NEMA MG 1.
2. Motors controlled by adjustable frequency drive systems shall not exceed sound levels of 3 dBA higher than NEMA MG 1.

B. Balance and Vibration Control: In accordance with NEMA MG 1.

C. Equipment Finish:
1. Protect motor for service conditions:
a. ODP enclosures: Indoor industrial atmospheres.
b. Other enclosures: Outdoor industrial atmospheres, including moisture and direct sunlight exposure.
2. Minimum two coats of epoxy paint.
3. Internal finish: Bore and end turns coated with clear polyester or epoxy varnish.

PART 3 EXECUTION

3.1 INSTALLATION

A. In accordance with the Manufacturer's instructions and recommendations.
B. Align motor carefully and properly with driven equipment.
C. Secure equipment to the mounting surface with anchor bolts. Provide anchor bolts meeting the Manufacturer's recommendations and of sufficient size and number for the specified seismic conditions.
D. Motor lead connections with products shown on the Drawings, unless otherwise approved by the ENGINEER.

3.2 QUALITY CONTROL

A. Functional test, conduct on each motor:
1. Test complete assemblies for proper alignment; verify that motors have proper rotation.
2. Sound level tests.
3. Final megger of motor from T-leads through motor.
4. Startup services for the existing pump and new motor shall include, but not limited to, packing adjustment, lubrication verification, and verification of proper dynamic operation.
5. Field vibration test. The rotating equipment shall meet the following limits:
a. Driving unit alone: Less than 80% of NEMA MG 1 limits.
b. Complete rotating assembly including pump, coupling, drive unit, and motor: Less than 90% of limits established in the Hydraulic Institute Standards for displacement and velocity.
c. Determine that accessories are properly connected and functioning.
6. Temperature rise: Run motors at 1.00 SF for a minimum of 3 hours. Measure and record the temperature of the hottest embedded detector, kW, amperage, voltage, and PF in 15 minute intervals.
7. Motors:
a. Visual and mechanical inspection:
1) Proper electrical and grounding connections.
2) Blockage of ventilating air passageways.
3) Operate motor at the designed rotational speed and check for:
a) Excessive mechanical and electrical noise.
b) Overheating.
c) Correct rotation.
d) Excessive vibration.
4) Check vibration detectors, RTDs, or motor inherent protectors for functionality and proper operation.
b. Determine that accessories are properly connected and functioning.
c. Electrical Tests: Measure running current and voltage at designed rotational speed and evaluate relative to load conditions and nameplate FLAs.

B. Performance tests at 25%, 50%, 75%, and 100% of rated hp, a minimum of 15 minutes at each speed.
1. Record values in Supplement A.
2. Use values to calculate water to wire efficiency.

C. Required Factory Testing:
1. Perform factory testing on the actual motors and submit certified factory testing reports for approval before the motor is shipped.
2. Testing in accordance with NEMA MG 1 and IEEE 112 for polyphase motors.
3. Routine production tests on motors in accordance with NEMA MG 1 plus no load power at rated voltage and polyphase, rated voltage measurement of locked rotor current.
4. Locked rotor amperes and torque at three-phase, rated voltage.
5. Breakdown torque.
6. The temperature rise shall not exceed the 1.00 SF Class B NEMA MG 1 temperature rise requirements of 80°C for resistance method of temperature determination and 90°C for embedded RTD method of temperature determination, minus a reduction for altitude in accordance with NEMA MG 1. The altitude temperature reduction shall be 1% for every 330 feet above 3,300 feet. The factory temperature rise test shall be a minimum of 4 hours.

If the motors do not meet the temperature rise requirements of both methods of temperature determination, the motors shall be rejected. RTDs testing data shall be submitted for approval.

7. Winding resistance.
8. High-potential test.
9. Mechanical balance.
10. Certified performance tests at 25%, 50%, 75%, and 100% of rated hp in accordance with IEEE 112, Test Method B and NEMA MG 1, Part 12:
    a. Efficiency.
    b. PF.
    c. Speed.
    d. Current.
    e. kW input.
11. Routine test reports form: IEEE 112, Form A-1.

D. Field Testing: Additional testing as specified in SECTION 26 08 00.

E. Manufacturer's Services: A Manufacturer's Representative shall be present at the site for startup and commissioning of motors.

3.3 SUPPLEMENTS

A. Supplement A – Water to Wire Performance Test Chart

END OF SECTION

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SUPPLEMENT A
WATER TO WIRE PERFORMANCE TEST

Pump-Motor																																															
Mechanical															Electrical																																
															Field PITs		MPR - 369																VFD (if applicable)							Incoming SWGR Power Meter							
Test		RMP at Unit	Reservior Level	Suction Pressure (psi)	Discharge Pressure (psi)	Valve Position % Open at Valve	Flow - Flowmeter at Magmeter	Flow - Hydraulics	Pump Bearing Temp - Inboard	Pump Bearing Temp - Outboard	Vib Outboard Vent	Vib Outboard Horiz	Vib Inboard Vent	Vib Inboard Horiz	Discharge Pressure	Suction Pressure	kW	Power Factor	Volts A to B	Voltz B to C	Voltz C to A	Phase Amps A	Phase Amps B	Phase Amps C	Moror Bearing Temp - Inboard	Motor Bearing Temp - Outboard	Motor Stator Temp A	Motor Stator Temp B	Motor Stator Temp C	Motor Stator Temp A	Motor Stator Temp B	Motor Stator Temp C	Discharge Valve Position (Red Lion)	Discharge Pressure (Red Lion)	Output Frequency to Motor	Moror Speed in RPM	Motor Amps	Motor Voltage	DC-Bus Voltage	KW	Power factor	Volts A to B	Volts B to C	Volts C to A	Phase Amps A	Phase Amps B	Phase Amps C
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SECTION 26 70 02
MOTORS 50 HP AND LESS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for motors 50 hp and less.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. American Bearing Manufacturers Association (ABMA):

1. 9 – Load Ratings and Fatigue Life for Ball Bearings
2. 11 – Load Ratings and Fatigue Life for Roller Bearings

B. ASTM International (ASTM):

1. B 117 – Standard Practice for Operating Salt Spray (Fog) Apparatus

C. Institute of Electrical and Electronic Engineers (IEEE):

1. 841 – Standard for Petroleum and Chemical Industry-Premium-Efficiency, Severe Duty, Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors – Up to and Including 370 kW (500 hp)

D. National Electrical Manufacturers' Association (NEMA):

1. MG 1 – Motors and Generators
2. MG 2 – Safety Standard for Construction and Guide for Selection, Installation, and Use of Electric Motors and Generators

E. National Fire Protection Agency (NFPA):

1. 70 – National Electrical Code (NEC)

F. Underwriters Laboratories, Inc. (UL):

1. 674 – Electric Motors and Generators for Use in Hazardous (Classified) Locations

1.3 DEFINITIONS

A. Motor Nameplate hp: That rating after any derating required to allow for extra heating caused by the harmonic content in the voltage applied to the motor by its controller, or by site elevation requirements, or low rpm requirements from VFDs.

1.4 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Conduit entrance locations and connection information.
4. Anchoring instructions and details.
5. Typed tabulation:
    a. Motor name; tag (equipment) numbers as shown on the Drawings.
    b. Motor hp.
    c. Nameplate information.
    d. Currents and voltages.
    e. Weight.
    f. Inertia.
6. Certified drawings of the equipment, including but not limited to: Dimensional, electrical drawings showing the equipment dimensions, size, mounting requirements, and locations of connections for equipment, detailed base drawing showing dimensions and materials used in fabrication, driven equipment shaft interface, including couplings, keyway, bolts, and shaft dimensions.
7. Motor bearing life calculations.
8. Power and control wiring diagrams, including terminals and numbers.
9. Complete motor data sheets shall include, but not be limited to the following:
    a. Manufacturer’s name and the date manufactured.
    b. Model number.
    c. Serial number.
    d. Descriptive information.
    e. Nameplate data in accordance with NEMA MG 1.
    f. Additional rating information:
        1) SF.
        2) Locked rotor current.
        3) No load current.
        4) Safe stall time: Stall time/thermal limit curve.
        5) Performance data curves showing speed, slip, torque, current, kW input, PF, and percent efficiency from shutoff to maximum capacity.
        6) X/R ratio, reactances, resistances, short-circuit time constants, open circuit time constants, rotor inertia, etc.
        7) Complete motor model/equivalent circuit.

g. Enclosure type and mounting.
h. Conduit box dimensions and usable volume in accordance with NEMA MG 1 and NFPA 70.
i. Motor interconnection boxes.
j. Dimensions and total weight.
k. Bearing type, lubrication and life.
l. Description and rating of motor thermal protection.
m. Motor sound power level in accordance with NEMA MG 1.
n. Maximum brake hp required by the equipment driven by the motor.
o. Space heater wattage and voltage.
p. The Motor Manufacturer shall submit a certified letter stating that the motor provided will be designed and constructed for continuous operation, at rated current and voltage, at the project and site conditions. The Motor Manufacturer shall include any derating calculations and standards applicable to the derating. The ENGINEER shall approve motor derated values.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M Manuals:
a. Provide preliminary and final manuals.
b. As specified in SECTION 01 78 23.
c. Shop Drawing information.
d. Manufacturer's installation instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
e. Factory functional and performance test reports.
f. Factory and field test reports.
g. Shipping, storage, protection, and handling instructions.
h. Manuals shall include, but not be limited to:
1) Standard motor operational manuals normally furnished by the Manufacturer.
2) A motor shop manual equivalent to the manual used by factory-authorized shop repair personnel.
3) A motor repair parts manuals normally furnished by the Manufacturer.
4) Details of parts and subassemblies available as repair parts.
i. Manufacturer's certificate of proper installation (after the motor has been installed).
j. Suggested spare parts list to maintain the equipment in service for a period of 5 years. Include a list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
k. Tabulated data for operating drive motors at design points:
1) Rated hp.
2) Full load speed, rpm.
3) PF.
4) Efficiency curves at 1/2, 3/4, and full load.
5) SF.
6) kW input.
3. Final As-Built Drawings.
a. Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW’s current CAD Standards and shall include, but not be limited to, the Standards located online in DW’s CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
1) Drawings shall be on a standard DW provided title block and border.
2) As-Builts and Manufacturer’s drawings shall be provided:
a) On a standard DW provided title block and border.
b) With the drawing graphics and text, assigned to a pen 2 color (yellow).
c) Text: Minimum 0.1 inches, maximum 0.2 inches.
d) Titles: 0.2 inches.

E. Warranty Documentation.
F. Supplements listed in this Section.

1.5 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.
1. UL compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing.
2. Complete electrical data.
3. Torque, current, and PF versus speed curves:
a. At 100% rated voltage for the full voltage started and VFD driven motors.
b. For motors on reduced voltage start at 70%, 80%, 90%, and 100% rated voltage.
4. Accessories data:
a. PF correction capacitors:
1) Size in KVAR for motors not connected to variable frequency drives.
b. Winding temperature detectors:
1) Type.
2) Rating.

c. Moisture detectors.
5. Mechanical data:
a. Bearing design and bearing life calculations.

1.6 SITE CONDITIONS

A. Environmental Requirements: Materials and equipment shall be designed and constructed for continuous operation, at rated current and voltage, at 6,000 feet above mean sea level, -30°F (exterior and non-environmentally controlled areas) to 104°F ambient temperature and 95% relative humidity. The Equipment Manufacturer shall submit a certified letter in the Shop Drawing Submittal stating the equipment provided meets this requirement.

1.7 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the AC induction motors system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. AC Induction Motors:
1. ABB/Baldor/Reliance
2. General Electric
3. TECO-Westinghouse
4. WEG

B. Motor Lead Connections:
1. ABB Installation Products/Blackburn, motor pigtail connectors, MD style

2.2 MATERIALS

A. General:
1. For multiple units of the same type of equipment, furnish identical motors and accessories of a single Manufacturer.
2. Frame assignments in accordance with NEMA MG 1.
3. Motors shall be specifically designed for the use and conditions intended with a NEMA design letter classification to fit the application.
4. Lifting lugs on motors weighing 100 lbs or more.
5. Operating conditions:
a. Maximum ambient temperature not greater than 104°F.
b. Motors shall be suitable for continuous operation at the site conditions without any reduction being required in the nameplate rated hp or exceeding the rated temperature rise.
c. Overspeed in either direction in accordance with NEMA MG 1.
d. Motors shall be derated for operation at site conditions.
6. Induction premium efficiency type motor.
7. Horizontal mounting.
8. The motors shall be continuous duty.
9. Stator windings shall be made of copper only.

B. Hp Rating:
1. As specified in the Contract Documents and as shown on the Drawings.
2. Brake hp of the driven equipment at any operating condition not to exceed motor nameplate hp rating at site conditions, excluding any SF.

C. SF:
1. Motors shall be provided with 1.15 minimum at rated ambient temperature. SF shall not be used in normal equipment loading or in derating for altitude.
2. The full load rating of each motor shall be as required to meet the brake hp as specified at 1.00 SF, (without using 15% additional SF rating).
3. Variable frequency, adjustable speed applications: Driven equipment brake hp at any operating condition not to exceed inverter duty rated motor nameplate hp rating, excluding any SF.

D. Voltage and Frequency Rating:
1. System frequency: 60 Hz.
2. Voltage rating, unless shown otherwise:

Size	Voltage	Phases
Less than 1/2 hp	115	1
1/2 hp to less than 51 hp	460	3

3. Suitable for full voltage starting.
4. Suitable for reduced voltage starting with 65% or 80% voltage tap settings on reduced inrush motor starters. Provide thermal damage curves/information for reduced voltage starting applications.
5. Suitable for reduced voltage starting with VFDs, solid-state reduced voltage starters, or autotransformers. Provide thermal damage curves/information for reduced voltage starting applications.
6. Suitable for accelerating the connected load with supply voltage at motor starter supply terminals dipping to 90% of motor rated voltage.

E. Efficiency and PF:
1. Efficiency: Premium efficient. Exceed efficiency values in accordance with NEMA MG 1, Part 12.60, and Table 12-12 to be classified as premium efficient.
2. PF: Manufacturer’s standard.

F. Locked Rotor Ratings:
   1. Locked rotor kVA Code F or lower if the motor hp is not covered by NEMA MG 1 tables.
   2. Safe stall time 15 seconds or greater.

G. Insulation Systems:
   1. Three-phase and integral hp motors: Class F with Class B temperature rise at nameplate hp and designated operating conditions.
   2. The temperature rise shall not exceed the 1.00 SF Class B NEMA MG 1 temperature rise requirements of 80°C for resistance method of temperature determination and 90°C for embedded detector method of temperature determination, minus a reduction for altitude in accordance with NEMA MG 1. The altitude temperature reduction shall be 1% for every 330 feet above 3,300 feet. If the motors are not in accordance with the temperature rise requirements of both methods of temperature determination, the motors shall be rejected.

H. Terminal (Conduit) Boxes:
   1. Oversize main terminal boxes for motors.
   2. Diagonally split, rotatable to each of four, 90 degree positions. Threaded hubs for conduit attachment.
   3. Except open drip-proof, furnish gaskets between box halves and between box and motor frame.
   4. Terminal for connection of equipment grounding wire in each terminal box, two servit posts on frame.
   5. The configurations detailed herein shall be followed unless otherwise changed by the ENGINEER during the Submittal process.

I. Bearings and Lubrication:
   1. Horizontal motors:
      a. 3/4 hp and smaller: Permanently lubricated and sealed ball bearings or regreasable ball bearings in labyrinth sealed end bells with removable grease relief plugs.
      b. 1 hp through less than 60 hp: Regreasable ball bearings in labyrinth sealed end bells with removable grease relief plugs.
      c. Minimum 100,000 hours L-10 bearing life for ball and roller bearings in accordance with ABMA 9 and ABMA 11. Dynamically balanced in accordance with NEMA MG 1, Part 7, maximum amplitude, inches peak-to-peak 0.0025.
         1) The motor bearings shall be shipped from the Manufacturer with sufficient grease for a long operating period.
         2) Re-lubrication procedures supplied by the Motor Manufacturer shall be provided in the instruction tag shipped with the motors.

J. Special Features and Accessories:
   1. Nameplates:
      a. Raised or stamped letters on SST.
      b. Provide large SST motor identification tag number, 2 inches by 4 inches minimum, on the motor.
      c. Display motor data required by NEMA MG 1 in addition to bearing numbers for both bearings.
      d. Premium efficiency motor nameplates shall also display NEMA nominal efficiency, full load PF, and maximum allowable KVAR for PF correction capacitor.
      e. Guaranteed minimum efficiency and altitude rating shall be shown.

K. Special Motors:
   1. Requirements in this paragraph take precedence over conflicting features specified elsewhere in this Section.
   2. Multispeed: Speeds, number of windings, and load torque classification are in accordance with the Contract Documents.
      a. Inrush kVA/hp no greater than NEMA MG 1 and NFPA 70, Code F.
   3. Submersible pump motors:
      a. Efficiency: Premium efficiency. Equal or exceed efficiency values in accordance with NEMA MG 1, Part 12.60 to be classified as premium efficiency.
      b. At 100% load:

hp	Guaranteed Minimum Efficiency	Guaranteed Minimum PF
5 thru 10	80	82
10 thru 50	85	82

      c. Insulation system: Class F.
      d. Motor capable of running dry continuously.
      e. Enclosure:
         1) Hermetically sealed, watertight, for continuous submergence up to 65 foot depth.
         2) Listed in accordance with UL 674 and NFPA 70 for Class 1, Division 1, Group D, hazardous atmosphere for the sanitary sewer pumps.
         3) Seals: Tandem mechanical.
      f. Bearing and lubrication:
         1) Permanently sealed and lubricated, replaceable anti-friction guide and thrust bearings.
         2) Minimum 15,000 hours L-10 bearing life.
      g. Inrush kVA/hp no greater than NEMA MG 1 and NFPA 70, Code F.

h. Protection:
   1) Incorporate thermal switches in series in stators to monitor the temperature of each phase winding and stop the motor and activate an alarm.
   2) Install a leakage sensor to detect water in the stator chamber and activate an alarm.
   3) Provide a solid-state sensing relay to detect pump motor high temperature and pump leak to the Motor Starter Manufacturer for installation in the motor control cabinet.
i. Connecting cables:
   1) One cable containing power, control, and grounding conductors.
   2) Each cable suitable for hard service, submersible duty with watertight seal where cable enters motor.
   3) Length: 40 feet minimum.
   4) UL 1 listed and sized in accordance with NFPA 70.

L. Three-Phase Induction Motors – General:
1. Voltage:
   a. Motors 1/2 hp and larger shall be rated 460 V, three-phase unless otherwise shown on the Drawings.
   b. Dual voltage motors rated 230/460 V, three-phase are acceptable provided the leads are brought to the conduit box.
2. Motors driving identical machines shall be identical.
3. Motors greater than 1 hp to less than 60 hp are in accordance with the NEMA Premium Efficiency percent listed in NEMA MG 1.
4. Hp ratings shown on the Drawings are based on vendor estimates. Provide motors sized for the load of the actual equipment furnished without operating in the SF.
5. Torque:
   a. Provide motors that develop sufficient torque for acceleration to full speed at voltage 10% less than motor nameplate rating.
   b. When started using reduced voltage starters:
      1) Provide motors that develop sufficient torque for acceleration to full speed.
   c. NEMA Design B except where driven load characteristics require other than normal starting torque:
      1) In no case shall starting torque or breakdown torque be less than the values specified in NEMA MG 1.
6. Enclosures:
   a. In accordance with the Contract Documents. Specific requirements shall be as follows:
      1) TEFC:
         a) CI conduit box.
         b) Tapped drain holes with Type 316 SST plugs for frames 286 and smaller, and automatic breather and drain devices for frames 324 and larger.
      2) Lifting devices: Motors weighing 100 lbs or more shall have suitable lifting devices for installation and removal.
7. Manufactured with CI frames in accordance with NEMA MG 1 and MG 2 or the Manufacturer’s standard material for the specified rating.
8. Insulation systems:
   a. Motors installed in ambient temperatures 40ºC or less:
      1) Provide Class F insulation.
      2) Design temperature rise consistent with Class B insulation.
      3) Rated to operate at an ambient temperature of 40ºC at the altitude where the motor will be installed.
   b. Motors installed in ambient temperatures between 40ºC and 50ºC:
      1) Provide Class F insulation.
      2) Design temperature rise consistent with Class B insulation.
      3) Rated to operate at an ambient temperature of 50ºC at the altitude where the motor will be installed.
   c. Motors installed in ambient temperatures between 50ºC and 65ºC:
      1) Provide Class H insulation.
      2) Design temperature rise consistent with Class F insulation.
      3) Rated to operate at an ambient temperature of 65ºC at the altitude where the motors will be installed.
9. Motor leads: Insulated leads with non-wicking, non-hydroscopic material. Class F insulation.
10. Noise: Maximum operating noise level in accordance with NEMA MG 1.

M. Motors (Severe Duty) Installed in Corrosive Environments:
1. Nameplate in accordance with IEEE 841.
2. Stator double dipped in varnish and baked.
3. Stator and rotor coated with corrosion resistant epoxy.
4. Frame, brackets, fan guard and conduit box coated with minimum of two coats of epoxy paint.
5. Withstand salt spray tests in accordance with ASTM B 117.

N. Single-Phase Motors:
1. 115 V, 60 Hz, unless otherwise specified in this Section or as shown on the Drawings.
2. TEFC motors manufactured in accordance with NEMA MG 1.
3. Ball bearings: Sealed, prelubricated, anti-friction ball bearings or sleeve bearings suitable for radial and thrust loading.
4. Motors shall be one of the following, dependent on the starting torque and specific operational application:
   a. Capacitor start designed for:
      1) Definite duty cycle, not continuous operation.

        2) High starting torque, approximately 300% to 450% full load torque.
        3) Frequent starts.
    b. Permanent split capacitor start designed for:
        1) High efficiency.
        2) High PF.
        3) Continuous duty.
        4) Starting torque typically 80% of full load amperes.
    c. Capacitor start, capacitor run designed for:
        1) Continuous duty.
        2) High starting torque.
        3) High inertia loads.
        4) Frequent starts.
    d. Fan motors 1/2 hp or less fan motors:
        1) Split-phase or shaded pole type when standard for the equipment.
        2) Open type when suitably protected from moisture, dripping water, and lint accumulation.
5. Wound rotor or commutator type single-phase motors only when their specific characteristics are necessary for application and their use is acceptable to the ENGINEER.
6. Thermal protection: Internal protection to automatically open power supply circuit to motor when winding temperature exceeds a safe value calibrated to temperature rating of motor insulation. Thermal-protection device shall automatically reset when motor temperature returns to normal range.

2.3 ACCESSORIES

A. Motor Winding Temperature Detectors:
1. Provide factory installed motor winding temperature detectors with leads terminating in the motor terminal box:
    a. Three snap-action, bi-metallic, temperature switches embedded in the connection end turns of each phase of the motor winding.
    b. Normally closed contacts wired in series, to open upon excessive winding temperatures.
    c. Temperature switch SP shall be pre-calibrated by the Manufacturer.
    d. Reset of temperature switch shall be automatic upon a decrease in winding temperature.
2. Provide where required in accordance with the Contract Documents or as shown on the Drawings.

B. Motor Connections:
1. High-conductivity, electro-tin plated copper connectors.
2. Male and female motor lead disconnects.
    a. Snap-together.
    b. Compression conductor connections.
3. Overall slip-on insulator over the mated connection and secured with a cable tie.

2.4 FABRICATION

A. Noise:
1. Measured in accordance with NEMA MG 1.
2. Motors controlled by adjustable frequency drive systems shall not exceed sound levels of 3 dBA higher than NEMA MG 1.

B. Balance and Vibration Control: In accordance with NEMA MG 1.

2.5 FINISHES

A. Equipment Finish:
1. Protect motor for service conditions: Outdoor industrial atmospheres, including moisture and direct sunlight exposure.
2. Minimum two coats of epoxy paint.

B. Internal Finish: Bore and end turns coated with clear polyester or epoxy varnish.

PART 3 EXECUTION

3.1 INSTALLATION

A. In accordance with the Manufacturer's instructions and recommendations.
B. Align motor carefully and properly with driven equipment.
C. Secure equipment to the mounting surface with anchor bolts. Provide anchor bolts meeting the Manufacturer's recommendations and of sufficient size and number for the specified seismic conditions.
D. Motor lead connections with products shown on the Drawings, unless otherwise approved by the ENGINEER.

3.2 QUALITY CONTROL

A. Functional test, conduct on each motor:
1. Test complete assemblies for proper alignment; verify that motors have proper rotation.
2. Sound level tests.
3. Final megger of motor from T-leads through motor.
4. Motors:
    a. Visual and mechanical inspection:
        1) Proper electrical and grounding connections.
        2) Blockage of ventilating air passageways.
        3) Operate motor at the designed rotational speed and check for:
            a) Excessive mechanical and electrical noise.
            b) Overheating.
            c) Correct rotation.

            d) Excessive vibration.
    b. Determine that accessories are properly connected and functioning.
    c. Electrical Tests: Measure running current and voltage at designed rotational speed and evaluate relative to load conditions and nameplate FLAs.

B. Factory Testing:
  1. Perform the Manufacturer’s standard production tests including but not limited to:
    a. No load current.
    b. High potential test.
    c. Winding resistance.
  2. Furnish copies of standard test reports on prototype or identical units.

C. Field Testing: Additional testing as specified in SECTION 26 08 00.

3.3 SUPPLEMENTS

A. Supplement A – Motor Data Sheet

END OF SECTION

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SUPPLEMENT A
MOTOR DATA SHEET

MOTOR/ EQUIPMENT TAG ______________ MOTOR NUMBER ______________

SPECIFICATION NUMBER OF DRIVEN MACHINE ______________

MOTOR NAMEPLATE DATA

MANUFACTURER ______ MODEL/SERIES ______ MODEL NO. ______

FRAME ______ ENCLOSURE ______ NEMA DESIGN ______

HP ______ SERVICE FACTOR ______ RPM ______

INSULATION CLASS ______ VOLTS ______ FULL LOAD AMPERES ______

AMBIENT TEMP ______ PHASE ______ NO LOAD AMPERES ______

DESIGN TEMP RISE ______ HERTZ ______ LOCK ROTOR AMPERES ______

INRUSH CODE LETTER ______

	100% LOAD	75% LOAD	50% LOAD	25% LOAD
GUARANTEED MINIMUM EFFICIENCIES:	______	______	______	______
GUARANTEED MINIMUM POWER FACTOR:	______	______	______	______

MAXIMUM SIZE OF POWER FACTOR CORRECTION CAPACITOR: ______ KVAR

ACCESSORIES

MOTOR WINDING HEATER ______ VOLTS ______ WATTS

WINDING THERMAL PROTECTION

WINDING TEMP SWITCHES (YES/NO) ______

RTD:

TYPE ______ QUANTITY PER PHASE ______ # OF WIRES ______

NOMINAL RESISTANCE ______ NOMINAL TEMP ______ COEFFICIENT ______

RECOMMENDED ALARM ______ ºC RECOMMENDED TRIP ______ ºC

SPECIAL APPLICATIONS

INVERTER DUTY* (YES/NO) ______ PART WINDING (YES/NO) ______ WYE - DELTA ______

2 SPEED, 1 WINDING (YES/NO) ______ 2 SPEED, 2 WINDING (YES/NO) ______

AREA CLASSIFICATION:

CLASS ______ DIVISION ______ GROUP ______ TEMP CODE ______

* In accordance with NEMA MG-1 Part 31.

END OF SUPPLEMENT

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SECTION 27 00 00
COMMUNICATIONS SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for communications systems.

B. Related Sections:
1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 26 05 19 – LOW-VOLTAGE CONDUCTORS
4. SECTION 26 43 00 – LOW-VOLTAGE SURGE PROTECTIVE DEVICES

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):
1. 802.3 – Standard for Ethernet

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
1. Itemized Bill of Material including the Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Detailed descriptions of equipment including weights, dimensions, and installation requirements.
4. Complete dimensional plan views indicating sizes and clearances required for equipment.
5. Manufacturer's fiber optic system cut sheets, manuals, and schematics.
6. Conduit/conductor schedule spreadsheet (in XLS/XLSX) and As-Built Drawings in hardcopy and electronic formats, include approximate lengths.
7. Fiber and copper cable mapping, devices, and tag numbers.
8. Testing related Submittals.
   a. Schedule for performing inspection and tests.
   b. References, procedures and equipment to be used for each test.
   c. Test equipment calibration certified documentation.
   d. A sample copy of the equipment and materials inspection test form.

D. Quality Control Submittals:
1. Testing related Submittals.
2. O&M manuals:
   a. Provide preliminary and final manuals.
   b. As specified in SECTION 01 78 23.
   c. Shop Drawing Submittal information.
   d. The Manufacturer's instructions for installation, operation, maintenance, and troubleshooting.
      1) Startup procedures including receiving and installation requirements.
      2) Provide maintenance instructions listing preventive and corrective maintenance procedures.
      3) Provide spare parts data for each item of material and equipment specified.
   e. Factory and field certified test reports.
   f. Conduit/conductor schedule spreadsheet (in XLS/XLSX) and As-Built Drawings in hardcopy and electronic formats, include exact lengths.
   g. Final As-Built Drawings:
      1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         a) Drawings shall be on a standard DW title block and border provided by DW.
         b) As-Builts and Manufacturer's drawings shall be provided:
            (1) On a standard DW provided title block and border.
            (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
            (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
            (4) Titles: 0.2 inches.
   h. Warranty documentation.

E. Extra Materials:
1. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials:
   a. Fuses: A minimum of three of each type and size.
   b. Lamps and LEDs: A minimum of two of each type and size.

1.4 QUALITY ASSURANCE

A. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Established by the CONTRACTOR to facilitate access of equipment to final installation location.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the communications systems and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Racks:
   1. CPI
   2. Great Lakes
   3. Hoffman
   4. Ortronics

B. Fiber Optic Cable Accessories:
   1. Fiber optic connectors:
      a. Commscope
      b. Corning
      c. Panduit
      d. Systimax

C. Fiber Optic Patch Cords:
   1. ST type connector: C2G3650X
   2. LC type connector: C2G 3651X
   3. ST/LC type connectors: C2G 3652X

D. Fiber Optic Electronic Units:
   1. Fiber optic to 10/100 Base T media converters/transceivers:
      a. Allied Telesyn Media Converters AT-FS201-90
   2. Ethernet SCADA hub/switch:
      a. CISCO IE-2000-4TS-G-B (4TX/2SFP)
      b. CISCO IE-2000-8TC-G-B (8TX/2SFP)
      c. CISCO IE-2000-16TC-G-E (16TX/2SFP)
   3. Telephone/data wall jack plate:
      a. LEVITON Quickport
   4. Data patch panel:
      a. 24-port: Panduit CP24688BL
      b. 48-port: Panduit DP24688TGY
   5. Analog to fiber optic transmitter/receiver and power supply:
      a. Ultra Electronics, 2T92, 2R18, 2A56

E. Fiber Optic Cable:
   1. Corning ALTOS Lite Loose Tube, Gel-Free, Single-Jacket, Single-Armored Cable, 6-288 Fibers, Single-mode (OS2)
   2. Corning ALTOS Lite Loose Tube, Gel-Free, Single-Jacket, Single-Armored Cable, 6-288 Fibers, Multi-mode (OM3)
   3. Low-Temperature Applications: Corning ALTOS Low-Temperature, Loose Tube, Gel-Free, Double-Jacket, Single-Armored Cable, 12-288 Fibers, Single-mode (OS2)

F. Fiber Optic Cable Connector Adhesive and Primer:
   1. Henkel, Loctite 648 Anaerobic Adhesive
   2. Henkel, Loctite 7090 Anaerobic Primer, or Loctite 4649

G. Network/Data/Telephone Cable CAT-6:
   1. Belden 7953A

H. Data Cable (RS-485):
   1. Belden 3107A

I. Label Maker:
   1. P-Touch Edge PT-E500

J. OTDR:
   1. Fluke DTX 5000
   2. Noyes M200
   3. Noyes M700

2.2 COMPONENTS

A. Communications Racks:
   1. Miscellaneous rack features:
      a. Wall-mount type.
      b. EIA 310-D compliant rail: 19 inches.
      c. Front swing gate.
      d. Hook and loop type straps.

B. Fiber Optic Patch Panels:
   1. At each fiber optic cable termination, the connectorized fibers shall be integrated into a fiber optic patch panel. The panel shall be of metallic construction with a lockable cover totally enclosing the connectors. The panel shall accept LC and ST type bulkhead connectors.

2. Fiber optic patch panels shall be enclosed within the LCP cabinets and communications racks as shown on the Drawings.
3. Product: As approved by the ENGINEER.

C. Fiber Optic Splice Enclosure:
1. Fiber optic splice enclosures shall not be used.
2. Splice enclosures shall protect the spliced fibers from moisture and damage and provide strain relief for the fiber optic cable and the fibers. At each splicing location, sufficient cable shall be provided to properly rack and splice the cables and allow for additional future splices.
3. Fiber optic splices shall be fusion type only.

D. Fiber Optic Electronic Units:
1. The fiber optic transceiver units shall be located within the specified control panels. The units shall be compatible with the fiber optic cable, panels, cords, and connectors as specified in the Contract Documents.
2. Fiber optic to 10/100 Base T media converters/transceivers: Fiber optic Ethernet transceivers shall be in accordance with IEEE 802.3. Conversion from the fiber optic media to the media required by the communications equipment shall be accomplished through the use of one device; the use of multiple transceivers/converters to perform a single media conversion is not acceptable. The converter/transceiver shall be capable of detecting and reporting link failures at the transceiver. The transceiver shall be supplied with LED indicators for displaying transmit, receive, and collision status.
3. Fiber optic repeaters: Provide power for repeaters if their use is required to meet the requirements of the Contract Documents. At a minimum, the repeater shall regenerate the optical signal at the required transmission rate and be mechanically and optically compatible with the entire fiber optic subsystem; location and installation shall be approved by the ENGINEER.

E. Ethernet SCADA hub/switch:
1. 10-port Simple Network Management Protocol (SNMP) managed Ethernet switch, unless otherwise shown on the Drawings.
2. SNMP managed Ethernet switch:
   a. 10/100 BASE-T Ethernet ports (RJ-45) and two dual-purpose ports, each with a 10/100/1000BASE-T copper port and an SFP (small form-factor pluggable) module slot (LC type connectors).
   b. Eight fast Ethernet TX ports and two combo (TX or SFP) gig Ethernet ports minimum.
   c. Transmission speed 10/100 Mbps on RJ-45 ports.
   d. DIN rail-mounted.
   e. 24 VDC power.

F. Telephone/Data Wall Jack Plate:
1. The wall jack plate shall be capable of being wired for four jacks and shall match nearby electrical cover plates in color and style. SST plates shall be used in industrial areas where cast metal or SST electrical device plates are used.
2. Unused jack openings shall be covered with a flush plug the same color as the plate and made by the same Manufacturer.
3. Shield and drain wires shall be grounded at the patch panel. Ground shield and drain wires at one end.
4. Female telephone jacks on the wall plates: Match nearby electrical device plates in color or white with SST plates.
5. Female data jacks on the wall plates: Orange.
6. Female fax jacks on the wall plates: Match nearby electrical device plates in color or white with SST plates.
7. Female SCADA/process control jacks on the wall plates: Red.
8. Jacks shall be compatible with CAT-6 cable and connectors using 568B pinouts.
9. Each wall plate shall be labeled using nomenclature specified in this Section.
10. Wall plate jacks shall be provided with in-use type covers.

G. Data Patch Panel:
1. Data patch panel shall be rack-mounted type.
2. Jacks on patch panel shall be labeled using ENGINEER-approved nomenclature and labels for TIA/EIA-606-A Compliance.
3. 48-port, Category 6 patch panel with RJ-45, eight-position, eight-wire ports unless otherwise shown on the Drawings.
4. 24-port, Category 6 patch panel with twenty-four pre-installed RJ-45 six channel compliant couplers.

H. Analog to Fiber Optic Transmitter/Receiver and Power Supply:
1. 4 mA to 20 mA to fiber optic.
2. 35 mm din rail-mount.
3. Single mode.
4. 120 VAC/24 VDC.

I. Communications Cable:
1. Fiber optic cables:
   a. Provide and install cables and connectors. The Manufacturer shall design and specify these components:
      1) Each link shall consist of two separate fiber optic cables.
      2) Each cable shall contain the number of strands shown on the Drawings. If not shown on the Drawings, the cable shall contain twice the number of strands required to handle the specified communications functions. A minimum of twelve strands shall be in any cable.
      3) Optical fiber shall be coated with a suitable material to preserve the intrinsic strength of the glass. Fiber shall be protected by a protective tube, a jacketed strength member, and an exterior jacket.

4) Conductors shall be single-mode unless multi-mode is shown on the Drawings, graded index, solid glass waveguides with the following characteristics:
   a) Fiber category: G.652.D.
   b) Fiber code: E.
   c) Wavelengths: 1310 nm / 1383 nm / 1550 nm.
   d) Maximum attenuation: 0.35 dB/km / 0.35 dB/km / 0.25 dB/km.
   e) Nominal core diameter: 50 microns.
   f) Minimum ellipicity: 1.0%.
   g) Outside clad diameter: 125 microns.
   h) Minimum numerical aperture: 0.200.
   i) Single-mode:
      (1) Maximum attenuation (1310 nm): 00.4 dB/km.
      (2) Maximum attenuation (1550 nm): 0.3 dB/km.
   j) Multi-mode:
      (1) Maximum attenuation (850 nm): 3.0 dB/km.
      (2) Minimum bandwidth (850 nm): 2000 MHz*km.
      (3) Maximum attenuation (1300 nm): 1.0 dB/km.
      (4) Minimum bandwidth (1300 nm): 500 MHz*Km.
5) Glass cladding shall be nominally concentric with the fiber core.
6) Each fiber shall be continuous with no factory splices.
7) Mechanical stress present in the cable shall not be transmitted to the optical fibers. The fiber optic cable shall use loose tube construction allowing for thermal expansion and free movement of the fiber within the protective container.
8) Protective coatings in any single length of cable shall be continuous and of the same material. The protective coverings shall be free from holes, splices, blisters, and other imperfections. A flooding compound shall be applied into the interior of the fiber buffer tubes.
9) Strength members shall be an integral part of the cable construction. The combined strength shall be sufficient to support the stress of installation and protect the cable in service.
10) The outer cable jacket shall be made of HDPE.

2. Fiber optic cable accessories:
   a. Fiber optic cable terminations: Fiber optic cable shall be fanned out to allow direct connectorization of the fiber optic cable. Each individual fiber shall be sleeved over with a Kevlar-reinforced furcation tube. At the convergence point of furcation tubes, provide strain relief with a high-density plastic fan-out collar.
   b. Where fiber optic cables are run through EHH, cables shall be supported on EHH walls by an ENGINEER-approved method. An additional 10 foot loop of spare fiber optic cable shall be installed in the EHH.
   c. Fiber optic connectors:
      1) Fibers shall be terminated with an ST and LC type SST or ferrule bayonet keyed connector.
      2) Fiber optic system backbone shall be terminated with SST ST type connectors. The fiber optic system backbone shall be determined and approved by the ENGINEER.
      3) Fiber optic equipment and cable shall use the same type connectors. Connectors shall be installed using a primer and adhesive that provides a robust curing, high temperature performance, and oil tolerance. The connector shall be in accordance with the following:
         a) Attenuation (typical/maximum): 0.3 dB/0.4 dB.
         b) Fiber nominal outside diameter: 125 microns.
         c) Cable nominal outside diameter: 2.4 mm or 3.0 mm.
         d) Loss repeat: Less than 0.2 dB per 1,000 reconnects.

3. Network/data/telephone cable (CAT-6):
   a. Industrial Ethernet cable with the following features:
      1) Four twisted pairs shielded, #24 AWG solid bare annealed copper conductors.
      2) Insulation: Polyolefin.
      3) Outer jacket: Industrial grade CMP.
      4) Suitable applications: Industrial Ethernet cable, harsh environments, 100 MHz CAT-6, RJ-45 compatible, noisy environments, 100Base-TX.
      5) Each cable shall be labeled in visible locations at both ends using the materials and nomenclature specified herein.

4. Data cable (RS-485):
   a. Two twisted pairs, overall 100% shielded, #22 AWG stranded, tinned, copper conductors.
   b. Each cable shall be labeled in visible locations at both ends using the materials and nomenclature specified herein.

2.3 ACCESSORIES

A. Fiber Optic Patch Cords: Patch cords shall be utilized to connect the fibers within the fiber optic patch panel to the fiber optic transmitter and receiver modules. Patch cables shall be 50 microns and possess the attenuation and bandwidth parameters as specified for fiber optic cable plant. Fibers shall be placed in individual tight thermoplastic buffer tubes, protected with Kevlar-strength members, and enclosed with a thermoplastic jacket. Terminate patch cords with LC and ST type connectors.
   1. Optical Multimode 3 (OM3) duplex multimode fiber optic cable. Constructed to support OM3 transmission standards.

2. Multimode fiber construction – 50/125μm diameter core and cladding.
3. Supports up to 10 gigabit transfers and Ethernet communication.
4. Jacket: 1.8 mm OD, low smoke zero halogen, optical fiber nonconductive riser.
   a. LC type connector: Aqua jacket.
   b. ST type connector: Blue jacket.
5. Lifetime warranty.

B. Provide surge protective devices as specfied in SECTION 26 43 00.

PART 3 EXECUTION

3.1 INSTALLATION

A. Communications Cable:
1. Communications fiber optic cable and copper communications cable shall be installed as specified in SECTION 26 05 19, in accordance with the Manufacturer's instructions, and as approved by the ENGINEER.
2. Install cable into wall plates and patch panels in accordance with the Manufacturer's instructions using only tools approved by the Manufacturer.
3. Bundling: When cables run outside of conduit, bundle them together with other cables of the same type throughout their exposed length with plenum hook and loop fasteners, placed at intervals of 24 inches o.c. Use J-hook or Arlington loops every 5 feet to 6 feet with an approved amount of sag. Cable running above suspended ceilings shall be fastened securely to roof joists or other locations approved by the ENGINEER with J-hooks or equivalent means, at a maximum spacing of 6 feet o.c.
4. Cable runs from each jack to the communications distribution equipment shall be pulled as one continuous piece of cable; splicing is not permitted.
5. Data cables shall be bundled together with plenum hook and loop fasteners approved by the ENGINEER.
6. Temporary and permanent outdoor cable that is not in a raceway shall be direct burial and waterproof gel filled Icy-Pick type cable. Typical conductor colors:
   a. Data: Blue.
   b. SCADA/process control: Red.
   c. Telephone/fax: White.

B. Labeling:
1. Provide and install labels for each cable, wall plate, and patch panel:
   a. Cables shall be labeled in visible locations at each end with pre-printed, wrap-around labels.
   b. Cables shall be labeled in visible locations at each pull box condulet and EHH with pre-printed, wrap-around labels.
   c. Wall plates and data patch panels shall be labeled using a label-maker with 1/4 inch black letters on a white background.
   d. Labeling shall be approved by the ENGINEER.
2. Telephone circuits shall be labeled sequentially, assuming the eventual use of two jacks per location. For example, the first telephone location shown on the Drawings would have cable labeled V1 and jacks labeled V1-1 and V1-2 (wires within the cable may eventually be split into two jacks; only one needs to be wired as part of the Work). The second telephone location would have cable labeled V2 and jacks labeled V2-1 and V2-2. Labeling shall be approved by the ENGINEER.
3. SCADA/process control circuits shall be labeled sequentially using nomenclature PC1, PC2, etc. Labeling shall be approved by the ENGINEER.
4. Data circuits shall be labeled sequentially using nomenclature D1, D2, etc. Labeling shall be approved by the ENGINEER.

C. Install communications systems, including telephone and network systems. Coordinate Work with the OWNER and the phone utility.

D. Provide, install, and be responsible for communications between equipment, offices, and areas of the site.

E. Install equipment and materials required by the Contract Documents including, but not limited to:
1. Communications racks, patch panels, switches, routers, hubs, transceivers, converters, conduits, cables, connectors, and wall plates.
2. CAT-6 cable from each telephone and data jack shown on the Drawings to the communications equipment (e.g., a location that contains one phone, one fax, and one data jack will require three CAT-6 cables to be run to the communications distribution equipment).

F. Communications fiber optic cable and copper communications cable shall be provided, terminated, and tested in accordance with the Contract Documents.

G. Work on existing systems shall be coordinated with the OWNER.

H. The complete communications system shall be provided and installed as required by the Contract Documents. The fiber optic system shall provide communications and control for the SCADA PLC/RTU data highway and process Ethernet network both internal and external to the facilities. The fiber optic system shall provide communications and control for the SCADA system between the various areas, equipment, and control rooms.
1. Fiber optic to copper cable, (e.g., RS-485, RJ-11, RJ-45), interface: Cables and devices required for the interconnection between the fiber optic system and the specific system-required cable shall be provided and installed as required. This includes, but is not limited to, connectors, patch panels, power supplies, transceivers, communications ports, I/O racks, and cables. Verify specific system compatibility with the fiber optic system.

I. Provide as noted, install, test, and be responsible for communications between facilities: Fiber optic cable, fiber jumper cable, fiber optic transceivers, multimedia switches, ports, connectors, etc. shall be provided for the new fiber optic infrastructure shown on the Drawings. Include a drawing of the patch panel connections for the OWNER's review during the submittal process.

J. Provide and install equipment and materials required by the Contract Documents including, but not limited to:
   1. Communications racks, patch panels, transceivers, converters, connectors, and wall plates.
   2. Fiber optic and data cable breakout kits, terminations, and testing.

3.2 QUALITY CONTROL

A. An OPM with OTDR shall be used to map fiber runs, including spare fibers, from start to finish to provide a warning of any microbending or other signal loss. The OPM with OTDR shall provide an electronic copy and a hardcopy printout. A hardcopy map of fiber runs shall be submitted to the ENGINEER.

B. Fiber connections shall be checked under a video microscope for optical clarity and tested for insertion loss by a power meter connected on the opposite end to a laser source. Measurements shall be documented and provided to the ENGINEER within 10 days of the test.

C. Data cables shall be tested after they have been terminated. A test report shall be submitted for each data cable and contain, at a minimum:
   1. Cable identification number.
   2. Test summary (pass or fail).
   3. Project name.
   4. Cable location.
   5. Date and time of cable test.
   6. Name of person conducting the test.
   7. Test standard.
   8. Cable type.
   9. Test instrument used.
   10. Length of cable tested.
   11. Propagation delay (ns).
   12. Delay skew (ns).
   13. Impedance (ohms).
   14. Attenuation (dB).
   15. Frequency (MHz).
   16. Limit (dB).

END OF SECTION

SECTION 28 00 00
SECURITY SYSTEM

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for the security system.

B. Related Sections:
   1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   4. SECTION 26 43 00 – LOW-VOLTAGE SURGE PROTECTIVE DEVICES

1.2 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
   1. Itemized Bill of Material including Manufacturer, complete model number, and options included.
   2. Catalog, descriptive and specification information for equipment, components, and devices.
   3. External power and signal connections.
   4. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
   5. The Drawings indicate locations of the door interlocks, keypad, and security control panel. The Drawings provide a one-line diagram to indicate the intended interconnection of the system devices.
   6. Dimensional drawings.
   7. Anchoring instructions and details.
   8. One-line diagrams.
   9. Schematic (elementary) diagrams.
   10. Outline diagrams.
   11. Interconnection diagrams.
   12. Installation Details: Include modifications or further details required.
   13. Spares, expendables, and test equipment.
   14. The Gate Manufacturer's Submittal package consisting of gate elevations, hardware, and installation details.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing Submittal information.
      d. Legend abbreviation lists.
      e. Factory and field certified test reports.
      f. Device O&M manuals for components, electrical devices, and mechanical devices shall include:
         1) Operations procedures.
         2) Installation requirements and procedures.
         3) Maintenance requirements and procedures.
         4) Troubleshooting procedures.
         5) Internal schematic and wiring diagrams.
      g. List of spares and expendables required and recommended.
      h. Final As-Built Drawings:
         1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW title block and border provided by DW.
            b) As-Builts and Manufacturer's Drawings shall be provided:
               (1) On a standard DW provided title block and border.
               (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
               (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
               (4) Titles: 0.2 inches.
   3. Warranty documentation.

E. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% Project completion the following extra materials:
   1. Fuses: A minimum of three of each type, voltage, and current rating installed.
   2. Lamps and LEDs: A minimum of two of each type, voltage, and current rating installed.

1.3 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 consecutive years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Verification that the Electrical Subcontractor will provide and install raceways and conductors.

D. Installation shall be supervised and tested by the System Equipment Manufacturer. Supervisory and testing work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly trained and qualified for the Work.

E. Manufacturer's Services:

1. Provide a Manufacturer's Representative as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
   a. Installation assistance, inspection of installation, and system programming with the OWNER after the system has been installed: 1.
   b. Functional and performance testing: 1.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Upon receipt at the job site, materials shall be checked to ensure that no damage occurred during shipping or handling.

B. Materials shall be stored in such a manner to ensure proper ventilation and drainage, and to protect against damage, weather, vandalism, and theft.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 18 months from the Substantial Completion date for the satisfactory performance and installation of the security system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Security System:

1. Hirsch by Identiv: The system shall be designed, coordinated, and supplied by the system Manufacturer or its authorized agent who is regularly engaged in the business of designing and installing security systems.

B. Door Locks:

1. Best Access Systems, Model 35HW-EWEU-RQE electrified mortise lock

C. Electric Hinge:

1. SDC PTH-4Q
2. HES, Model SB:1006-12/24D-630-LBM

D. Miniature End of Line Modules:

1. Hirsch by Indetiv, MELM3

E. Armored Door Contact:

1. NASCOM N505AU/ST

F. Recessed Door Contact:

1. GE/Sentrol, 1078C-G

G. Earth Magnet:

1. GE/Sentrol, SR-1840N

H. Security Keypad:

1. Hirsch by Identiv Model DS47L-SSP-TS-HL Scramble Pad Reader
2. Hirsch by Identiv, Inc., Model T100, Advanced Reader

I. Security Panels:

1. Hirsch by Identiv, M8N Model 2 with 24 VDC power supply
2. Hirsch by Identiv, Model MX4 with 24 VDC power supply

J. Security Cameras:

1. Outdoor PTZ applications (all outdoor cameras on-site except gate camera):
   a. Camera housing:
      1) Axis – P3807-PVE Network Camera
      2) Q3709-PVE Network Camera with T91G61 Mount
   b. Mount:
      1) Axis T94P01B or other T91/T94 series mount based on application
2. Outdoor fixed applications (gate camera):
   a. Camera/housing:
      1) AXIS P3807-PVE Network Camera for 180-degree pivot
      2) AXIS P3719-PLE Network Camera for 360-degree pivot
   b. Pole mount:
      1) AV-PMA
      2) AV-WMJB
      3) SO-CAP
   c. Surge protector:
      1) Axis T8061 Ethernet Surge Protector
      2) Vigitron Vi2001 Ethernet Surge Protector

3. Indoor applications:
    a. Camera:
        1) Axis P1435-LE Network Camera
    b. Surge protector:
        1) Vigitron Vi2001 Ethernet Surge Protector

K. Gate Sensing Loops:
    1. BD Loops # EL44-60.

L. Electric Strikes:
    1. HES 1006 Series

2.2 COMPONENTS

A. Individual Device Specifications:
    1. Door locks, hinges, line modules, and contacts:
        a. The door locks shall be provided and installed as shown on the Drawings and as recommended by the Manufacturer. The door locks (core housing, lever style, trim style, finishes, and handing shall be coordinated with the Contract Documents to provide complete and functional security system doors).
        b. The electric strikes shall be provided and installed as shown on the Drawings and as recommended by the Manufacturer. The electric strikes (voltage, housing, trim style, finishes, and handling) shall be coordinated with the Contract Documents to provide complete and functional security system doors.
        c. The electric hinges shall be provided and installed as shown on the Drawings and as recommended by the Manufacturer.
        d. The miniature line modules shall be provided and installed as shown on the Drawings and as recommended by the Manufacturer.
    2. Security keypads: Security high intensity door keypads shall have an alphanumeric display capable of providing complete messages during all stages of operation and programming of the system, and display relevant operating and test data. The keypad shall be capable of arming and disarming any portion of the security system based on P.I.N. authorization.
    3. Security control panels:
        a. The security panel shall be capable of monitoring a minimum of eight zones.
        b. Interface cables between the panel, keypads, door contacts, and door locks shall be provided and installed as shown on the Drawings, as recommended by the Manufacturer, and as approved by the ENGINEER.
        c. The panel shall have a minimum of 2 spdt, 5 A rated output relays. One alarm relay contact shall provide an alarm input to the control system when any zone is alarmed.
        d. The security panel shall allow authorized users to enter, change, or delete the daily on and off schedules for the output relays and to establish permanent opening and closing schedules for each day of the week.
        e. The keypad in the security door system shall be provided with entry and exit delay, adjustable from 0 seconds to 250 seconds.
        f. When a zone is entered, its associated keypad shall sound a pre-warn tone and shall display an enter code message on its alphanumeric display. If a valid code is not entered prior to the expiration of the entry delay, an alarm shall be transmitted to the plant control system. When the above zone is exited, an exit delay shall be displayed and counted down on its associated keypad's alphanumeric display. If the zone is in an alarm condition at the expiration of the existing delay, the entry delay sequence shall commence immediately.
        g. SPD: As specified in SECTION 26 43 00.
    4. Security cameras:
        a. 12 VDC, IP PTZ cameras capable of rotating 180 degrees.
        b. Outdoor applications: Accessories shall include heater and fan options.
    5. Security gate: Two security keypads shall be provided to control and operate the gate.

B. Gate Sensing Loops:
    1. Verify compatibility and interface with the existing gate operator and new security system.
    2. Solid 16 AWG ridged loop wire designed for superior performance.
    3. Pre-phased.
    4. Minimum required lead wire to reach controller with soldered connections.
    5. Lead wires installed in 1/2 inch PVC-coated RGS conduit.
    6. Entrance and exit loops installed following the Manufacturers recommendations.

PART 3 EXECUTION

3.1 INSTALLATION

A. The system shall be installed by the Electrical Subcontractor with the conduits, conductors, outlet boxes, fittings, connectors, and accessories necessary to ensure a complete, operable system in compliance with applicable codes and regulations.

B. Wiring shall be installed in conduit or within equipment. Conductor within equipment enclosures shall be carefully cabled and laced. Individual conductors shall be tagged indicating circuit number and type. Markers shall be used on equipment at each outlet or pull box and at each equipment enclosure. Install equipment in accordance with NEMA ICS 2.3, Submittal Drawings, and Manufacturer's instructions and recommendations.

C. Install equipment plumb and in longitudinal alignment with pad or wall.

D. Coordinate terminal connections with the installation of cables.

E. Coordinate with DW security personnel for terminations and programming.

F. When a gate operator is installed coordinate with the Fencing Subcontractor and Electrical Subcontractor for proper installation and commissioning.

3.2 QUALITY CONTROL

A. Verify wiring, installation, and identification.

B. Inspect support and grounding connection.

C. Verify proper system operation.

D. Provide installation certification.

END OF SECTION

SECTION 28 46 00
FIRE ALARM SYSTEM

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for fire alarm systems.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
4. SECTION 26 05 19 – LOW-VOLTAGE CONDUCTORS
5. SECTION 26 43 00 – LOW-VOLTAGE SURGE PROTECTIVE DEVICES

1.2 REFERENCES

A. International Code Council (ICC):

1. International Building Code (IBC)

B. International Organization for Standardization (ISO):

1. 9001 – Quality Management Systems – Requirements

C. National Fire Protection Association (NFPA):

1. 70 – National Electrical Code (NEC)
2. 72 – National Fire Alarm and Signaling Code

D. Underwriters Laboratories, Inc. (UL):

1. 268A – Smoke Detectors for Duct Application

1.3 DEFINITIONS

A. Fire Department: Authority Having Jurisdiction

1.4 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:

1. Itemized Bill of Material including the Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. External power and signal connections.
4. Scaled drawings showing exterior dimensions and locations of electrical and mechanical interfaces.
5. Dimensional drawings.
6. Anchoring instructions and details.
7. One-line diagrams.
8. Schematic (elementary) diagrams.
9. Outline diagrams.
10. Detailed interconnection diagrams. Use Contract Document conduit and conductor tags.
11. Battery and battery charger sizing and respective device voltage drop calculations.
12. Installation details: Include modifications or further details required.
13. Spares, expendables, and test equipment.

D. Quality Control Submittals:

1. Testing related Submittals.
2. O&M manuals:
    a. Provide preliminary and final manuals.
    b. As specified in SECTION 01 78 23.
    c. Shop Drawing Submittal information.
    d. Legend abbreviation lists.
    e. Final As-Built Drawings and wiring diagrams.
    f. Factory and field certified test reports.
    g. Battery sizing and battery charger respective device voltage drop calculations.
    h. Shop Drawing information.
    i. Device O&M manuals for components, electrical devices, and mechanical devices shall include:
        1) Operation procedures.
        2) Installation requirements and procedures.
        3) Maintenance requirements and procedures.
        4) Troubleshooting procedures.
        5) Internal schematic and wiring diagrams.
    j. Fire permit signed by the authority having jurisdiction.
    k. Warranty information including requirements, exclusions, and warranty effective dates.
    l. System startup, training, and commissioning details and requirements.
    m. Signed Manufacturer's certificate of proper installation form.
    n. List of spares and expendables required and recommended.

o. Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
   1) Drawings shall be on a standard DW title block and border provided by DW.
   2) As-Builts and Manufacturer's drawings shall be provided:
      a) On a standard DW provided title block and border.
      b) With the drawing graphics and text, assigned to a pen 2 color (yellow).
      c) Text: Minimum 0.1 inches, maximum 0.2 inches.
      d) Titles: 0.2 inches.

p. Warranty documentation.

E. Extra Materials:
   1. Submit spare parts for products installed as detailed in this Section.
   2. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver prior to 75% Project completion the following extra materials:
      a. Fuses: A minimum of three of each type and size.
      b. Lamps and LEDs: A minimum of two of each type and size.
      c. Required software, hard keys, and equipment necessary to maintain, modify, and troubleshoot the fire alarm system.

1.5 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 consecutive years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark unless otherwise approved by the ENGINEER.

C. The Manufacturer shall provide a certificate of ISO 9001 compliance.

D. Installation shall be supervised and tested by the System Equipment Manufacturer. The supervisory and testing Work shall be performed by skilled technicians under the direction of experienced engineers, all of whom shall be properly trained and qualified for the Work.

E. Manufacturer's Services: Provide a Manufacturer's Representative as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
   1. For installation assistance and inspection of installation: 1.
   2. For functional and performance testing: 1.
   3. For post-startup training of the OWNER's personnel. Training shall not commence until an accepted detailed lesson plan for each training activity has been reviewed by the ENGINEER: 1.

1.6 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.7 WARRANTY

A. Manufacturer: Warranty for 18 months from the Substantial Completion date for the satisfactory performance and installation of the fire alarm system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Control Panel:
   1. Notifier, NFS2-320-SYS

B. Manual Stations:
   1. Notifier, NBG-12LX

C. Smoke Detectors:
   1. Notifier, FSP-851/B210LP

D. Duct Detectors:
   1. Notifier, DNR/FSP-851R

E. Remote Test Stations:
   1. Notifier, RTS151

F. Heat Detectors:
   1. Notifier, FST-851

G. Horn/Strobe Combination:
   1. Notifier, P2WL
   2. Notifier, SWL, strobe only

H. Control Relay Module:
   1. Notifier, FRM-1

I. Addressable Monitor Module:
   1. Notifier, FMM-1

J. Annunciator Panel:
   1. Notifier LCD2-80

K. Alarm Communicator:
   1. Notifier, UDACT-2

L. Gateway:
1. Notifier, NFN-GW-EM-3
M. Drawing Storage Box:
1. SDI Fire SAE60-DSB

2.2 COMPONENTS

A. General:
1. The system shall be Class A, addressable, supervised circuits, operating on 24 VDC and shall include a standby battery and automatic battery charger.
2. Equipment shall be UL listed and bear the UL label.

B. The fire alarm system shall consist of the necessary hardware and software equipment to perform the fire alarm and detection operations.

C. Furnish and install fire alarm system equipment as defined by the Contract Documents, to be wired, connected, and left in first-class operating condition.

D. Control Panels:
1. Surface-mounted in a NEMA 12 enclosure with exterior metal, finished fire engine red with a hinged door with a cylinder lock. The door shall contain full width viewing windows allowing visual identification of the various modules, their pilot lights, etc. Equip the interior with rail/bracket mounting channels for the modules.
2. An annunciator panel with the following display and associated keys:
   a. Fire alarm (LED), alarm acknowledge (key).
   b. System supervisory (LED), supervisory acknowledge (key).
   c. System trouble (LED), trouble acknowledge (key).
   d. Alarm silenced (LED), alarm silence (key).
   e. AC power (LED), system reset (key).
3. An 80-character backlit LCD screen shall display normal status, time, and date during normal conditions. The screen shall display the alarm conditions in chronological order of occurrence. The entry of the appropriate acknowledge key shall silence the local audible alarm. Subsequent entry of key shall chronologically scroll through the specifics for each abnormal condition. Additional keys for expanded operator function and programming shall be concealed behind the lockable door.
4. The battery module for the system shall consist of a 24 VDC battery set of the sealed gelled electrolyte type rated to provide 120% of the system requirements. The standby battery shall have sufficient capacity to operate the entire system for a period of at least 1 day with no outside source of power. Capacity shall include the operation of alarm horns and flashing lights for a period of 10 minutes during any portion of the 1-day period.
5. Provide auxiliary alarm and trouble contacts as follows:
   a. One alarm contact per zone.
   b. One trouble contact per zone.
   c. One common trouble contact.
6. Protective devices for low-voltage electrical power circuits: As specified in SECTION 26 43 00.

E. Annunciator panels shall be the recess-mounting type and shall be the lamp-only type. Zone alarm and trouble signals shall have their individual indicating lights with designator nameplates. An alarm buzzer and silence switch shall be provided. A lamp test feature shall be provided.

F. Fire Alarm System Building Plan Drawing: Provide and install a laminated, framed fire alarm system building plan drawing including, but not limited to, devices, equipment, zones, building details, etc.

G. Manual stations shall be dual action with normally open, SPST contact. They shall be surface-mounted, finished fire engine red with white lettering. The pull-down operating slider shall lock in position after releasing a spring-loaded contact switch. The front cover of the station shall be provided with a keylock for resetting.

H. Smoke Detectors:
1. Photoelectric type. Provide dual contacts, one for alarm and one for a pilot light mounted on the housing to indicate alarm. Provide a pulsing power-on LED indicator.
2. Remote lights shall be provided as required by the local jurisdiction and as shown on the Drawings.

I. Photoelectronic duct detectors shall be in accordance with UL 268A.

J. Wire:
1. As specified in SECTION 26 05 19.
2. Wire for smoke detectors shall be No. 18 twisted pair, 300 V insulated.
3. Wire for horn/strobe combination shall be XHHW #14 AWG, 600 V insulated.
4. Color code DC wiring throughout the entire length of each conductor in accordance with the Manufacturer's recommendation.
5. Do not use phase color tape.

PART 3 EXECUTION

3.1 GENERAL

A. Work shall be in accordance with ICC IBC, NFPA 70 and NFPA 72.

3.2 QUALITY CONTROL

A. Field Testing:
1. After wiring is installed and before connection of solid-state equipment, megger each conductor from conductor to ground and between conductors in each run with a 500 VDC megger. Demonstrate that insulation resistance measurements obtained this way are in excess of 25 megohms.
2. Connect equipment and demonstrate its operation in accordance with the Contract Documents.

3. Activate or simulate alarm conditions and functional and demonstrate that the entire system operates in accordance with the Specifications.
4. After satisfactory completion of the tests, replace the elements of heat detectors that were operated.
5. Provide 8 hours of OWNER training from a factory-certified representative.

B. System Operation:
1. Normal periods:
   a. The system shall maintain a state of readiness to receive a trouble or alarm signal from any station or automatic detector.
   b. Supervision shall be maintained by a constant DC current, controlled by the end-of-line resistor in each zone and alarm circuit. When the current is interrupted by an open circuit or reduced by an unacceptable resistance, the system's trouble light shall turn on, a trouble signal shall sound, the auxiliary trouble contact shall close, and the troubled circuit shall be identified on the screen of the control panel. The trouble bell shall sound until the silencing key is operated.
   c. A battery charger driven by commercial power shall be provided to automatically maintain the battery at 95% full charge.
2. Loss of commercial power:
   a. Loss of commercial power shall cause the fire alarm system to automatically connect the standby battery and disconnect the 24 VDC output of the power supply to maintain operation of the system under battery power for at least 1 day.
   b. The trouble bell shall sound and the auxiliary trouble contact shall close until the silencing key is operated.
   c. Upon restoration of commercial power, the system shall automatically reset to the normal state as specified above and the trouble bell shall sound until the silencing key is operated.
3. Alarm mode:
   a. An alarm received from an automatic detector or manual station shall cause the system to sound every horn and activate every strobe in the building, sound the alarm in the control panel, turn on the fire alarm LED, and display the alarm condition on the LCD screen.
   b. The appropriate auxiliary alarm contact shall close upon alarm initiation.
4. Resetting after alarm:
   a. Smoke detectors shall automatically reset when products of combustion are no longer present.
   b. Manual stations shall be manually reset by use of a key to open the box front allowing resetting of the manual station.
   c. The control panel annunciator shall be reset by the operation of the alarm acknowledge key on the panel.

END OF SECTION

SECTION 31 01 01
SITE RESTORATION AND CLEANUP

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for site restoration and cleanup.

1.2 QUALITY ASSURANCE

A. System Description:

1. Design requirements: Perform site rehabilitation and restoration as soon as possible after Work activity.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 PREPARATION

A. Dust Prevention: Give unpaved streets, roads, detours, or haul roads used in the Work area a dust-preventive treatment approved by the OWNER or periodically water to prevent dust. Follow applicable environmental regulations for dust prevention.

3.2 REPAIRS

A. Keep construction areas clean and orderly.

B. Stockpile excavated materials in a manner that will cause the least damage to adjacent lawns, grassed areas, agricultural crops, shrubbery, livestock enclosures, driveways, and fences regardless of whether on private property or on public ROWs.

C. Assume full responsibility for the consequences of excavation and street cuts. Comply with the requirements of street cut and ROW permits.

D. Replace pavement and damaged curbs and gutters in accordance with asphalt and concrete Specifications and permit requirements. Replace asphalt across trench sections prior to re-opening the street.

E. Replace damaged driveways to an equal to, or better than, condition. Saw cut damaged pavement or curbs and gutter as required for replacement.

F. Re-open existing drainage ditches and culverts and restore the grade and natural drainage as soon as possible after disturbance. Restore broken or damaged culverts to original condition and location.

G. Restore existing landscape irrigation and appurtenances to original grade and condition. Restore sprinklers, piping, and other broken or damaged irrigation structures to original condition and location.

H. Restore landscaped and grassed areas damaged by construction activities to a condition equal to or better than that immediately prior to construction. Care for restored areas until growth is established.

I. Restore porous brick pavement to the original grade and condition.

J. Re-grade, rake, and drag disturbed areas leaving them free from rocks, gravel, clay, or any other foreign material and in suitable condition for re-vegetation upon completion of the pipeline installation. Remove temporary structures, temporary fencing, rubbish, and waste materials. Grade disturbed areas to blend in with abutting undisturbed property. The finished surface shall be free-draining and free from holes, ruts, rough spots, or other surface features detrimental to the road shoulder and borrow ditch areas.

3.3 CLEANING

A. Road Clean-Up During Work: Thoroughly clean spilled dirt, gravel, or other foreign material caused by the Work operations at the conclusion of each day’s operation.

B. Prior to the Substantial Completion date, repair damage caused by equipment and leave the site free of debris or excess material of any sort.

C. Maintain the site, partially finished structures, material stockpiles, and other like areas in a reasonable state of order and cleanliness.

D. If the CONTRACTOR fails to perform cleanup, it may be performed by the OWNER at the CONTRACTOR’s expense.

END OF SECTION

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SECTION 31 05 19
GEOTEXTILES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for geotextiles.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 31 23 33 – TRENCH BACKFILL

1.2 REFERENCES

A. American Association of State Highway Transportation Officials (AASHTO):

1. M 288 – Standard Specification for Geosynthetic Specification for Highway Applications

B. ASTM International (ASTM):

1. D 4355 – Standard Test Method for Deterioration of Geotextiles by Exposure to Light, Moisture, and Heat in a Xenon Arc-Type Apparatus
2. D 4491 – Standard Test Methods for Water Permeability of Geotextiles by Permittivity
3. D 4533 – Standard Test Method for Trapezoid Tearing Strength of Geotextiles
4. D 4632 – Standard Test Method for Grab Breaking Load and Elongation of Geotextiles
5. D 4751 – Standard Test Methods for Determining Apparent Opening Size of a Geotextile
6. D 4873 – Standard Guide for Identification, Storage, and Handling of Geosynthetic Rolls and Samples
7. D 6241 – Standard Test Method for Static Puncture Strength of Geotextiles and Geotextile-Related Products Using a 50-mm Probe
8. D 6461 – Standard Specification for Silt Fence Materials
9. D 6913 – Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

C. Colorado Department of Transportation (CDOT):

1. Standard Specification for Road and Bridge Construction

1.3 DEFINITIONS

A. Apparent Opening Size: A property which indicates the approximate largest particle that would effectively pass through the geotextile.

B. Geosynthetic: A planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system.

C. Geotextile: A permeable geosynthetic comprised solely of textiles.

D. Grab Test: A tension test in which only a part of the width of the specimen is gripped in the clamps.

E. MARV (Minimum Average Roll Value): A QC tool used to allow Manufacturers to establish published values such that the user/purchaser will have a 97.7% confidence the property in question will meet published values. For normally distributed data, MARV is calculated as the typical value minus 2 standard deviations from documented QC test results for a defined population from one specific test method associated with one specific property.

F. Non-destructive Sample: A representative sample of finished geotextile, prepared for testing without the destruction of the geotextile.

G. Nonwoven Geotextile: A fabric produced by the bonding and/or interlocking of fibers by mechanical, thermal, or chemical means to create a pervious sheet of polymeric fibers with a uniform random fiber pattern.

H. Overlap: The distance measured perpendicular from the overlapping edge of one sheet to the underlying edge of the adjacent sheet.

I. Permittivity: The volumetric flow rate of water per unit cross-sectional area per unit head under laminar flow conditions, in the normal direction through a geotextile.

J. Woven Geotextile: A fabric composed of polymeric yarn interlaced to form a planar structure with a uniform weave pattern where the elements pass each other usually at right angles and one set of elements is parallel to the fabric axis.

1.4 SUBMITTALS

A. Product Data:

1. Geotextile: Manufacturer, product name, chemical composition.
2. Manufacturer's application chart for selected geotextile.
3. Manufacturer's installation recommendations:
   a. Overlap recommendations.
   b. Stapling/securing recommendations.
4. Appurtenant materials: Securing materials.

B. Shop Drawings:

1. Application specific installation Drawings:
   a. Geotextile sheet layout.
   b. Overlap dimensions, pattern for staples or pins, and direction and location of seams.
2. CONTRACTOR's installation methods:
   a. Description of the proposed method of geotextile deployment.
   b. Seaming procedures: Sewing equipment, sewing methods, and provisions for holding geotextile temporarily in place until it is permanently secured.
   c. For field sewn seams, submit the seam assembly description including seam type, stitch type, sewing thread type, and stitch density.

C. Samples, if requested by the ENGINEER:
1. Geotextile sample.
2. Sewn seams:
a. Field sewn seams: Provide a 6 foot length of sewn seam for sampling prior to geotextile installation.
b. Factory seams: Random samples taken off rolls to be used for Project.

D. Certifications: The Manufacturer’s certificate stating the furnished geotextile meets the MARV requirements of the specification as evaluated under the Manufacturer’s QC program.

1.5 QUALITY ASSURANCE

A. Geotextiles for the following applications are covered in this Section:
1. Drainage.
2. Separation.
3. Stabilization.
4. Silt fence.
5. Pavement reinforcement fabric.

B. This Section does not cover geogrids, geocomposites, geomembranes, rolled erosion control products, landscape fabrics, or turf reinforcement products.

C. Manufacturer’s QC Program: Maintain a QC program to ensure compliance with the requirements of the specification. Documentation shall be made available upon request.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Labeling, shipment, and storage of geotextiles shall be in accordance with ASTM D 4873. Product labels shall clearly show the Manufacturer or the Supplier name, style name, and roll number. Each shipping document shall include a notation certifying the material is in accordance with the Manufacturer’s certificate.

B. Each geotextile roll shall be wrapped with a material that protects the geotextile, including the ends of the roll, from damage due to shipment, water, sunlight, and contaminants. The protective wrapping shall be maintained during periods of shipment and storage.

C. Store rolls off the ground.

D. During storage, protect rolls from site construction damage, extended UV radiation (including sunlight), chemicals, flames (including welding sparks), and temperatures above 160°F or below -22°F.

PART 2 PRODUCTS

2.1 MATERIALS

A. Subsurface Drainage/Filtration:
1. General:
a. Includes geotextiles placed against soil to retain the in situ soil and allow for long-term passage of water into a subsurface drain.
b. The material properties of the geotextile selected for this use requires an assumption of the percentage of fines in the in-place soil, which is the percentage of soil passing the No. 200 sieve (0.075 mm sieve size) in accordance with ASTM D 6913.
c. Requirements given represent the MARV in the weaker principal direction, except for the apparent opening size, which is the maximum average roll value.
2. Geotextile strength (survivability) class:
a. Class 2 geotextiles in accordance with AASHTO M 288, Table 1; strength properties include the following:
1) ASTM D 4632: Grab strength, sewn seam strength.
2) ASTM D 4533: Tear strength.
3) ASTM D 6241: Puncture strength.
b. Woven or nonwoven textiles are acceptable but shall be recommended by the Manufacturer for the intended use.
3. Additional properties, in accordance with AASHTO M 288, required for Class 2 geotextiles for use in subsurface drains and for filtration include the following:

Table 1

Name	**Test Method**	**Units**	**Requirements In-Place Soil <15% Fines**	**Requirements In-Place Soil 15% to 50% Fines**	**Requirements In-Place Soil >50% fines**
Permittivity	ASTM D 4491	sec^{-1}	0.5	0.2	0.1
Apparent Opening Size	ASTM D 4751	mm	0.43	0.25	0.22, unless Plasticity Index (PI) >7 then use 0.30
UV Stability (retained strength)	ASTM D 4355	%	50% after 500 hours of exposure	50% after 500 hours of exposure	50% after 500 hours of exposure

B. Separation:
1. General:
a. Includes geotextiles placed to prevent the mixing of two dissimilar materials where water seepage through the geotextile is not a critical function, such as the separation of a subgrade soil with an aggregate cover material.

b. Property requirements given represent the MARV in the weaker principal direction, except for the apparent opening size which is the maximum average roll value.

2. Geotextile strength (survivability) class from AASHTO M 288:
   a. Woven or nonwoven textiles are acceptable but shall be recommended by the Manufacturer for the intended use.
   b. The required geotextile class shall be determined from Table 2.
   c. Geotextile strength requirements for separation geotextiles, in accordance with AASHTO M 288, shall include the following:

Table 2

Subgrade Condition	**Low Ground Pressure Equipment ≤3.6 psi**	**Medium Ground Pressure Equipment >3.6 psi to ≤7.3 psi**	**High Ground Pressure Equipment >7.3 psi**
Subgrade smooth and level, cleared of major obstacles, no humps/depressions over 18 inches; 6 inch to 12 inch initial lift thickness	Class 3	Class 2	Class 1
12 inch to 18 inch initial lift thickness	Class 2	Class 1	Do not use

3. Additional required properties, in accordance with AASHTO M 288, for separation fabrics shall include the following:
   a. Permittivity in accordance with ASTM D 4491: 0.02 sec^{-1}.
   b. Apparent opening size in accordance with ASTM D 4751: 0.60 mm.
   c. UV stability, retained strength in accordance with ASTM D 4355: 50% after 500 hours of exposure.
4. Exception: For geosynthetics required by the City of Denver in backfill in trench cuts, the following standards are required:
   a. Minimum grab tensile strength in accordance with ASTM D 4632: 220 lb.
   b. Minimum water flow rate in accordance with ASTM D 4491: 4.0 gpm/sf.
   c. Minimum permeability in accordance with ASTM D 4491: 0.008 cm/sec.

C. Stabilization:
1. General:
   a. Includes geotextiles used over wet, saturated subgrades (by virtue of high groundwater or prolonged periods of wet weather) to provide separation and filtration functions between an overlying layer.
   b. Property requirements given represent the MARV in the weaker principal direction, except for the apparent opening size which is the maximum average roll value.
2. Geotextile strength (survivability) class in accordance with AASHTO M 288:
   a. Class 1 geotextiles.
   b. Woven or nonwoven textiles are acceptable but shall be recommended by the Manufacturer for the intended use.
3. Additional required properties, in accordance with AASHTO M 288, shall include the following:
   a. Permittivity in accordance with ASTM D 4491: 0.05 sec^{-1}.
   b. Apparent opening size in accordance with ASTM D 4751: 0.43 mm.
   c. UV stability, retained strength in accordance with ASTM D 4355: 50% after 500 hours of exposure.

D. Permanent Erosion Control:
1. General:
   a. Includes geotextiles used between energy absorbing armor systems and the in situ soil to prevent soil loss resulting in excessive scour and to prevent hydraulic uplift pressures causing instability of the permanent erosion control system.
   b. The material properties of the geotextile selected for this use requires an assumption of the percentage of fines in the in situ soil, which is the percentage of soil passing the No. 200 sieve (0.075 mm sieve size) in accordance with ASTM D 6913.
   c. The minimum property requirements given represent the MARV in the weaker principal direction, except for the apparent opening size which is the maximum average roll value.
2. Geotextile strength (survivability) class in accordance with AASHTO M 288:
   a. Class 2 geotextiles required: For geotextiles with less than 50% elongation, typically wovens, except for woven silt film geotextiles are not allowed.
   b. Class 1 geotextiles required: For geotextiles with greater than 50% elongation, typically nonwovens.

3. Additional required properties, in accordance with AASHTO M 288, for use in permanent erosion control shall include the following:

Table 3					
Name	**Test Method**	**Units**	**Requirements In-Place Soil <15% Fines**	**Requirements In-Place Soil 15% to 50% Fines**	**Requirements In-Place Soil >50% fines**
Permittivity	ASTM D 4491	sec^{-1}	0.7	0.2	0.1
Apparent Opening Size	ASTM D 4751	mm	0.43	0.25	0.22, unless PI>7 then use 0.30
UV Stability (retained strength)	ASTM D 4355	%	50% after 500 hours of exposure	50% after 500 hours of exposure	50% after 500 hours of exposure

E. Temporary Silt Fence:
   1. General:
      a. Includes geotextiles used as a vertical, permeable interceptor designed to remove suspended soil from overland water flow. The function is to filter and allow the settlement of sediment soil particles from sediment-laden water.
      b. Materials shall be in accordance with CDOT Section 208.

F. Paving Reinforcement Fabric:
   1. General:
      a. Geotextiles that are saturated with asphalt cement and used between pavement layers shall act as a waterproofing and stress relieving membrane.
      b. Paving fabrics shall be either a Type I or Type II fabric in accordance with AASHTO M 288.

G. Appurtenances:
   1. Staples:
      a. Galvanized steel wire.
      b. 0.091 inch or larger in diameter.
      c. U-shaped, with legs 6 inches long and a 1-inch crown.
   2. Securing pins and washers:
      a. Galvanized steel, 12 inches long.
      b. 3/16 inch diameter.
      c. Pointed on one end, headed on the other end to retain washer.
      d. 1/8 inch thick washer designed to fit securing pin.
   3. Seam thread (for sewn seams):
      a. High-strength PP or polyester.
      b. No nylon thread.
      c. Contrasting color to geotextile.
      d. For erosion control applications: Resistant to UV radiation.
   4. Silt fence appurtenances:
      a. Wood, steel, or synthetic posts having a minimum length of 3 feet plus the burial depth needed.
      b. Wire or polymer support fences shall be meet the same UV degradation requirements as the geotextile. Support fences shall be at least 30 inches high and strong enough to support applied loads. Wire fences shall have at least 6 horizontal wires a minimum thickness of 14 gauge.

PART 3 EXECUTION

3.1 PREPARATION

A. Do not place geotextile prior to obtaining the ENGINEER's approval of underlying materials.

B. The graded surface to receive geotextile shall be smooth and free of debris. There shall not be void spaces between the geotextile and the underlying substrate.

C. Limit atmospheric exposure of the geotextile following lay down to a maximum of 14 days.

D. Do not place geotextile when weather conditions, in the opinion of the ENGINEER, are not suitable to allow proper placement or installation. This will normally be at times of wet conditions, heavy rainfall, extreme cold or frost conditions, or extreme heat.

E. Laydown of Geotextile:
   1. Lay and maintain geotextile smooth and free of tension, folds, wrinkles, or creases.
   2. On curves, the geotextile may be folded or cut and overlapped to conform to the curve. If site conditions require geotextile seaming, the geotextile shall be cut and seamed on the curve.
   3. The geotextile shall not be dragged across the subgrade.

3.2 INSTALLATION

A. Drainage Geotextile Installation in Trenches:
   1. Place and secure the geotextile loosely in the trench with sufficient slack for the geotextile to contact the trench sides and bottoms when fully backfilled.
   2. Successive sheets of geotextiles shall be overlapped as recommended by the Manufacturer, but at least 12 inches.
   3. Overlap the geotextile in the direction of flow, with the upstream sheet overlapping the downstream sheet.
   4. Place drainage aggregate immediately following placement of the geotextiles. Backfilled aggregate shall not be dropped from a height greater than 3 feet.
   5. Where a pipe is not used, cover the geotextile with at least 12 inches of aggregate prior to compaction. If a drainage pipe is used, install pipe as shown on the Drawings and as specified in SECTION 31 23 33. Compact aggregate material as specified in SECTION 31 23 33.
   6. Fold geotextile over the top of the compacted drain material sufficient to produce a minimum overlap of 12 inches, unless otherwise shown on the Drawings; secure overlap.
   7. Unless otherwise shown on the Drawings, place and compact earthfill over the drain/pipe zone as specified in SECTION 31 23 33. Follow the Manufacturer's recommendations for the thickness of the first lift over the geotextile to avoid damage during compaction.

B. Separation/Stabilization Geotextiles:
   1. Roadway installations:
      a. Inspect the area to receive geotextile and identify soft or unsuitable subgrade areas. Excavate and backfill these areas with select material and compact using normal procedures.
      b. Place geotextile in the direction of construction traffic, overlapping as shown on the Drawings. Use the overlap and stapling pattern recommended by the Manufacturer for the site condition encountered. The minimum overlap for non-sewn seams shall be 12 inches except for non-sewn roll ends which shall have a 3 foot overlap.
      c. The ENGINEER will inspect the geotextile prior to covering.
      d. Place the cover material by end dumping onto the geotextile from the edge, or over previously placed aggregate. Do not drop cover material on an unprotected geotextile from a height more than 3 feet.
      e. The aggregate shall be placed such that at least the minimum specified lift thickness shall be between the geotextile and the equipment tire/tracks at all times.
      f. Construction equipment shall not be allowed directly on the geotextile.
      g. The aggregate base shall be spread from the back-dumped pile using a bulldozer or motor grader. Sudden slopes, starts, or turns on the sub-base material by construction equipment shall not be allowed.
      h. The aggregate shall be in lifts as shown on the Drawings.
      i. Compact the aggregate using a smooth drum roller, unless otherwise shown on the Drawings. Vibratory compaction equipment shall not be allowed on the first lift.

C. Permanent Erosion Control:
   1. Geotextile installation:
      a. Inspect the area to receive geotextile and identify soft or unsuitable subgrade areas. Excavate and backfill these areas with select material and compact using normal procedures.
      b. Construct anchor/toe trenches to the dimensions recommended by the Manufacturer or as shown on the Drawings.
      c. Place the geotextile with the machine direction (long direction) parallel to the direction of water flow:
         1) For runoff and wave action place parallel to the slope.
         2) For streambank/channel protection place parallel to stream or channel.
      d. Install geotextile in anchor/toe trench.
      e. Use the stapling/securing pattern and overlap distances as recommended by the Manufacturer for the site conditions encountered or as shown on the Drawings. Use offset overlaps between adjacent sheets.
      f. Successive sheets of geotextile shall be overlapped upstream over downstream or upslope over downslope.
      g. In cases where wave action or multidirectional flow is anticipated, seams perpendicular to the direction of flow shall be sewn.
   2. Backfill installation:
      a. Place armor material starting from the toe and proceeding up the slope.
      b. Place materials so as to avoid stretching and tearing of the geotextile.
      c. Armor material over 6 inches in size shall not be dropped from a height of more than 1 foot onto the geotextile or allowed to roll down the geotextile. Smaller aggregate shall not be dropped from a height exceeding 3 feet.
      d. For underwater applications, install the geotextile and the armor the same day.
      e. Void spaces in the armor stone shall be backfilled with smaller stone to ensure full coverage.
      f. Following installation, do not perform activities that result in movement of the stone directly above the geotextile.

D. Silt Fence:
   1. General:
      a. Install silt fences in a continuous manner following the contours of the site.
      b. Install fence in a manner transverse to flow, making sure that water cannot run off around the end of the fence.
      c. Do not use silt fences on slopes greater than 1 horizontal to 1 vertical or areas with high flow rates without the ENGINEER's approval.

2. Installation:
   a. Install geotextile in one piece, or continuously sewn to make one piece, for full length and height of fence. Splice the fabric together with a sewn seam at a support post location or overlap two sections of fence.
   b. The bottom edge of the geotextile shall be laid in a 6 inch deep trench in a J configuration. Backfill the trench with native material and tamp in place.
   c. Space posts as required by the type of geotextile being used. Posts shall be driven a minimum of 18 inches into the ground or otherwise secured to prevent overturning due to sediment loading.
   d. Securely fasten geotextile to the uphill side of the posts or supports in a way that will not result in tearing of geotextile when the fence is subjected to service loads.
3. Maintenance:
   a. Inspect silt fences immediately after each rainfall and daily during prolonged rainfall.
   b. Promptly repair or replace silt fence that becomes damaged.
   c. Remove deposited sediment as directed by the local jurisdiction but as a minimum after sediment reaches half the height of the fence.

E. Installing Pavement Reinforcement Fabric:
1. Preparation:
   a. Air and pavement temperatures shall be sufficient to allow the asphalt sealant to hold the paving fabric in place. For asphalt emulsions, the air temperatures shall be 60°F and rising; for asphalt cements, the air temperatures shall be 50°F and rising.
   b. The surface to receive the fabric shall be free of dirt, water, vegetation, or other debris.
   c. Cracks exceeding 0.10 inch width shall be filled with crack filler and cured.
2. Installation:
   a. Follow the Manufacturer’s recommended procedures.
   b. Fabric sealant: Use a paving grade asphalt recommended by the Manufacturer to impregnate and seal the paving fabric and bond it to both the base pavement and the overlay.
   c. Use an asphalt distributor capable of spraying asphalt sealant at the prescribed uniform application rate recommended by the Manufacturer without streaking, skipping, or dripping.
   d. Apply the sealant to a width approximately 6 inches beyond the sides of the fabric.
   e. Maintain the minimum temperature required by the sealant but do not exceed the maximum temperature allowed for the paving fabric.
   f. Place the fabric onto the asphalt sealant with minimum wrinkling prior to the time the asphalt has cooled and lost tackiness. Wrinkles or folds larger than 1 inch shall be slit and laid flat.
   g. Roll or broom the paving fabric into the sealant coated surface.
   h. Overlap the fabric joints sufficient to ensure full closure of the joint but not beyond 6 inches. Lap transverse joints in the direction of paving.
   i. Placement of the hot mix overlay shall closely follow the paving fabric laydown. The hot mix temperature shall be compatible with the paving fabric.

3.3 REPAIRS

A. Protect geotextile from contamination that would interfere, in the ENGINEER's opinion, with its intended function. Remove and replace contaminated geotextile with clean geotextile.

B. Repair or replace torn, punctured, flawed, deteriorated, or otherwise damaged geotextile.
1. Place a patch of undamaged geotextile over any damaged area plus at least 18 inches in all directions beyond the damaged area.
2. Remove interfering material as necessary to expose damaged geotextile for repair.
3. Sew or secure patches by a means approved by the ENGINEER.

END OF SECTION

SECTION 31 05 20
GEOCOMPOSITE DRAINAGE SYSTEM

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for geocomposite drainage systems.
- B. Related Section:
  1. SECTION 07 13 13 – SELF-ADHERING SHEET WATERPROOFING

1.2 REFERENCES
- A. ASTM International (ASTM):
  1. D 1621 – Standard Test Method for Compressive Properties of Rigid Cellular Plastics
  2. D 4491 – Standard Test Methods for Water Permeability of Geotextiles by Permittivity

1.3 SUBMITTALS
- A. Manufacturer Information: Panels and ancillary materials.
  1. Shop Drawings: Layout, product components, and accessories.
  2. Product Data: QC data and installation instructions.

1.4 QUALITY ASSURANCE
- A. Installer Qualifications: An authorized applicator as determined by the Drainage Manufacturer.
- B. Product Warranty: 5 years.

1.5 DELIVERY, STORAGE, AND HANDLING
- A. Deliver in original packaging.
- B. Store in a clean dry area away from UV exposure.

1.6 SITE CONDITIONS
- A. When used in conjunction with a waterproofing membrane as specified in SECTION 07 13 13, the drainage panels shall be installed in accordance with the methods approved by the Waterproofing Manufacturer.
- B. Do not install when ambient temperature is below 20ºF unless approved by the Manufacturer.
- C. Coordinate the outfall of any drainage pipe used with the drainage panels with the site drainage.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
- A. Carlisle Coating & Waterproofing (CCW): Miradrain 6000, 6200, 6000XL, 6200XL
- B. W.R. Meadows: MEL-DRAIN 5035, 5035-B
- C. Polyguard Products Inc: Polyflow 15, 15P

2.2 MATERIALS
- A. Geocomposite drainage panels consisting of a nonwoven filter fabric bonded to a molded polymeric core.
  1. Compressive strength of the core shall be a minimum of 15,000 psf in accordance with ASTM D 1621.
  2. The flow rate shall be a minimum of 110 gpm/sf and in accordance with ASTM D 4491.
  3. The drainage panel shall be at least 0.40 inch thick.
- B. Accessory Materials:
  1. Adhesives, mastic, or tape shall be the Manufacturer's recommended product.
  2. Connectors to drain systems shall be as shown on the Drawings or recommended by the Manufacturer.

PART 3 EXECUTION

3.1 INSTALLATION
- A. Clean the substrate to remove the drainage panel. Remove loose debris and contaminants that will affect the performance of the drainage composite.
- B. Install drainage panels to the limits shown on the Drawings, in accordance with the Manufacturer's recommendations.
- C. Position the panels with the filter fabric facing the soil.
- D. Install panels and connect adjacent panels as recommended by the Manufacturer. Make connections in a shingle fashion so that moisture flows over the overlap and not against it. Overlap fabric in the direction of water flow.
- E. Make corners by bending the panel to the required form.
- F. Where panel terminations are to be made, protect panel edges from soil intrusion with the filter fabric by tucking the fabric behind the core.
- G. To attach the panel system to the underdrain pipeline system, peel back the bottom fabric flap from the core. Place the pipe next to the dimpled core and wrap the fabric over the top and around the pipe securely tucking the fabric under the pipe. Where fabric is used in the underdrain trench, lap the panel fabric to the outside vertical face of the trench fabric.
- H. Backfill immediately in a manner that avoids damaging or dislodging the panels.

END OF SECTION

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SECTION 31 10 00
SITE CLEARING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for site clearing.

1.2 SITE CONDITIONS

A. Obstructions:

1. The location of some utilities and obstructions may not be shown on the Drawings.
2. Call for utility locates and inspect markings for conflicts prior to clearing operations.
3. Obstructions and conflicts shown on the Drawings or marked in the field shall be potholed by the CONTRACTOR to verify location and elevation prior to site clearing.
4. Inspect existing facilities before beginning Work.
5. Anticipate the removal and replacement of minor obstructions (e.g., electrical conduits, air, gas piping, and water piping) even though they may not be shown on the Drawings or specifically mentioned.
6. Major obstructions:
   a. Immediately report major obstructions not shown on the Drawings and that could not have been foreseen by visual inspection of the Work site.
   b. The ENGINEER will make the determination for proceeding with Work.
   c. If the ENGINEER finds that an obstruction adversely affects the CONTRACTOR’s costs or the schedule for completion, a proper adjustment to the Contract will be made in accordance with the General Conditions.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 PREPARATION

A. Demolition:

1. Preserve existing structures encountered during Work until approved for removal.
2. Repair existing pipes or structures damaged during Work at no cost to the OWNER.
3. Obtain approval for the removal of abandoned pipes.

B. Removal and Salvage of Materials:

1. Carefully remove materials specified to be reused or salvaged so as not to damage the material.
2. The reuse of salvaged material is not permitted, except as specifically shown on the Drawings.
3. Existing materials to be removed or replaced that are not specifically designated for salvage shall become the property of the CONTRACTOR.

C. Clearing Site:

1. Clear areas within the outline of new structures, paved areas, site fills, and embankments of stumps, shrubs, brush, and other vegetative growth.
2. Strip material containing roots, grasses, and other deleterious or organic matter generally found in the top 6 inches of undisturbed natural terrain from areas requiring excavation, grading, trenching, and subgrade preparation for foundations and embankment Work.
3. Stockpile and preserve stripped topsoil that is suitable for spreading over finished grades; at the finished grading operation, spread uniformly over areas to be seeded or sodded.
4. Prior to the Substantial Completion date, the completion of a particular phase of the Work, or the termination of the use of particular area, site, storage yard right-of-way, or easement, promptly and neatly clean up the area and re-establish the ground to the contours required by the Work or to conditions prior to the commencement of the Work.

D. Clearing and Grubbing:

1. The clearing of ground surface in fill areas will be directed by the ENGINEER.
2. Clear the area to be occupied by permanent construction and the surfaces of borrow pits, stockpiles, and fill areas of trees, stumps, exposed roots, brush, rubbish, and other objectionable matter.

E. Stripping: Strip fill areas to a minimum depth of 6 inches or as required to remove surface boulders and loose rock, debris, topsoil, vegetable matter, including stumps and roots, and other perishable and objectionable materials that are unsuitable for use in the permanent construction or that might interfere with the proper bonding of the embankment with the foundation or the proper compaction of fill materials.

F. Disposal:

1. Remove waste and organic materials from clearing operations from the construction site.
2. Locate waste piles in areas that will not interfere with the natural flow of stream and drainage channels, construction operations in borrow areas, or the operation of reservoirs.

END OF SECTION

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SECTION 31 23 13
SUBGRADE PREPARATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for subgrade preparation.

B. Related Sections:

1. SECTION 01 40 00 – QUALITY REQUIREMENTS
2. SECTION 02 41 19 – SELECTIVE DEMOLITION
3. SECTION 31 23 16 – EXCAVATION
4. SECTION 31 23 19 – DEWATERING
5. SECTION 31 23 23 – FILL

1.2 REFERENCES

A. ASTM International (ASTM):

1. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
2. D 6938 – Standard Test Method for In Place Density and Water Content of Soil Aggregate by Nuclear Methods (Shallow Depth)

B. Colorado Department of Transportation (CDOT):

1. Standard Specification for Road and Bridge Construction

1.3 DEFINITIONS

A. Optimum Moisture Content: As specified in SECTION 31 23 23.

B. Prepared Ground Surface: The top of a compacted lift of soil backfill prepared in accordance with the requirements; can be working grade or final grade.

C. Compaction: As specified in SECTION 31 23 23.

D. Relative Density: As specified in SECTION 31 23 23.

E. Subgrade: The layer of existing soil after the completion of clearing and grubbing, the scalping of sod, the stripping of topsoil, and excavation to grade prior to the placement of fill or concrete.

F. Proof-Rolling: The testing of subgrade by compactive effort to identify areas that will not support future loading without excessive settlement.

1.4 SEQUENCING AND SCHEDULING

A. Complete applicable Work as specified in SECTION 02 41 19 and SECTION 31 23 16 prior to subgrade preparation.

1.5 QUALITY ASSURANCE

A. Notify the ENGINEER in writing when the subgrade is ready for compaction or proof-rolling or when compaction or proof-rolling is resumed after a period of extended inactivity.

1.6 SITE CONDITIONS

A. Environmental Requirements: Prepare subgrade when unfrozen and free of ice and snow.

PART 2 PRODUCTS

2.1 MATERIALS

A. In accordance with CDOT Standard Specification for Road and Bridge Construction, Division 700.

PART 3 EXECUTION

3.1 GENERAL

A. Shape subgrade to produce as uniform and regular a profile as possible, with no abrupt changes in slope, sharp projections, overhangs, or benches, except as shown on the Drawings or approved by the ENGINEER.

B. Keep subgrade free of water, debris, and foreign matter during compaction or proof-rolling.

C. Bring subgrade to proper grade and cross-section, then either proof-roll or scarify to a depth of 12 inches, and uniformly compact the surface. The method to be used shall be determined by the ENGINEER for Project-specific conditions.

D. Do not use sections of prepared ground surface as haul roads; protect prepared subgrade from traffic.

E. Maintain the prepared ground surface in a finished condition until the next course is placed.

3.2 PREPARATION

A. Moisture Conditioning:

1. Dry subgrade: Add water, then mix to a uniform moisture content throughout.
2. Wet subgrade: Aerate material by blading, discing, harrowing, or other methods to hasten the drying process.

B. Stabilization:

1. In the event the subgrade layer at the bottom of the excavation below groundwater level is unstable and exhibits pumping during surface preparation compaction, stabilize subgrade by one of following methods:
   a. Increasing dewatering efforts so groundwater is drawn down further than the minimum level as specified in SECTION 31 23 19.
   b. Placing a layer of foundation stabilization rock as specified in SECTION 31 23 23 and proceeding to backfill.
   c. Placing foundation stabilization rock only if the groundwater level has been drawn down and subgrade is still insufficient.
   d. In moderately unstable conditions, to avoid excessive over-excavation, a geosynthetic reinforcement material may be placed on native materials below stabilization rock. Stabilization rock shall be pushed into subgrade with a bucket or a track vehicle.
   e. When stabilization rock is used, cover it with a layer of geotextile fabric to prevent fines from the material above escaping into the rock.
2. Minimum compaction and moisture control requirements apply to the backfill placed regardless of the method used to stabilize the subgrade. Testing shall begin after 12 inches to 18 inches of material is placed over geotextile fabric.

C. Subgrade Protection: Protect from damage during foundation cleanup and placement of overlying fill. Protect from physical damage due to construction equipment and deterioration from frost, wetting and drying, or erosion.

3.3 INSTALLATION

A. Compaction:

1. For scarification method:
   a. Prior to placing compacted fill, the upper 12 inches of the subgrade soils at the base of the fill zone shall be scarified, moisture conditioned, and re-compacted to at least 95% of the standard Proctor in accordance with ASTM D 6938 and ASTM D 698.
   b. Maximum dry density at moisture contents within two percentage points of the optimum moisture content for granular subgrade soils and within zero and plus three percentage points of optimum for clay subgrade materials.
   c. Other areas to receive new fill not specifically addressed herein shall be scarified to a depth of at least 8 inches and re-compacted to at least 95% of the standard Proctor in accordance with ASTM D 6938 and ASTM D 698, maximum dry density within the moisture bands recommended herein.
2. For proof-roll method:
   a. This method of determining subgrade competency is only permitted with written approval of the ENGINEER based on geotechnical investigation or site-specific conditions.
   b. Use a fully loaded water truck, loader with a full bucket, or other approved vehicle driven on the finished subgrade to detect soft, loose, or unsuitable material.
3. Excessive wetting and drying of excavations and prepared subgrade areas shall be avoided during construction. If prepared subgrade areas are left exposed to precipitation or dry weather for more than 24 hours, scarification, moisture conditioning, and re-compaction as recommended herein may be required at the Engineer's discretion.
4. During extremely hot and dry conditions, the duration of exposure may need to be significantly shorter.
5. The prepared subgrade soils shall also be protected from freezing. Be prepared to cover or seal or otherwise protect the prepared subgrade soils.

3.4 QUALITY CONTROL

A. Remove surface materials at locations designated by the ENGINEER and provide necessary assistance for sampling and testing.

B. Perform QA/QC testing as specified in SECTION 01 40 00.

3.5 ADJUSTING

A. For soft or loose subgrade select one of following methods:

1. Adjust moisture content and re-compact.
2. Over-excavate as specified in SECTION 31 23 16 and replace with suitable material from excavation, as specified in SECTION 31 23 23.

B. Unsuitable Material: Over-excavate as specified in SECTION 31 23 16 and replace with suitable material from excavation as specified in SECTION 31 23 23.

END OF SECTION

SECTION 31 23 16
EXCAVATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for excavation.

B. Related Sections:

1. SECTION 31 23 19 – DEWATERING
2. SECTION 31 50 00 – EXCAVATION SUPPORT AND PROTECTION

1.2 COORDINATION

A. Stockpiling Excavated Material:

1. Stockpile excavated material suitable for use as fill or backfill until it is needed.
2. Post signage:
   a. Indicate the proposed use of material stockpiled.
   b. Ensure signage is clearly worded and readable by equipment operators from a normal seated position from the directions of approach to each stockpile.
3. Confine stockpiles within approved areas.
4. Do not obstruct roads or streets.
5. Do not stockpile excavated material adjacent to trenches and other excavations unless excavation sideslopes and excavation support systems are designed, constructed, and maintained for stockpile loads.
6. Do not stockpile excavated materials near or over existing facilities, adjacent property, or completed Work if the weight of stockpiled material could induce settlement.

1.3 SEQUENCING AND SCHEDULING

A. Excavation Support: Install and maintain, as specified in SECTION 31 50 00, support to the sides of excavations and prevent the detrimental settlement and lateral movement of existing facilities, adjacent property, and completed Work.

B. Dewatering prior to initiating excavation: As specified in SECTION 31 23 19.

1.4 QUALITY ASSURANCE

A. Provide adequate survey control to avoid unauthorized over-excavation.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 GENERAL

A. Excavate to lines, grades, and dimensions as shown on the Drawings, and as necessary to accomplish Work.

B. Excavate to within a tolerance of ±0.1 foot except where dimensions or grades are shown on the Drawings as maximum or minimum.

C. Allow for forms, working space, granular base, topsoil, and similar items, where applicable.

D. Trim to neat lines where concrete is to be placed against earth.

E. Do not over-excavate without the ENGINEER's written authorization.

F. Stockpile topsoil removed during excavation that is to be applied after backfill operations.

3.2 PREPARATION

A. Trench Excavation:

1. As shown on the Drawings. If not shown on the Drawings, excavation shall be:
   a. Minimum width:
      1) Single pipes, conduits, direct-buried cables, and ductbanks: 24 inches greater than the OD or width of pipe, conduit, direct-buried cable, or ductbank.
      2) Multiple pipes, conduits, cables, or ductbanks in a single trench: 24 inches greater than the aggregate width of pipes, conduits, cables, ductbanks, plus space between.
      3) Increase widths by thicknesses of sheeting.
      4) At the bottom and the top of pipe: Minimum 24 inches plus the OD of pipe and a maximum 36 inches plus the OD of pipe.
   b. Minimum depth: 6 inches below the bottom of pipe or below the bottom of encasement if applicable.
2. Excavate sides and maintain as vertical as practical. Use shoring as necessary to maintain integrity and safety of excavation sides.
3. Excavate as needed outside the normal trench section at field joints for field connection operations.

B. Embankment and Cut Slopes:

1. Shape, trim, and finish cut slopes to be in accordance with the lines, grades, and cross-sections as shown on the Drawings with proper allowance for topsoil or slope protection as shown on the Drawings.
2. Remove stones and rock that exceed 3 inches in size and that are loose and may roll down the slope.
3. Remove exposed roots from cut slopes.
4. Round the tops of cut slopes in the soil to not less than a 6 foot radius, provided such rounding does not extend off-site or outside easements and ROW or adversely impact existing facilities, adjacent property, or completed Work.
5. Construct berms around the tops of excavations to provide protection from surface runoff entering excavation.

C. Disposal of Spoil: Material 3 inches and larger, asphalt, concrete, organic material, and other such unsuitable material for fill or backfill shall be disposed off-site.

END OF SECTION

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SECTION 31 23 16.01
VACUUM EXCAVATION FOR KEYHOLE INSTALLATION OF APPURTENANCES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for vacuum excavation for keyhole installation of appurtenances.

B. Related Sections:

1. SECTION 02 41 19 – SELECTIVE DEMOLITION
2. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE
3. SECTION 31 23 23 – FILL
4. SECTION 31 23 33 – TRENCH BACKFILL
5. SECTION 32 12 16 – ASPHALT PAVING

1.2 DEFINITIONS

A. Keyhole Core: The same as core.

B. Keyhole Coring: The operation of coring a circular hole through a roadway pavement, sidewalk, other improved area, grassy area, or ROW, removing materials from the ground by water or air vacuum excavation method, and disposal.

1.3 SEQUENCING AND SCHEDULING

A. Provide legal permitting and traffic control pertaining to the Work.

1.4 SUBMITTALS

A. Product Data: Manufacturer's catalog data sheet for bonding material.

B. Batch information for backfill material as specified in SECTION 03 30 00 and SECTION 31 23 33.

C. Approved traffic control plan.

D. Quality Control Submittals: CONTRACTOR's experience for installations.

E. Warranty Documentation:

1. Sample warranty.
2. Warranty.

1.5 QUALITY ASSURANCE

A. Provide adequate survey control to avoid unauthorized over-excavation.

B. Vacuum Excavation Qualifications:

1. A minimum of 3 years of documented experience in the Work of this Section. The installer shall have personally accomplished five or more successful installations.
2. Approved by the Manufacturer.

C. Surface Tolerance:

1. Pavements: The reinstated core shall be flush and level with the adjacent pavement and in its original orientation. No gap, attributable to the core, shall be found between the bottom of the straight edge and the surface of the pavement when a straight edge 36 inches long is placed in any direction on the surface, except across the crown or drainage gutters.
2. Sidewalks: The reinstated core shall be flush and level with the adjacent pavement. No gap, attributable to the core, shall be found between the bottom of the straight edge and the surface of the pavement when a straight edge 36 inches long is placed in any direction on the surface.

D. A keyhole is considered unacceptable when one of the following conditions exist:

1. The keyhole core contains any vertical cracks wider than 3/16 inch extending full depth or partial depth through core.
2. Any deteriorated piece of keyhole core is larger than 10% of the overall area of the keyhole core.
3. Two or more successive layers of asphalt in the core become horizontally delaminated and cannot be rebounded to each other with the bonding compound.

1.6 SITE CONDITIONS

A. Do not use material excavated when frozen or when air temperature is less than 32°F until the material completely thaws.

B. Do not use over-saturated material that will interfere with proper compaction.

1.7 WARRANTY

A. Warranty for 3 years from the Substantial Completion date for the satisfactory performance and installation of the vacuum excavation for keyhole installation of appurtenances system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Bonding Material:

1. Utilicor Technologies, Utilibond

2.2 MATERIALS

A. Bonding: Bonding material shall be a multi-component, super plasticized, cementitious compound, impervious to water penetration after the joint application. The bonding material shall securely bond the undamaged keyhole core to the pavement or sidewalk and fill the annular space at the joint. The bonding material shall support equivalent traffic load of at least three times the AASHTO H-20 within 30 minutes at an ambient temperature of 70°F.

B. Backfill:

1. CLSM as specified in SECTION 31 23 33.
2. Pea gravel and imported granular fill as specified in SECTION 31 23 23.
3. Granular fill shall be placed 1 foot above the pipe prior to placement of CLSM.

PART 3 EXECUTION

3.1 GENERAL

A. Products shall comply with federal, state, and local requirements.

B. Provide locates applicable to the area of excavation.

C. Repair damage to existing utilities or underground appurtenances to the satisfaction of the ENGINEER and other utility representatives at the CONTRACTOR'S sole expense.

D. Protect facilities exposed during the vacuum excavation operations throughout the Work. Utilities rendered unsupported due to vacuum excavation shall be temporarily supported by shoring or other means. Protect the utility form heavy or sharp items falling into the excavation that could damage the utility.

E. Excavated material shall be stored by the CONTRACTOR and disposed of as specified in SECTION 02 41 19 and at the CONTRACTOR'S sole expense.

3.2 INSTALLATION

A. Excavation and Core:

1. Excavation requires coring a circular hole through the concrete or asphalt surface using drilling/coring equipment and removing the intact pavement core. The vertical alignment of the coring shall be perpendicular to the horizon and cutting shall be extended through the entire surface of the paved section.
2. Cores cut into pavement for excavation shall not exceed 18 inches in diameter or 12 inches by 12 inches square. Large cores, overlapping cores, or cores closer than 3 feet from one another may be allowed only with the prior written approval of the ENGINEER.
3. Cores shall not be closer than 3 feet for each other, a joint, or any longitudinal or transverse crack greater than 0.10 inch.
4. Removed pavement cores shall be marked to ensure replacement will be aligned to original orientation.
5. Soil shall be removed by air/vacuum or water/vacuum excavation methods to expose pipe or utilities. The zone of the excavation shall be a vertical plane extending below the edges of the core hole, though large enough to accommodate the installation of required appurtenances.
6. Material containing environmentally hazardous components shall be excavated using a specialized HEPA filtration system.
7. The interface between the core and pavement shall be wiped clean prior to replacement.
8. Where the core is found to be fractured or defective upon removal, or becomes damaged after removal and prior to reinstallation, the defective core shall not be used.
9. Remove excess excavated material from the Work site.

B. The excavation shall be backfilled with imported granular fill to 1 foot above the top of the pipe. The imported granular fill shall contain enough moisture to ensure compaction while tamping as specified in SECTION 31 23 23.

C. Reinstate the keyhole core within 1 day of cutting the pavement. Openings allowed to remain open shall be covered with an approved steel road plate capable of supporting traffic loads.

D. CLSM may be used above the imported granular fill to a level 2 inches below the base of the pavement or sidewalk, using a vibrator as necessary. A 2 inch level of pea gravel shall be placed on the CLSM or backfill once it is set. Pea gravel may be tamped by hand. If no pavement exists, pea gravel shall be placed to the specification of the ENGINEER.

E. Excessive bonding material shall be removed from the restored surface. Prevent a patched appearance in surface restoration.

F. For installation in a grassy or ROW area, replace removed grass core in a manner that promotes the re-establishment of existing landscape in vicinity.

3.3 QUALITY CONTROL

A. Keyhole cores that are damaged or do not meet the surface tolerances shall be removed, disposed of off-site, and a matching replacement core installed. In the case of defective keyhole cores, complete the restoration as specified in SECTION 32 12 16 or in accordance with the requirements of the city having jurisdiction to match existing.

END OF SECTION

SECTION 31 23 19
DEWATERING

PART 1 GENERAL

1.1 SUMMARY

- A. Section includes general information and execution for dewatering.
- B. Related Sections:
  1. SECTION 01 50 00 – CONSTRUCTION FACILITIES AND TEMPORARY CONTROLS
  2. SECTION 31 23 23 – FILL

1.2 SUBMITTALS

- A. Shop Drawings:
  1. Dewatering systems.
  2. Water control plan; as a minimum, include the following:
     - a. Descriptions of proposed groundwater and surface water control facilities including, but not limited to, equipment, methods, standby equipment and power supply, pollution control facilities, discharge locations to be utilized, and provisions for immediate temporary water supply as required.
     - b. Drawings showing the locations, dimensions, and relationships of the elements of each system.
     - c. If a system is modified during installation or operation, revise or amend and resubmit the water control plan.
- B. Discharge Permits (as specified in SECTION 01 50 00):
  1. General Permit COG080000 – Discharges from Short-term (<2 years) Construction Dewatering Activities
  2. General Permit COG317000 – Discharges from Short-term (<2 years) Remediation Activities

1.3 SITE CONDITIONS

- A. Anticipated groundwater depths are described in the subsurface investigation report found as an Exhibit to this contract.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 GENERAL

- A. Continuously control water, including during weekends, holidays, and periods of Work stoppages. Provide adequate backup systems to maintain the control of water.

3.2 PREPARATION

- A. Water Disposal:
  1. Obtain a discharge permit for water disposal.
  2. Adhere to permit requirements.
  3. Treat the water collected by dewatering operations, as required, prior to discharge.
  4. Discharge water as required by the discharge permit and in a manner that will not cause erosion or flooding or otherwise damage existing facilities, completed Work, or adjacent property. Provide analytical data as required by the permit.

3.3 INSTALLATION

- A. Dewatering Systems:
  1. Provide sufficient size and capacity systems to permit dry excavation and subsequent construction, and to lower and maintain the groundwater level a minimum of 1 foot below the lowest point of excavation.
  2. Continuously maintain excavations free of water, regardless of the source, and until backfilled to the final grades as shown on the Drawings.
  3. Maintain excavation and backfill activities on a surface that is free of standing or running groundwater or surface runoff.
  4. Protect excavations from surface runoff.
  5. Design, operate, and maintain dewatering systems to prevent the loss of ground as water is removed. Avoid inducing settlement or damage to existing facilities, completed Work, or an adjacent property; relieve artesian pressures and resultant uplift of the excavation bottom.
  6. Provide ditches and sumps as necessary to collect water from local seeps.
  7. If dewatering systems fail during backfilling operations:
     - a. Repair or replace the failing components of the system to avoid the saturation of placed material.
     - b. If placed material becomes saturated, excavate a 3 foot thick layer of soil from the excavation and replace with material as specified in SECTION 31 23 23.
     - c. Material excavated under this provision may be reused once dried to the proper moisture content.
- B. Dewatering Wells at Dams: Do not install dewatering wells on or within 50 feet of the toe of the dam or water-retaining embankment using jetting techniques.

3.4 PROTECTION

- A. Make an assessment of the potential for a dewatering induced settlement.
- B. Provide and operate devices or systems including, but not limited to, reinjection wells, infiltration trenches, and cutoff walls necessary to prevent damage to existing facilities, completed Work, and adjacent property.
- C. Securely support existing facilities, completed Work, and adjacent property vulnerable to settlement due to dewatering operations.
- D. Support shall include, but not be limited to, bracing, underpinning, or compaction grouting.

END OF SECTION

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SECTION 31 23 22
ZONED FILL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for zoned fill.

B. Related Sections:
   1. SECTION 01 45 29 – MATERIALS TESTING
   2. SECTION 31 10 00 – SITE CLEARING
   3. SECTION 31 23 13 – SUBGRADE PREPARATION
   4. SECTION 31 23 19 – DEWATERING

1.2 REFERENCES

A. ASTM International (ASTM):
   1. C 33 – Standard Specification for Concrete Aggregates
   2. C 117 – Standard Test Method for Materials Finer than 75-μm (No. 200) Sieve in Mineral Aggregates by Washing
   3. D 75 – Standard Practice for Sampling Aggregates
   4. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
   5. D 1556 – Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
   6. D 4253 – Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
   7. D 4254 – Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
   8. D 4318 – Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils
   9. D 6913 – Standard Test Methods for Particle-Size Distribution (Gradation) of Soils Using Sieve Analysis

1.3 DEFINITIONS

A. Borrow Material: Material from required excavations or from designated borrow areas on or near the site.

B. Certified/Certification: Prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

C. Compaction:
   1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D 698.
   2. Apply corrections for oversize material to either as-compacted field dry density or maximum dry density, as determined by the ENGINEER.

D. Completed Course: Course or layer ready for the next layer or phase of Work, free from irregularities with a tight, even surface, true rolling, and cross-section.

E. Coverage: One coverage is defined as the requirement for successive trips of a piece of compaction equipment, which by means of sufficient overlap will ensure contact on the entire surface of the layer by the equipment.

F. Deleterious Materials: Organic matter, trash, rubbish, debris, oversize materials, and soluble materials.

G. Fines: Materials passing No. 200 sieve as determined in accordance with ASTM D 6913.

H. Imported Material: Material obtained from sources off-site.

I. Granular Soil: A free draining, non-cohesive soil comprised of mostly gravel and sand.

J. Lift: A loose, uncompacted, layer of material.

K. Optimum Moisture Content: Moisture content in accordance with ASTM D 698.

L. Oversize Materials: Soil particles, soil clods, sedimentary fragments, rocks, and other materials having a maximum dimension larger than the specified limits.

M. Particle Size: The size of a particle before compaction measured parallel to its longest dimension.

N. Period of Inactivity or Extended Shutdown: 4 days.

O. Pipe Zone: The backfill zone that includes the full trench width and extends from the prepared trench bottom to the upper limit above the top outside surface of pipe.

P. Prepared Foundation: Subgrade surface after the completion of foundation preparation activities as specified prior to the placement of overlying fill, backfill, or structure.

Q. Prepared Trench Bottom: The graded trench bottom after the stabilization and installation of bedding material.

R. Relative Density: Calculated in accordance with ASTM D 1556 based on the maximum index density determined in accordance with ASTM D 4253 and the minimum index density determined in accordance with ASTM D 4254.

S. Well Graded: An even representation of particle sizes from largest to smallest.

1.4 SUBMITTALS

A. Samples:
   1. Imported material taken at the source and collected in accordance with ASTM D 75.
   2. Minimum size of field samples shall be in accordance with ASTM D 75.
   3. Clearly mark to show the source of the materials and the intended use; include gradation if applicable.

B. Quality Assurance and Control Submittals:
   1. Certified gradation, Atterberg limits, soundness, and deleterious substances analysis: Imported materials.
   2. Catalog the Manufacturer's data sheets for compaction equipment.
   3. During the production of imported material, provide one manufacturer gradation test for the Project.

C. Backfill Plan: Submit a complete backfill plan that includes the aspects of earthwork including excavation and fill. The plan needs to be approved by the ENGINEER prior to initiating any earthwork activities. Include the following at a minimum:
   1. Proposed schedule, sequence, procedures, and production rates for placing filter sand, drain gravel, and earth fill.
   2. Order of constructing the various components of the Work.

3. Planned equipment spread for material processing, hauling, placement, and compaction.
4. Methods, sequence, equipment spread, and procedures for the placement of each type of backfill.
5. Narrative with figures to illustrate the plan.
6. Coordinate with dewatering, excavation support, and sub-drainage pipe.
7. Placement plan for avoiding contamination of materials, especially filter sand and drain gravel during construction.
8. Proposed haul routes which limit disturbance to the site.
9. Methods to resume fill placement after extended shutdown.

1.5 QUALITY ASSURANCE

A. Notify the ENGINEER in writing when any one of the following occurs:
   1. The foundation excavation and subgrade preparation for foundation has been completed.
   2. The structure or pipe is ready for backfilling, and whenever backfilling operations are initiated or resumed after a period of inactivity.
   3. Soft or loose subgrade materials are encountered wherever zoned fill or miscellaneous fill is to be placed.
   4. Fill material deviates from the Contract Documents.
   5. Fill is about to be placed on a prepared subgrade or when fill operations are resumed after a period of inactivity.
   6. The initial sampling of the imported material source is to be conducted or the importing of material to the site is to begin.
   7. Borrow excavation is about to be shifted from one area to another or a change in borrow materials is encountered.
   8. Equipment change due to breakdown or redeployment.

B. OWNER Testing:
   1. The ENGINEER will perform field QA tests to measure the density and the water content of soil in place, laboratory full compaction and associated one-point compaction tests, and gradation or index tests to confirm the materials placed meet the specified requirements..
   2. The OWNER's tests will be performed on materials taken at the place of excavation, stockpiles, conveyors, and in the fill.
   3. Remove surface material at locations designated by the ENGINEER and provide assistance as necessary for sampling and testing.
   4. The ENGINEER may direct the CONTRACTOR to construct inspection trenches in compacted or consolidated fill or backfill to determine compliance with the Contract Documents.

1.6 SITE CONDITIONS

A. Environmental Requirements: Do not place fill or backfill if fill or backfill material is frozen or if the surface upon which the fill or backfill is to be placed is frozen, soft, rutting, or does not meet the moisture requirement of this Section.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Metallic Marking Tape:
   1. Boddingtons, Ultra Strong Detectatape
   2. Reef Industries, Terra Tape Detectable

2.2 MATERIALS

A. Zoned Fill:
   1. A suitable mixture of clay, silt, sand, and gravel that meets specified gradation requirements and is free from rocks larger than 3 inches, from roots and other organic matter, asphalt, concrete, ashes, cinders, trash, and other deleterious material.

B. Miscellaneous Fill:
   1. A suitable mixture of clay, silt, sand, and gravel that meets specified gradation requirements and is free from rocks larger than 6 inches, from roots and other organic matter, asphalt, concrete, ashes, cinders, trash, and other deleterious material.
   2. Fill may be obtained from approved site excavations.

C. Filter Sand:
   1. Sand material, well graded, and in accordance with ASTM C 33 for soundness and deleterious substances.
   2. Conforming to the following limits when tested by means of laboratory sieves in accordance with ASTM D 6913:

ATSM C 33 Fine Aggregate

Sieve Size	Total Passing by Sizes (Percentage by Weight)
3/8 inch	100
No. 4	95 to 100
No. 8	80 to 100
No. 16	50 to 85
No. 30	25 to 60
No. 50	5 to 30
No. 100	0 to 10
No. 200	0 to 3

   3. The material passing a No. 40 sieve shall be non-plastic when tested in accordance with ASTM D 4318.
   4. Material will meet specified gradation requirements when delivered to the fill and after placement and compaction.

D. Drain Gravel:
1. Gravel material, well graded, and in accordance with ASTM C 33 for soundness and deleterious substances
2. Conforming to the following limits when tested by means of laboratory sieves in accordance with ASTM D 6913:

ASTM C 33 Coarse Aggregate No. 8

Sieve Size	Total Passing by Sizes (Percentage by Weight)
1/2 inch	100
3/8 inch	85 to 100
No. 4	10 to 30
No. 8	0 to 10
No. 16	0 to 5
No. 200	0 to 3

3. The material passing a No. 40 sieve shall be non-plastic when tested in accordance with ASTM D 4318.
4. Material will meet specified gradation requirements when delivered to the fill and after placement and compaction.

E. Topsoil: Topsoil selectively excavated from site clearing Work as specified in SECTION 31 10 00 and excavated organics and peat having a maximum particle size of 3 inches, free from deleterious materials, and containing sufficient organics to support vegetative growth.

F. Water for Moisture Control: Free of hazardous or toxic contaminants or contaminants deleterious to proper compaction.

G. Moisture Conditioning Equipment:
1. Provide water trucks or tankers and other supplemental equipment necessary to uniformly apply water to material for proper compaction and for watering of completed courses until overlying courses are placed.
2. Watering equipment shall be equipped with pressurized distributor bars or other means necessary to ensure uniform application or water.
3. Provide blades, discs, and other supplemental equipment necessary to process materials, blend non-uniform fill and backfill materials, for aerating and drying out wet materials, and for scarification of completed courses.
4. Discs will be of sufficient size and power to blend the full depth of the loose lifts, and to cut into and scarify the underlying completed course to a depth of 2 inches to allow bonding of successive lifts. In addition, discs shall be adjustable to allow light scarification of completed courses or haul roads that require reconditioning prior to placement of overlying fill.

H. Compaction Equipment:
1. Provide dedicated compaction equipment of a suitable type that is capable of achieving the requirements of the Specifications and which provides a satisfactory uniform, homogeneous fill.
2. Hauling and placement equipment shall not be considered compaction equipment.
3. Provide hand-operated equipment for use in confined areas not accessible to regular compaction equipment or where regular compaction equipment might damage structures or piping. Compaction equipment shall be subject to the approval of ENGINEER.
4. Equipment used for compaction of earthfill shall consist of a self-propelled, sheepsfoot or tamping foot roller capable of kneading material into a uniform embankment.
   a. Properly maintain tamping heads and cleaner bars.
   b. Maintain spacing between tamping feet clear of materials that could impact the effectiveness of the tamping roller.
   c. The weight of each roller will be at least 3,300 lbs/ft of drum length and the feet will be at least 7 inches long measured from the drum surface. Rollers will be free to pivot about an axis parallel to the direction of travel.
5. Equipment used for the compaction of filter sand shall consist of a self-propelled, steel drum vibratory roller. The static weight of the roller shall be at least 2,200 lbs. Centrifugal force shall be at least 3,400 lbs/ft of drum width.
6. Equipment used for the compaction of filter sand and drain gravel, adjacent structures or piping, and in tight, restricted areas shall consist of a vibratory plate compactor. Vibratory plate compactors shall have a minimum static weight of 270 lbs and a minimum dynamic force of 1,000 lbs.

PART 3 EXECUTION

3.1 GENERAL

A. Do not place material until the subgrade has been approved by the ENGINEER.

B. Keep the placement surfaces free of water, debris, and foreign material during the placement and compaction of fill and backfill materials.

C. Provide temporary construction as necessary to protect exposed filter sand and drain gravel from surface drainage.

D. Provide a Fill Supervisor at all times at the location of each fill placement.

E. Place and spread fill and backfill materials in horizontal lifts of uniform thickness in a manner that avoids segregation.

F. Compact each lift at the specified moisture content, using the specified equipment, and to the specified densities, prior to placing succeeding lifts.

G. Each layer of each zone shall be constructed continuously and approximately horizontal for the width and length of the layer. Slope lifts only where necessary to conform to final grades or as necessary to keep placement surfaces drained of water.

H. The maximum allowable particle size delivered in the fill and backfill at the placement location and prior to any compaction shall be no larger than the maximum specified in this Section.

I. Process by ripping, blading, discing, harrowing, or other ENGINEER-approved methods as necessary to provide sufficient disaggregation and blending of fill and backfill. Blend materials so that compacted fill is homogeneous and free from lenses, pockets, streaks, voids, laminations, and other imperfections. Moisture conditioning and processing of materials to achieve the required particle size shall occur in borrow areas.

J. Except for filter sand and drain gravel, key or bench lifts into adjacent undisturbed foundation, undisturbed existing embankment, or compacted embankment to provide overlap of compactive effort.

K. Maintain the moisture content of delivered materials and compact materials in the lift to produce the specified fill characteristics.

L. During filling and backfilling around structures and pipes, keep the level of fill and backfill even on all sides of the structure.

M. Do not place fill or backfill if fill or backfill material is frozen or if the surface upon which the fill or the backfill is to be placed is frozen.

N. Tolerances:
   1. Final lines and grades: Within a tolerance of 0.1 foot unless dimensions or grades are shown or specified otherwise.
   2. Grade to establish and maintain slopes and drainage as shown on the Drawings. Reverse slopes are not permitted.

O. Settlement: Correct and repair any subsequent damage to structures, slabs, piping, and other facilities caused by settlement of fill or backfill.

P. If particle size limits do not meet specification requirements or if unsuitable material is observed in the fill, terminate material placement and take corrective action prior to resuming fill placement.

Q. Rework materials that do not meet the specified gradation, moisture content, and density requirements until approved results are obtained.
   1. Reworking may include removal, rehandling, reconditioning, recompacting, or combinations thereof.
   2. No additional compensation is due to the CONTRACTOR for reworking materials.

3.2 PREPARATION

A. Trench:
   1. Dewatering: As specified in SECTION 31 23 19.
   2. Remove foreign material and backfill that is contaminated with foreign material that falls into the trench.
   3. Trench bottom preparation:
      a. Firm subgrade:
         1) Grade with hand tools.
         2) Remove loose and disturbed material.
         3) Trim off high areas and ridges left by the excavating bucket teeth.
         4) Allow space for filter sand or drain gravel if shown or specified.
      b. Soft subgrade:
         1) Notify the ENGINEER if subgrade is soft or cannot be compacted as specified in SECTION 31 23 13.
         2) The ENGINEER will determine the depth of additional excavation if required.

3.3 INSTALLATION

A. Moisture Conditioning and Processing:
   1. Moisture condition and process material prior to and during borrow excavation so that material is within the specified moisture content and particle size limits at the time it is delivered to the fill area.
   2. Provide supplemental sprinkling on the fill to keep material within the specified moisture content limits throughout the placement and compaction process, and to preserve moisture in completed courses until placement of overlying courses.
   3. Blend material by discing, blading, or harrowing to maintain uniform moisture content throughout the lift.
   4. Do not attempt to compact material that contains excessive moisture. Material that becomes too wet shall be removed or reworked. Aerate material by blading, discing, harrowing, or other methods to hasten the drying process.
   5. Provide suitable types and numbers of watering and blending equipment to keep pace with fill and backfill placement activities. Provide additional equipment or restrict material placement rates if watering and blending equipment cannot keep pace with fill and backfill placement.
   6. Maintain moisture conditions of the fill surface during nights, weekends, holidays, and other periods of temporary work stoppage.
   7. Blending equipment will operate continuously in active fill areas.

B. Compaction:
   1. Compact material by mechanical means. If tests indicate that compaction or moisture content is not as specified, or if compaction equipment being used is not as specified, terminate material placement and take corrective action prior to resuming material placement.
   2. Operate compaction equipment in strict accordance with the Manufacturer's instructions and recommendations. Maintain equipment in such condition that it will deliver the Manufacturer's rated compactive effort.
   3. Where a minimum number of coverages is specified, provide 20% overlapping roller passes for each complete roller coverage per lift.
   4. Provide suitable numbers of equipment to keep pace with fill and backfill placement activities. Restrict material placement rates if compaction equipment cannot keep pace with fill and backfill placement.
   5. Provide dedicated compaction equipment for each active fill area.

C. Zoned Fill:
   1. Construct fills to the lines and grades shown.
   2. Overbuild slopes by at least 2 feet to allow full compaction of the horizontal lifts to the design lines, then remove outer material and trim completed fill to design lines with allowance for topsoil, where applicable.

3. The materials exposed on the compacted slopes shall be at the as-compacted density and moisture content when the overlying slope protection and topsoil are placed.
4. In any separate work area being constructed, construct each placement lift layer continuously and approximately horizontally for the width and length of such Work area.
5. Maintain the surface of the fill, including sloping the surfaces to drain, preventing or repairing gullies, and maintaining surfaces free of weeds or other vegetation until final completion and acceptance of Work.
6. After a layer has been placed and spread to less than the maximum specified lift thickness, disc as necessary to blend the materials.
7. Remove and rework by discing and scarifying any smooth hard surfaces and deep ruts in the surface of the fills resulting from the passage of construction equipment prior to placing overlying fill.
8. Protect fill during periods of inactivity or extended shutdown. Grade surfaces to facilitate runoff and wheel roll or compact with a smooth drum roller to reduce infiltration and softening. A loose lift of material can be placed to protect the fill during periods of frost.
9. After periods of inactivity or extended shutdowns, prepare the fill surface prior to the resumption of fill and backfill activities:
    a. For earth fill, recondition the fill surface by scarifying to a minimum depth of 8 inches, moisture conditioning and recompacting as specified. If previously placed fill has become damaged by saturation, frost, or desiccation to a depth greater than 8 inches, over-excavate damaged material and replace/recompact.
    b. For filter sand and drain gravel, remove and replace material contaminated by adjacent fill materials, as determined by the ENGINEER.
    c. No separate payment will be made for fill restoration after periods of inactivity or shutdown.
10. Minimize equipment travel on fill and foundations to prevent segregation, contamination, or breakdown of materials.
11. Zoned fill:
    a. Maximum lift thickness: 8 inches, 6 inches if compacted with hand-operated equipment.
    b. Compaction: Not less than 98% relative compaction in accordance with ASTM D 698.
    c. Compaction moisture: Between 1% below and 3% above optimum water content.
12. Miscellaneous fill:
    a. Maximum lift thickness: 12 inches, 6 inches if compacted with hand-operated equipment.
    b. Compaction: Not less than 98% relative compaction in accordance with ASTM D 698.
    c. Compaction moisture: Between 1% below and 3% above optimum water content.
13. Filter sand:
    a. Maximum lift thickness: 9 inches.
    b. Compaction: Between 60% and 70% relative density in accordance with ASTM D 4253 and ASTM D 4254.
    c. Compaction moisture: Compact at in-situ, stockpile, or saturated water content. Modify as requested by the ENGINEER.
    d. Provide zone width or thickness equal to or greater than the minimal neat line dimension shown on the Drawings.
    e. Use placement procedures to prevent contamination of filter sand by adjacent materials.
    f. Do not over compact filter sand and cause the breakdown of particles.
    g. Cover completed portions of filter sand with at least 1 foot of the required overlying material within 3 days of placing filter sand.
    h. Protect filter sand against damage and contamination. Remove and replace any filter sand material that is contaminated or damaged.
    i. Maintain placement of filter sand between 6 inches and 12 inches above the placement surface for adjacent materials.
    j. Where necessary, cross filter sand with construction traffic at a limited number of crossings. Place geotextile between filter sand and road crossing material. Protect from contamination and repair any damage. Remove geotextile and road crossing material prior to resuming fill placement.
14. Drain gravel:
    a. Maximum lift thickness: 6 inches.
    b. Compaction: 3 passes of a vibratory plate compactor as specified in this Section.
    c. Compaction moisture: Compact at in-situ, stockpile, or saturated water content. Modify as requested by the ENGINEER.
    d. Provide zone width or thickness equal to or greater than the minimal neat line dimension shown on the Drawings.
    e. Use placement procedures to prevent contamination of drain gravel by adjacent materials.
    f. Do not over compact drain gravel and cause the breakdown of particles.
    g. Cover completed portions of drain gravel with at least 1 foot of the required overlying material within 3 days of placing the final lift of drain gravel.
    h. Protect gravel against damage and contamination. Remove and replace any gravel that is contaminated or damaged.
    i. Where necessary, cross drain gravel with construction traffic at a limited number of crossings. Protect from contamination and repair any damage during the removal of the traffic crossing.

D. Pipe Backfill for Drain Pipe:
1. Hand-grade to a uniform surface and check grade and correct irregularities in the drain gravel.
2. Loosen the top 1 inch to 2 inches of compacted material with a rake or by other means to provide a cushion before laying each section of pipe.
3. Excavate shallow holes in drain gravel at coupling locations to permit the proper assembly and inspection of joints and to provide uniform support along the barrel of pipe.

4. Backfill pipe as shown on the Drawings. Restrain pipe as necessary to prevent movement during backfilling. Placing and compacting material shall be in maximum 6 inch lifts on both sides of pipe. Maintain the top of fill within 2 inches on both sides of pipe.
5. Continue placement and hand-compacting material evenly on both sides of pipe until at least 24 inches of material has been placed over pipe.

E. Marking Tape Installation: Continuously install marking tape along the centerline of buried pipes and conduits on the top of the overlying filter sand.

F. Maintenance of Trench Backfill: After each section of trench is backfilled, maintain the surface of the backfilled trench even with adjacent ground surface until final surface restoration is completed.

G. Fill Under and Backfill Around Structures:
1. Required within 3 feet of structures, instrumentation, and pipes.
2. Place fill under structures in maximum 6 inch thick lifts.
3. Place backfill around structures and instruments in maximum 6 inch thick lifts. Use hand-operated or walk-behind compaction equipment within 5 feet of walls, footings, and instruments. Stop backfill at the required grade; make allowance for topsoil and other fills where required.

3.4 QUALITY CONTROL

A. General: As specified in SECTION 01 45 29.

B. Gradation Tests:
1. Perform as necessary to locate acceptable sources of imported material.
2. Prior to importing materials, provide certified QC test results for imported material.
3. During the production of imported materials, provide tests as specified.
4. The ENGINEER may perform gradation tests to verify submitted material.

C. Tests:
1. Perform water content, field density, gradation, and other tests during the blending of materials and during the fill placement as needed to develop and manage operations and produce consistent fill and backfill meeting the Specifications and the minimum testing frequencies specified.

3.5 ADJUSTING

A. Replace evacuation carried below grade lines shown on the Drawings or established as follows:
1. Beneath fill or backfill: The same material as specified for overlying fill or backfill.
2. Beneath filter drain: Materials that are filer compatible with the filter drain and underlying foundation materials.

B. Site Grading:
1. Perform earthwork to the lines and grade shown on the Drawings or established by the ENGINEER with proper allowance for topsoil as required.
2. Shape, trim, and finish slopes of channels to conform to the lines, grades, and cross-sections shown on the Drawings.
3. Slopes shall be free of exposed roots and stones that exceed 3 inches in diameter that are loose and liable to fall.
4. Round the tops of banks to circular curves not less than a 6 foot radius.
5. Neatly and smoothly trim rounded surfaces.
6. Neatly blend grading into the surrounding, existing terrain.

END OF SECTION

SECTION 31 23 23
FILL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for fill.

B. Related Sections:

1. SECTION 01 40 00 – QUALITY REQUIREMENTS
2. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE
3. SECTION 31 23 13 – SUBGRADE PREPARATION
4. SECTION 31 23 33 – TRENCH BACKFILL
5. SECTION 32 11 23 – AGGREGATE BASE COURSE

1.2 REFERENCES

A. ASTM International (ASTM):

1. C 33 – Standard Specification for Concrete Aggregates
2. D 75 – Standard Practice for Sampling Aggregates
3. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
4. D 1556 – Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
5. D 4253 – Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
6. D 4254 – Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
7. D 4643 – Standard Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating
8. D 6913 – Standard Test Methods for Particle-Size Distribution (Gradation) of Soil Using Sieve Analysis
9. D 6938 – Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. Colorado Department of Transportation (CDOT):

1. Standard Specification for Road and Bridge Construction

1.3 DEFINITIONS

A. Borrow Material: Material from required excavations or from designated borrow areas on or near the site.

B. Certified/Certification: Prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

C. Compaction:

1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D 698.
2. Verification that the proper ASTM D 698 Proctor Curve is being used for the individual test may require collecting a soil sample from the location of the test for running of a one-point Proctor Test to correlate to the full Proctor Curve. This verification shall be done on soil materials other than imported materials that have been processed through a controlled screening process for consistency.
3. Apply corrections for oversize material to as-compacted field dry density or maximum dry density, as determined by the ENGINEER.

D. Completed Course: Course or layer ready for the next layer or next phase of Work, free from irregularities with a smooth, tight, even surface, true rolling, and cross-section.

E. Embankment Material: Fill materials required to raise existing grade in areas other than under structures and pavements.

F. Fines: Materials passing No. 200 sieve as determined in accordance with ASTM D 6913.

G. Imported Material: Materials obtained from sources off-site that are suitable for specified use.

H. Influence Area: The area within planes sloped downward and outward at a 60 degree angle from horizontal measured from 5 feet outside the proposed structure lines as shown on the Drawings.

I. Lift: The loose, uncompacted, layer of material.

J. Moisture Content: In place moisture content of fill material being compacted in accordance with ASTM D 4643.

K. Optimum Moisture Content: Moisture content in accordance with ASTM D 698.

L. Relative Density: Calculated in accordance with ASTM D 1556 based on the maximum index density determined in accordance with ASTM D 4253 and the minimum index density determined in accordance with ASTM D 4254.

M. Selected Backfill Material: Materials that may be available on-site that the ENGINEER determines to be suitable for specific use.

N. Structural Fill: Fill materials as required under and around structures and pavements.

O. Well-Graded: A good representation of particle sizes from largest to smallest.

1.4 SEQUENCING AND SCHEDULING

A. Backfill against concrete structures only after concrete has attained 100% of design compressive strength as specified in SECTION 03 30 00.

B. Ensure that walls retaining earth are shored, or supporting elements are in place prior to placing backfill.

C. Backfill around underground structures only after the completion of waterproofing and joint sealant.

1.5 SUBMITTALS

A. Samples:

1. Imported material taken at the source and collected in accordance with ASTM D 75.
2. Specified material from each source: Minimum of 30 lbs of each.
3. Clearly mark to show the source of the materials intended use and include a hard copy of the Submittal and gradation, if applicable.

B. Quality Control Submittals:
   1. Certified test results and the name and location of the source for each imported material.
   2. Submit a gradation analysis from the production of imported material dated within 1 year.

1.6 QUALITY ASSURANCE

A. Notify the ENGINEER in writing when:
   1. The foundation excavation and subgrade preparation for foundation has been completed.
   2. The structure is ready for backfilling, and whenever backfilling operations are initiated or resumed after a period of inactivity.
   3. Soft or loose subgrade materials are encountered wherever embankment or site fill is to be placed.
   4. Fill material deviates from the Contract Documents.
   5. Fill is about to be placed on a prepared subgrade or when fill operations are resumed after a period of inactivity.
   6. The initial sampling of the imported material source is to be conducted or the importing of material to the site is to begin.

B. Environmental Requirements: Do not place fill or backfill if fill or backfill material is frozen or if the surface upon which fill or backfill is to be placed is frozen.

PART 2 PRODUCTS

2.1 MATERIALS

A. Earthfill:
   1. Suitable for use as backfill and free from rocks larger than 3 inches, from roots and other organic matter, asphalt, concrete, ashes, cinders, trash, debris, and other deleterious materials.
   2. Minimum of 50% by dry weight shall pass No. 4 sieve.
   3. Finely divided and free of masses of moist, stiff clays.

B. CLSM: As specified in SECTION 31 23 33.

C. Structural Fill: CDOT Class 1 Structural Fill.

D. Clay Fill:
   1. Relatively impervious silty to clayey sand with more than 35% passing the No. 200 sieve to a lean clay with varying sand content.
   2. Material shall be capable of sustaining vegetation.
   3. No bedrock material shall be used.

E. Aggregate Base Course: CDOT Class 6, aggregate base course as specified in SECTION 32 11 23.

F. Stabilization Rock: Clean washed, size No. 4 coarse aggregate in accordance with ASTM C 33. For areas where greater stabilization efforts are anticipated/required, use clean washed uniformly graded rock material up to 6 inches to 12 inches in size.

G. Controlled Low Strength Material: As specified in SECTION 31 23 33.

PART 3 EXECUTION

3.1 GENERAL

A. Subgrade Preparation: As specified in SECTION 31 23 13.

B. Keep placement surfaces free of water, debris, and foreign material during the placement and compaction of fill and backfill materials.

C. Place and spread fill and backfill materials in horizontal lifts of uniform thickness in a manner that avoids segregation and compact each lift to specified densities prior to placing succeeding lifts.

D. Slope lifts only where necessary to be in accordance with final grades or as necessary to keep placement surfaces drained of water.

E. During filling and backfilling, keep the level of fill and backfill even around each structure.

F. Do not operate earthmoving or compaction equipment other than hand-operated equipment within 5 feet of walls or concrete structures for the purpose of depositing or compacting backfill material.

G. If pipe, conduit, ductbank, or cable is to be laid within fill or backfill:
   1. Fill or backfill to an elevation 2 feet above the top of the item to be laid.
   2. Excavate trench for the installation of the item.
   3. Install bedding, if applicable, as specified in SECTION 31 23 33.
   4. Install item.
   5. Backfill the envelope zone and remaining trench, as specified in SECTION 31 23 33, before resuming the filling or backfilling that is specified in this Section.

H. Tolerances:
   1. Final lines and grades: Within ±0.10 foot unless dimensions or grades are shown on the Drawings or specified otherwise.
   2. Grade to establish and maintain slopes and drainage as shown on the Drawings.
   3. Reverse slopes are not permitted.

I. Correct the settlement of fill and backfill material and damage to structures, pavements, curbs, slabs, piping, and other facilities that results from Work.

3.2 PREPARATION

A. Moisture Control:
   1. During compacting operations, maintain the optimum practicable moisture content required for compaction purposes in each lift of fill.
   2. Insofar as practicable, add water to material at the site of excavation.
   3. Supplement, if required, by sprinkling fill.

4. Fill materials shall be compacted at moisture contents within two percentage points of the optimum moisture content for predominantly granular materials and within zero and plus three percentage points of optimum for predominantly cohesive materials.
5. Do not attempt to compact fill material that contains excessive moisture.
6. Remove or rework material that becomes too wet.
7. Aerate material by blading, discing, harrowing, or other methods to promote the drying process.

3.3 INSTALLATION

A. Compaction:
1. Compact materials under and around structures by mechanical means.
2. Compact fill in maximum lifts of 8 inches. Where hand-operated tampers or similar equipment is used for compaction, maximum lifts shall be 4 inches.
3. If compaction tests indicate that compaction or moisture content does not meet the specified requirements, terminate the material placement and take corrective action prior to continued placement.

B. Fill Under Structures:
1. Fill to slab or footing bearing elevation: Compact each lift to a minimum 98% maximum dry density as determined in accordance with ASTM D 6938 and ASTM D 698, with one-point Proctor on the sample from the field test location to verify correlation with the Proctor Curve being used; at the ENGINEER’s discretion.

C. Backfill Not Under Structures:
1. Backfill adjacent to structures:
   a. Backfill retaining and structure walls with structural fill, to an elevation within 2 feet of the finished grade and to a minimum horizontal distance equal to the depth of the backfill from footing, or to limits of excavation, whichever is less.
   b. The upper 2 feet of backfill over the structural fill shall be made of a clay cap material (at least 50% passing the No. 200 sieve).
   c. Compact each lift to a minimum 95% maximum dry density as determined in accordance with ASTM D 6938 and ASTM D 698.
   d. Make an allowance for 6 inches of topsoil surfacing and slope for protection where required.
2. Place earthfill (including embankment fill):
   a. In areas not designated or specified otherwise.
   b. Compact each lift to a minimum 95% maximum dry density as determined in accordance with ASTM D 6938 and ASTM D 698.
   c. Stop backfill at specified grade.
   d. Make an allowance for 6 inches of topsoil surfacing and slope for protection where required.

D. Fill beneath pavement, curb and gutter, parking areas, asphalt, and slabs on grade not covered above or dictated by a permitting jurisdiction shall be compacted to a minimum 98% maximum dry density as determined in accordance with ASTM D 6938 and ASTM D 698.

3.4 QUALITY CONTROL

A. General: As specified in SECTION 01 40 00.

B. Gradation Tests:
1. Perform as necessary to locate acceptable sources of imported material.
2. During the production of imported material, the performance of testing will be dependent upon the consistency of material sources.
3. The ENGINEER may perform to verify submitted material.

C. Tests:
1. The ENGINEER will take samples and perform moisture content, gradation, and compaction tests during the placement of backfill materials to check compliance with the Contract Documents.
2. Remove surface material at locations designated by the ENGINEER and provide such assistance as necessary for sampling and testing.
3. The ENGINEER may direct the CONTRACTOR to construct inspection trenches in compacted or consolidated fill or backfill to determine compliance with the Contract Documents.

D. Frequency:
1. Field and laboratory tests will be made at intervals determined by the ENGINEER on samples of compacted material at locations to ascertain that moisture content and density requirements are being met.
2. Inform the ENGINEER of the progress of Work so tests may be taken in accordance with the schedule.
3. Each layer of compacted material may be tested for moisture content and density:
   a. As determined by the ENGINEER.
   b. In areas where the ENGINEER is doubtful that compaction is sufficient.

E. Test Results:
1. The ENGINEER will expedite laboratory testing so results will be available as soon as possible.
2. The majority of test results will be available within one day after the initial field testing; however, some test results may take 2 days to receive.
3. Field data may be available immediately after field testing of imported material with existing Proctor Curves; however, the CONTRACTOR bears the sole responsibility for the interpretation of that data. Acceptance is based on the laboratory testing of moisture content and the one-point Proctor verification when necessary.
4. Any material represented by test results that does not meet the Specification requirements shall be removed or reworked back to the closest passing test result location in accordance with the Contract Documents immediately upon the receipt of test results.

5. Costs for reworking material and retesting to meet the Contract Documents shall be at the CONTRACTOR's sole expense.

3.5 ADJUSTING

A. Replace excavation carried below grade lines shown on the Drawings or established as follows:
   1. Beneath footings: Structural fill.
   2. Beneath fill or backfill: The same material as specified for overlying fill or backfill.
   3. Beneath slabs-on-grade: Structural fill.
   4. Trenches:
      a. Unauthorized over-excavation: Stabilization rock or granular pipe base material, as specified in SECTION 31 23 33.
      b. Authorized over-excavation: Stabilization rock, as specified in SECTION 31 23 13 and this Section.
   5. Permanent cut slopes where overlying area is not to receive fill or backfill.

B. Site Grading:
   1. Perform earthwork to lines and grade as shown on the Drawings or established by the ENGINEER with proper allowance for topsoil as required.
   2. Shape, trim, and finish slopes of channels in accordance with the lines, grades, and cross-sections shown on the Drawings.
   3. Slopes shall be free of exposed roots and stones that exceed 3 inches in size that are loose and liable to fall.
   4. Round the tops of banks to circular curves not less than a 6 foot radius.
   5. Neatly and smoothly trim rounded surfaces.
   6. Neatly blend grading into the surrounding, existing terrain.
   7. Over-excavating and backfilling to proper grade is not acceptable.
   8. Finished site grading is subject to review and approval by the ENGINEER.

END OF SECTION

SECTION 31 23 33
TRENCH BACKFILL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for trench backfill.

B. Related Sections:

1. SECTION 31 23 13 – SUBGRADE PREPARATION
2. SECTION 31 23 19 – DEWATERING
3. SECTION 31 23 23 – FILL

1.2 REFERENCES

A. ASTM International (ASTM):

1. C 33 – Standard Specification for Concrete Aggregates
2. C 131 – Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
3. C 136 – Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
4. C 150 – Standard Specification for Portland Cement
5. C 231 – Standard Test Method for Air Content of Freshly Mixed Concrete by the Pressure Method
6. C 260 – Standard Specification for Air-Entraining Admixtures for Concrete
7. C 494 – Standard Specification for Chemical Admixtures for Concrete
8. C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
9. C 796 – Standard Test Method for Foaming Agents for Use in Producing Cellular Concrete Using Preformed Foam
10. C 869 – Standard Specification for Foaming Agents Used in Making Preformed Foam for Cellular Concrete
11. C 1260 – Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)
12. C 1602 – Specification for Mixing Water Used in the Production of Hydraulic Cement Concrete
13. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
14. D 1140 – Standard Test Methods for Determining the Amount of Material Finer than 75-μm (No. 200) Sieve in Soils by Washing
15. D 1556 – Standard Test Method for Density and Unit Weight of Soil in Place by Sand-Cone Method
16. D 4253 – Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
17. D 4254 – Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
18. D 4832 – Standard Test Method for Preparation and Testing of Controlled Low Strength Material (CLSM) Test Cylinders
19. D 6938 – Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. Metropolitan Government Pavement Engineers Council (MGPEC):

1. Pavement Design Standards and Construction Specifications Manual

1.3 DEFINITIONS

A. Base Rock: Granular material upon which manhole bases and other structures are placed.

B. Bedding Material: Granular material upon which pipes, conduits, cables, or ductbanks are placed.

C. Compaction: As specified in SECTION 31 23 23.

D. Granular Soil: A free-draining, well-graded, non-expansive, non-cohesive soil comprised of gravel, sand, and silt with less than 5% passing the No. 200 sieve.

E. Imported Material: As specified in SECTION 31 23 23.

F. Lift: As specified in SECTION 31 23 23.

G. Moisture Content: As specified in SECTION 31 23 23.

H. Optimum Moisture Content: As specified in SECTION 31 23 23.

I. Pipe Zone: The backfill zone that includes the full trench width and extends from the prepared trench bottom to the upper limit above the top outside surface of the pipe, conduit, cable, or ductbank.

J. Prepared Trench Bottom: The graded trench bottom after the stabilization and installation of bedding material.

K. Relative Density: As specified in SECTION 31 23 23.

L. Selected Backfill Material: As specified in SECTION 31 23 23.

M. Structural Fill: As specified in SECTION 31 23 23.

N. Well-Graded: As specified in SECTION 31 23 23.

1.4 SUBMITTALS

A. Samples – Minimum of 30 lbs of each:

1. Stabilization rock.
2. Bedding and pipe zone material.
3. Granular drain.
4. Granular backfill.
5. Earth backfill.

B. Quality Control Submittals:

1. Certified gradation analysis: Imported materials or anticipated use for excavated materials.
2. Stabilization rock as needed.
3. CLSM test reports:
    a. Weight per cubic yard for each component of the mix.

b. Cement: Chemical analysis report.
c. Supplementary cementitious materials: Chemical analysis report and report of other specified test analyses.
d. A source test analysis report for fly ash.
e. Each trial mix design shall be signed by a qualified Mix Designer.
f. Compressive strength data from laboratory mixes.
g. Alkali aggregate reactivity: Aggregate shall be classified as innocuous as specified in this Section. Include documentation of test results in accordance with applicable standards.

1.5 QUALITY ASSURANCE

A. Notify the ENGINEER in writing when:
1. Backfill is to be placed in the trench or when backfill operations are resumed after a period of inactivity.
2. Pipe is ready for backfilling and whenever backfilling operations are resumed after a period of inactivity.
3. Soft or loose subgrade materials are encountered.
4. Fill material appears deviate from the Specifications.
5. The initial sampling of the imported material source is to be conducted or the importing of material to the Work site is to begin.

1.6 SITE CONDITIONS

A. Environmental Requirements:
1. Do not place fill or backfill if fill or backfill material is frozen or if the surface upon which the fill or backfill is to be placed is frozen.
2. Do not place CLSM against frozen ground; protect from freezing until surface moisture has evaporated.

PART 2 PRODUCTS

2.1 MATERIALS

A. Stabilization Rock: As specified in SECTION 31 23 23.
B. Granular Fill for Pipe Bedding – Bedding Sand (for 24 inch diameter and larger pipe):
1. Unfrozen, non-friable, and no clay balls, roots, or other organic material.
2. Clean or gravelly sand with less than 3% passing No. 200 sieve, in accordance with ASTM D 1140.
3. In accordance with the following limits when tested by means of laboratory sieves:

Sieve Size	**Total Passing by Sizes (Percentage by Weight)**
3/8 inch	100
No. 4	70 to 100
No. 8	36 to 93
No. 16	20 to 80
No. 30	8 to 65
No. 50	2 to 30
No. 100	1 to 10
No. 200	0 to 3

C. Granular Fill for Pipe Bedding – Squeegee (for smaller than 24 inch diameter pipe):
1. Unfrozen, non-friable, and no clay balls, roots, or other organic material.
2. Crushed material is not allowed.
3. Expanded clay lightweight aggregate is an acceptable alternative.
4. LA abrasion less than 30% in accordance with ASTM C 131.
5. Poorly graded rounded particles.
6. In accordance with the following limits when tested by means of laboratory sieves:

Sieve Size	**Total Passing by Sizes (Percentage by Weight)**
3/8 inch	100
No. 50	0 to 30
No. 100	0 to 10
No. 200	0 to 5

D. CLSM – Flow Fill:
1. General:
a. Compressive strength between 50 psi and 150 psi at 28 days when tested in accordance with ASTM D 4832.
b. RE, at 28 days, less than 1.5 when calculated by:

$$RE = \frac{W^{1.5} \times 104 \times C^{0.5}}{10^6}$$

Where: W=unit weight in pcf and C=28-day unconfined compressive strength.
c. The maximum lift thickness shall be 3 feet unless otherwise approved by the ENGINEER.
d. Provide adequate cure time for flow fill lifts before placing subsequent lifts above.
e. Any damage to pipes, structures, or soil failures caused by lifts that are too thick or inadequate cure times shall be repaired at the CONTRACTOR’s expense.

f. Cementitious materials:
   1) Cement: Type II portland cement in accordance with ASTM C 150.
   2) Fly ash: Class C or Class F, in accordance with ASTM C 618.
g. Aggregates:
   1) Grading and quality requirements in accordance with ASTM C 33.
   2) A maximum of 0.10% expansion in accordance with ASTM C 1260 for any aggregate product used in CLSM.
   3) Maximum aggregate size shall pass a 1-inch sieve.
h. Water: In accordance with ASTM C 1602.
i. Admixtures:
   1) Air entraining admixture in accordance with ASTM C 260 for concrete may be used in CLSM mix.
   2) Chemical admixtures that do not contain calcium chloride and are in accordance with ASTM C 494 for concrete may be used in CLSM mix.
   3) Compatible with cement and other admixtures in batch.

2. Pipe zone:
   a. Before placing CLSM, verify with the Corrosion Engineer that CP is adequate at transition areas from CLSM to soil.
   b. Maximum air content of 8%.
   c. Minimum slump of 7 inches.
3. Above pipe zone (frost zone):
   a. Material shall meet the requirements of local permitting jurisdiction.
   b. When local permitting jurisdiction does not have CLSM requirements or specifications, requirements of the MGPEC Pavement Design Standards and Construction Specifications Manual and herein shall control.
      1) Minimum air content of 6%.
      2) Slump range between 7 inches and 10 inches.

E. CLSM – Flash Fill:
   1. General:
      a. Flash fill mixes herein shall not be used as a wearing surface unless written approval from local permitting jurisdiction is obtained.
      b. Fly ash shall be in accordance with ASTM C 618, Type C or Type F.
      c. Air-entraining admixtures shall be in accordance with ASTM C 260.
      d. Water: In accordance with ASTM C 1602.
      e. Foaming agents shall be in accordance with ASTM C 869 and ASTM C 796.
      f. Minimum slump of 8 inches.
      g. RE, at 28 days, less than 1.5 when calculated by:

$$RE = \frac{W^{1.5} \times 104 \times C^{0.5}}{10^6}$$

Where: W=unit weight in pcf and C=28-day unconfined compressive strength.

   2. Pipe zone:
      a. Before placing CLSM, verify with the Corrosion Engineer that CP is adequate at transition from CLSM to soil.
      b. Compressive strength, 24 hours: 150 psi, minimum.
   3. Above pipe zone (frost zone):
      a. Material shall meet the requirements of local permitting jurisdiction.
      b. When local permitting jurisdiction does not have CLSM requirements or specifications, requirements of the MGPEC Pavement Design Standards and Construction Specifications Manual and herein shall control.
         1) Unconfined compressive strength, 28 day: 100 psi to 300 psi.
         2) Minimum air content for resistance to frost-heave of 15% when tested in accordance with ASTM C 231 or by volumetric calculation using the following equation:

$$\text{Air Content} = \frac{(\text{Unit Weight No Foam} - \text{Unit Weight Foamed}) \times 100\%}{\text{Unit Weight No Foam}}$$

PART 3 EXECUTION

3.1 GENERAL

A. Keep the placement surfaces free of water, debris, and foreign material during the placement and compaction of fill and backfill materials.

3.2 PREPARATION

A. Water Control: As specified in SECTION 31 23 19.
B. Remove foreign material and backfill that is contaminated with foreign material that falls into the trench.
C. Trench bottom preparation shall be as specified in SECTION 31 23 13.
   1. Firm subgrade:
      a. Grade with hand tools.
      b. Remove loose and disturbed material.
      c. Trim off high areas and ridges left by the excavating bucket's teeth.
      d. Allow space for bedding material.
      e. Compact over-excavated subgrade to a minimum 95% maximum density in accordance with ASTM D 6938 and ASTM D 698.

2. Soft subgrade:
   a. Notify the ENGINEER, in writing, if subgrade is encountered that may require removal to prevent pipe settlement.
   b. The ENGINEER shall determine the depth of over-excavation if required.

3.3 INSTALLATION

A. Stabilization Rock:
   1. Rebuild trench bottom with stabilization rock as specified in SECTION 31 23 13, as necessary.
   2. Place material over the full width of the trench in 6 inch thick lifts to the required grade providing allowance for bedding thickness.
   3. Compact each lift to provide firm, unyielding support for the bedding material prior to placing succeeding lifts.

B. Bedding:
   1. Furnish imported bedding material as specified herein.
   2. Place over the full width of the prepared trench bottom in equal lifts no greater than 8 inches thick when the required depth exceeds 8 inches.
   3. Hand-grade and compact each lift to provide a firm, unyielding surface.
   4. When not detailed on the Drawings, the minimum thickness shall be 6 inches.
   5. Check grade and correct irregularities in the bedding material.
   6. Install to form a continuous and uniform support except at bell holes, if applicable, or minor disturbances resulting from the removal of lifting tackle.
   7. Bell or coupling holes: Excavate in the bedding at each joint to permit the proper assembly and inspection of the joint and provide a uniform bearing along the barrel of pipe or conduit.

C. Backfill in Pipe Zone:
   1. Upper limit of pipe zone: If not detailed on the Drawings a minimum of 6 inches above the top of the pipe.
   2. Restrain pipe as necessary to prevent movement during backfill operations.
   3. Place material simultaneously in lifts on both sides of the pipe.
   4. Compaction – pipes 20 inches and larger in diameter:
      a. After the pipe has been adjusted for line and grade and the joint is made, place the remainder of the pipe zone material to the limits as shown on the Drawings.
      b. Compact bedding and pipe zone material by water jetting and vibrating to obtain a minimum 70% relative density in accordance with ASTM D 1556, ASTM D 4253, and ASTM D 4254.
      c. Take precautions to prevent flotation of the pipe.
      d. Pipe deflection:
         1) Install bedding and pipe zone material so that total pipe deflection in any direction does not exceed the Manufacturer's specified allowances for pipe, linings, or coatings for metallic pipe, or 4% of nominal diameter for PVC or other plastic pipe, whichever is more stringent.
         2) If allowable deflections are exceeded, remove pipe and bedding, replace bedding, and reinstall the pipe after the ENGINEER has observed the pipe and determined that no damage to the pipe, linings, or coatings has occurred.
         3) Perform removal and reinstallation at no additional expense to the OWNER.
         4) If, in opinion of the ENGINEER, pipe, linings, coatings, or other appurtenances have been damaged due to over-deflection, replace the damaged pipe, linings, coatings, and appurtenances at no additional cost to the OWNER.
         5) Make deflection using a mandrel or other approved means.
   5. Compaction – pipes smaller than 20 inches in diameter:
      a. Tamp each lift, including the area under the haunches, with handheld tamping bars supplemented by walking in and slicing material under the haunches with a shovel to ensure voids are completely filled before placing each succeeding lift.
      b. Compact material by a minimum of three passes with a vibratory plate compactor only over the area between the sides of the pipe and trench walls taking care not to damage the pipe.
      c. Do not use power-driven impact compactors to compact the pipe zone material.
      d. For pipe smaller than 20 inches in diameter that is installed in the same trench as pipe 20 inches or larger, compact the pipe zone material as specified for 20 inch in diameter and larger pipe.
   6. Concrete encasement of pipe:
      a. Discharge from a truck-mounted drum type mixer into trench.
      b. Place material within 3 feet of the desired final location.
      c. Place lifts as necessary to prevent the uplift of new and existing facilities.
      d. Fill the trench section labeled as bedding zone.
      e. Internally vibrate to obtain complete consolidation.

D. Backfill above Pipe Zone:
   1. General:
      a. Provide earthfill as specified in SECTION 31 23 23.
      b. Processed excavated material may be used with written approval of the ENGINEER.
      c. Adjust the moisture content as necessary to obtain the specified compaction.
      d. Do not allow backfill to free fall into the trench or allow heavy, sharp pieces of material to be placed as backfill until at least 2 feet of backfill has been placed over the top of the pipe.
      e. Do not use power-driven impact type compactors for compaction until at least 4 feet of backfill is placed over the top of the pipe.

f. Backfill to grade with proper allowances for topsoil, crushed rock surfacing, and pavement thicknesses, wherever applicable.
g. When a trench underlies or is next to structures, backfill around or under structures with the same class backfill as specified for the structure, unless otherwise shown on the Drawings or specified; use earthfill in all other locations.
2. Structural fill shall be compacted as specified in SECTION 31 23 23.
3. Limits and compaction: Backfill the trench to the limits shown on the Drawings or as required by excavation.

E. CLSM:
1. Verify adequate CP at transitions between CLSM and soil with the ENGINEER.
2. Use CLSM as pipe zone or backfill material with approval as required by permit or where specified. Use of CLSM to accelerate schedule or opening of roadway to traffic shall be at no additional cost to the OWNER.
3. Maximum lift thickness: 3 feet. Determine if smaller lifts are required to prevent floating of pipe or damage to adjacent structures.
4. Place under the pipe from one side so it flows under the pipe until it appears on the opposite side.
5. Deposit equally on both sides of the pipe until it fills the space around the pipe to the desired depth.
6. Each lift may require light vibration or rodding and shall be allowed to attain initial set before another lift is placed.
7. Allow CLSM to adequately set up before placing backfill above pipe zone to not cause damage to the pipe.

3.4 REPAIRS

A. Replacement of Topsoil:
1. Replace topsoil in the top 6 inches of the backfilled trench.
2. Maintain the finished grade of topsoil even with adjacent area and grade as necessary to restore drainage.

B. Maintenance of Trench Backfill:
1. After each section of trench is backfilled, maintain the surface of the backfilled trench even with adjacent ground surface until final surface restoration is completed.
2. Gravel surfacing rock:
a. Add where applicable to keep the surface of the backfilled trench even with the adjacent ground surface.
b. Grade and compact to keep the surface of backfilled trenches smooth, free from ruts and potholes, and suitable for normal traffic flow.
3. Topsoil: Add topsoil where applicable to maintain the surface of the backfilled trench level with the adjacent ground surface.
4. Other areas: Add excavated material where applicable and keep the surface of the backfilled trench level with the adjacent ground surface.

3.5 QUALITY CONTROL

A. Perform gradation analysis in accordance with ASTM C 136 for:
1. Earth backfill, including specified classes.
2. Stabilization rock.
3. Bedding and pipe zone material.

B. General:
1. Field and laboratory tests will be made by the ENGINEER on samples of compacted material to ensure moisture content and compaction are being met.
2. Notify the ENGINEER of the progress of Work so tests may be taken in accordance with the schedule.
3. The ENGINEER shall determine the locations for and frequency of samples.

C. Test Results:
1. The majority of test results shall be available within 1 day after initial field testing; however, some test results may take 2 days to receive.
2. Field data may be available to the CONTRACTOR immediately after field testing; however, the CONTRACTOR bears the sole responsibility for interpretation of that data. Acceptance is based on laboratory testing.
3. Any material represented by test results that does not meet the Specification requirements shall be removed or reworked in accordance with the Contract Documents immediately upon the receipt of test results.
4. Costs for reworking material and retesting to meet the Contract Documents shall be at the CONTRACTOR's sole expense.

3.6 ADJUSTING

A. Correct the settlement of fill and backfill material and damage to structures, pavements, curbs, slabs, piping, and other facilities that results from Work.

END OF SECTION

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SECTION 31 25 00
EROSION AND SEDIMENTATION CONTROL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for erosion and sedimentation control.

B. Related Sections:

1. SECTION 01 50 00 – CONSTRUCTION FACILITIES AND TEMPORARY CONTROLS
2. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
3. SECTION 31 23 19 – DEWATERING

1.2 REFERENCES

A. Colorado Department of Transportation (CDOT):

1. Erosion Control and Storm Water Quality Guide

B. Mile High Flood District (MHFD):

1. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices

1.3 SUBMITTALS

A. Shop Drawings:

1. Gravel gradation for construction entrances; tracking mat.
2. Storm drain inlet protection.

B. Quality Control Submittals:

1. Copies of permit applications.
2. SWMP.

1.4 QUALITY ASSURANCE

A. System Description: Design requirements: It is the intent that Work described herein is in accordance with MHFD Urban Storm Drainage Criteria Manual, Volume 3, the CDOT Erosion Control and Storm Water Quality Guide, CDPHE, and other jurisdictional requirements. In the event that a conflict occurs, provisions of the referenced Specifications shall control.

B. Colorado Water Quality Act:

1. The ENGINEER shall be responsible for:
   a. Preparation of the SWMP for the Work.
   b. The permit application as specified in SECTION 01 50 00.
   c. Receipt of the permit from CDPHE.
   d. The annual fee.
   e. Performance of a site inspection at least every 14 days, and after significant precipitation events.
2. Assume responsibility for conformation to the provisions of the permit and SWMP requirements.

1.5 WARRANTY

A. As specified in SECTION 01 60 00.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 GENERAL

A. Construction:

1. Install construction erosion and sedimentation control measures prior to commencing Work.
2. Plan and execute Work activities to control the surface drainage from earthwork, stockpile areas, and from borrow and waste disposal areas to prevent and control erosion and sedimentation, including:
   a. Minimizing the amount of bare soil exposed at any one time.
   b. Protecting disturbed areas as soon as possible.
   c. Limiting the area of disturbance.
   d. Surface roughening.

3.2 INSTALLATION

A. Construction Dewatering:

1. As specified in SECTION 31 23 19.
2. Do not directly introduce dewatering flows that carry sediment into a flowing body of water, storm sewer, or irrigation ditch.
3. Route dewatering flows to a sediment basin or traps prior to discharge to a body of water.
4. Protect properties and ROWs from sedimentation and erosion due to dewatering flows.

3.3 PROTECTION

A. Erosion and Sedimentation Control Measures:

1. Inspection:
   a. Periodically review erosion and sedimentation control measures for evidence of erosion and sedimentation as often as required by applicable standards.
   b. Promptly apply corrective measures to repair existing erosion, clean up existing sediment, and take measures to prevent continued erosion and sedimentation.
   c. In accordance with the best management practices of applicable regulatory agencies.
2. Maintenance: Maintain and modify erosion and sedimentation control measures as required including the temporary re-vegetation of stockpiles and soil areas subject to erosion.

3. Removal:
    a. Remove temporary erosion and sedimentation control measures and legally dispose of them within 30 days after final site stabilization is achieved, after erosion and sedimentation control measures are no longer required, or as directed by the ENGINEER.
    b. Perform the removal of erosion and sedimentation control measures in a manner as to prevent damage to completed Work and re-vegetated areas.
    c. Repair and stabilize damaged areas to prevent erosion and sedimentation.
    d. The ENGINEER may direct the CONTRACTOR to leave all or a portion of temporary erosion and sedimentation control measures in place until the Final Completion date.
    e. After review and acceptance of the Work, the OWNER will accept responsibility for subject measures.

END OF SECTION

SECTION 31 32 00
SOIL STABILIZATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for soil stabilization.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT

1.2 REFERENCES

A. ASTM International (ASTM):

1. C 593 – Standard Specification for Fly Ash and Other Pozzolans for Use with Lime for Soil Stabilization
2. C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
3. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3 (600 kN-m/m3))
4. D 5239 – Standard Practice for Characterizing Fly Ash for Use in Soil Stabilization
5. D 6938 – Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

B. Colorado Department of Transportation (CDOT):

1. CP-L2013 – Determining the Sulfate Ion Content in Water or Water-Soluble Sulfate Ion Content in Soil

1.3 DEFINITIONS

A. Activator: An additive to fly ash for soil stabilization. Class F fly ash is non-cementitious and requires an activator (lime or portland cement) to be added to the mix to provide the cementitious component required for soil stabilization. Class C fly ash is typically self-cementing and does not require an activator.

B. Delay Time: The elapsed time measured between when the fly ash first comes into contact with water and final compaction of the soil, fly ash, and water mixture.

C. Loss on Ignition: A test whereby a sample of the material is ignited at a specified temperature, allowing volatile substances to escape, until its mass ceases to change.

D. Pulvamixer: A road machine with a horizontal rotor turning in the opposite direction to the machine’s direction of travel that digs into the soil, mixing the fly ash thoroughly with the in-place soil.

1.4 SUBMITTALS

A. Product Data:

1. Fly ash source and Suppliers certificate of compliance with ASTM D 5239.
2. Job mix formula for each soil type, including the moisture content of soil prior to fly ash placement, and in-place density tests of fly ash treated soil.
3. Proposed plan for excavation, fly ash application, mixing, placement, and moisture control throughout the process.
4. Field application rate test.
5. Bituminous curing seal.
6. List of construction equipment for placement and mixing, prior to bringing equipment on-site.

1.5 QUALITY ASSURANCE

A. Required Data:

1. A job mix formula showing the amount of fly ash and water required per cubic yard and procedures for blending the soil-fly ash mixture for each type of existing soil to be stabilized shall be provided 10 days prior to the commencement of the Work.
2. At the same time, a list of equipment to be used and their relation to method of mixing, proportioning, blending, spreading, pulverizing, compacting subgrade, and other related Work.

B. Design Mix Requirements:

1. The optimum fines content for a job mix formula shall be 2% higher than the fines content at the maximum dry density as determined by a series of moisture density tests on samples created at the estimated optimum moisture from the soil to be used in the field and fly ash at varying concentrations.
2. The ratio of fly ash to aggregate determines the amount of matrix available to fill the void spaces between aggregate particles. Normally, fly ash contents range from 12% to 30% by dry weight of the total mix, but will vary based on the grading of the base soil.
3. At least 98% of the fly ash shall be finer than a 0.6 mm (No. 30) sieve and 70% finer than a 0.075 mm (No. 200) sieve in accordance with ASTM C 593.
4. Minimum compressive strength requirements for fly ash stabilized soils (without an activator) at 7 days and 21 days in accordance with ASTM C 593.
5. Fly ash used for soil stabilization does not have to meet the ASTM C 618 requirements of fly ash regarding loss on ignition.
6. Compressive strength: Compressive strength testing of fly ash stabilized soil mixtures is performed on Proctor-size specimens 4 inches in diameter by 4 1/2 inches in height, molded at the optimum moisture content of the mixture.

1.6 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00. Specific requirements in addition to SECTION 01 60 00 shall be as follows:

1. Deliver fly ash and bituminous materials in containers showing or including designated trade name, product identification, Specification number, Manufacturer's name, and source.
2. Store in closed, weatherproof containers such as a silo or pneumatic tanker until immediately before mixing in a plant, or before distribution for in-place mixing.
3. Discard fly ash exposed to moisture prior to mixing with the soils.

4. For fly ash furnished in trucks, each truck shall have the weight of fly ash certified on public scales, or a standard platform truck or hopper scale placed at a location approved by the ENGINEER.

1.7 SITE CONDITIONS

A. Stabilized materials shall develop a level of strength prior to the first freeze-thaw cycle. Strength development is time-dependent and temperature-dependent, and placement when the temperature conditions are below the specified limits is not allowed under any circumstance. Typically, October 15 is the cutoff date for fly ash treatment of soils in the Denver area.
   1. Do not construct subgrade when weather conditions detrimentally affect the quality of the materials. Do not apply fly ash unless the air temperature at ground level is at least 40°F in the shade and rising, the temperature shall remain above 40°F for at least 24 hours, and the temperature of the fly ash and soil is 35°F or higher.
   2. Do not place fly ash when it is foggy, rainy, or when the subgrade is frozen.
   3. The temperature of the fly ash treated soil for a minimum of 3 days after compaction shall be maintained above 50°F.

B. Remove and replace any damaged portion of the stabilized soil area that has been completed with new soil-fly ash material as specified in this Section.

1.8 WARRANTY

A. As specified in SECTION 01 60 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Coal Tar Emulsion:
   1. Neyra Industries, Jennite

2.2 MATERIALS

A. Fly Ash:
   1. Class C fly ash containing a minimum of 22% CaO.
   2. In accordance with the physical requirements of ASTM D 5239 and the chemical requirements of ASTM C 618 (except loss on ignition).
   3. Minimum compressive strength of 500 psi when tested at 7 days.
   4. Identify and obtain approval of the source from the ENGINEER to allow for compaction reference testing in accordance with ASTM D 698 prior to commencing soil stabilization.
   5. Class F fly ash is non-cementitious and may be used only if mixed with a cementitious reagent or activator such as lime or cement.

B. Soil:
   1. On-site or imported materials that are uniform in quality and gradation, as approved by the ENGINEER.
   2. Remove stones retained on a 2 1/2-inch sieve and deleterious and organic substances such as roots, sod, weeds, and debris.
   3. Sulfate content of soil to be stabilized shall be less than 3,000 ppm.

C. Water: Only potable is acceptable. Sulfate content shall be less than 500 ppm.

PART 3 EXECUTION

3.1 GENERAL

A. Supply, place, and protect a completed section of treated material which contains a uniform soil-fly ash mixture with no loose or segregated areas; has a uniform density and moisture content; is well bound for its full depth and with a smooth surface suitable for placing subsequent courses.

B. Work consists of disposing of unacceptable excavated materials, importing of acceptable materials, treating the soil subgrade by combining fly ash with the suitable soil subgrade material to the specified extents, and compacting the mixture to the specified moisture and density.

C. Regulate the sequence of the Work; process a sufficient quantity of material to provide a completed section as shown on the Drawings; use the proper amounts of fly ash; achieve final compaction within the specified time; maintain the Work; and rework the lifts as necessary to meet the requirements specified in this Section.

D. The blending or mixing of materials for a stabilized base can be accomplished either in a mixing plant or in-place. Plant mixing generally provides greater control over the quantities of materials batched and the production of a more uniform mixture. Plant-mixed materials shall be delivered to the jobsite as soon as possible after mixing and compaction shall be completed as quickly as possible after placement.

E. In-place mixing is also acceptable. The water and fly ash are delivered and spread on the area to be stabilized, mixed with the in-place soil, and compacted. The in-place method requires less handling of the in-place soils if imported material is not needed and less time for the mixture to set up during transport before placement and compaction can be completed.

3.2 PREPARATION

A. Clean debris from the area to be stabilized. Perform clearing and grubbing to a depth as shown on the Drawings.

B. Remove rocks larger than 3 inches. Inspect the original ground for adequacy for the forthcoming compactive effort of fly ash treatment Work.

C. Prior to beginning any fly ash treatment, the area where the fly ash stabilized material will be placed shall be cut and shaped in conformance with the lines and grades and/or cross-sections as shown on the Drawings, accounting for whether plant mixing, or in-place mixing is to be used.
   1. Grade control:
      a. When stabilized course is to be constructed to meet a fixed grade, provide adequate line and grade stakes for control.
      b. Finished and completed stabilized areas shall conform to the lines, grades, cross-section, and dimensions as shown on the Drawings.

c. Locate grade stakes in lines parallel to the center line of areas under construction, and suitably placed for string lining.
d. Maintain line and grade.

D. Subgrade areas beneath the stabilized soil zone shall be firm and able to support, without displacement, the construction equipment and the compaction hereinafter specified. Soft or yielding subgrade shall be corrected and made stable by scarifying, adding rock or fly ash, and compacting until it is of uniform stability.

3.3 INSTALLATION

A. Application Rate:
1. Typical fly ash application rates are 8% to 16% based on the dry weight of soil. The application rate depends on the nature of the soil, the characteristics of the fly ash, and the strength desired.
2. The application rate for fly ash shall be determined by a mix design prepared by the Geotechnical Engineer for the soil type at each location where fly ash stabilization is required.

B. Equipment:
1. The machinery, tools, and equipment necessary for proper execution of the Work shall be on the Project and approved by the ENGINEER prior to beginning construction operations.
2. Grading and scarifying shall be accomplished using a loader or dozer equipped for the required task.
3. Blending of the soil-fly ash mixture shall be accomplished by a direct hydraulic drive pulvamixer. The pulvamixer shall be equipped with a spray bar in the mixing drum capable of applying sufficient quantities of water to achieve the required moisture content.
4. Compaction shall be achieved using sheepsfoot or padfoot rollers. Rubber-tired rollers shall not be permitted except for finish rolling of the stabilized section.
5. Machinery, tools, and equipment used shall be maintained in a satisfactory and workmanlike manner.

C. Moisture Control:
1. Required moisture contents shall be established by the Geotechnical Engineer based on laboratory tests with the site soils and specific fly ash to be used for the treatment.
2. Final moisture content of the mix, immediately prior to compaction, shall not exceed the specified range of moisture content. If moisture contents exceed the specified limits, additional fly ash shall be added to lower moisture contents to the required limits.
3. Lowering moisture contents by aeration following the addition of fly ash is not allowed.
4. The moisture content of the soil used in soil-fly ash mixtures shall be maintained during stockpiling, if applicable. The moisture content of the soil shall be checked prior to mixing to ensure that excess moisture above optimum for the soil-fly ash mixture is not present.
5. Aside from possible adjustments to moisture content, there is little to no processing required for using fly ash in soil-fly ash mixtures. If a central-mix concrete plant is used, the fly ash shall be fed from a silo in dry form. If soil-fly ash materials are to be mixed in-place at the jobsite, the fly ash shall be applied dry to the area to be stabilized.
6. For Class C, self-cementing fly ashes, offset the rapid hardening of base materials by using a commercial retarder (such as gypsum or borax) blended at a low percentage with the fly ash as a means of delaying the initial set.
7. Moisture control at placement shall be achieved through use of a pulvamixer equipped with a spray bar in the mixing drum capable of applying sufficient quantities of water to achieve the required moisture content for the soil-fly ash mixture. The system shall be capable of being regulated to the degree necessary as to maintain moisture contents within the recommended range.
8. If used, Class F fly ash is typically placed and mixed in a conditioned form. Conditioned ash contains a minimal amount of water (usually 10% to 15%) to prevent dusting.
9. For Class F fly ash, the moisture content is dictated by the type of equipment to be used in producing the base course material. If a central-mix concrete plant is used, the fly ash shall be fed from a silo in dry form. If a pugmill mixing plant is used, the fly ash may be fed from a storage bin in conditioned form.
10. Activators (e.g., lime, portland cement) shall be added to the mixture in a dry form.

D. Delay Time:
1. Begin compaction immediately following the mixing and placement of the soil-fly ash mixture.
2. A maximum 90-minute delay time is allowed to ensure maximum strength of the soil-fly ash mixture. Delay time is critical due to the rapid reaction that occurs when Class C fly ash is mixed with water.
3. Both in-place density and compressive strength are significantly reduced with increasing delay time, particularly when Class C fly ash is used.

E. Application:
1. Application of the soil-fly ash mixture shall be limited only to those areas where mixing, placement, and compaction operations can be completed during the same day.
2. Immediately prior to the application of fly ash or in-place applications, the area shall be bladed to allow uniform distribution of fly ash. The fly ash shall be spread only on that area where the complete mixing, placement, and compaction operation can be completed within 90 minutes.
3. The fly ash shall be spread uniformly over the top of the subgrade by an approved screw-type auger spreader box or other approved spreading equipment. The amount of fly ash spread shall be the amount required for mixing to the specified depth which will result in the percentage determined in the job mix formula.
4. The fly ash shall be distributed at a uniform rate and in such manner as to keep the scattering of fly ash by wind to a minimum. Fly ash shall not be applied when wind conditions, in the opinion of the ENGINEER, are detrimental to a proper application or become objectionable to adjacent property owners. A motor grader shall not be used to spread the fly ash. Fly ash that has been displaced by construction traffic or other means shall be replaced or redistributed before mixing is started.

5. Plant-mixed materials shall not be stockpiled and shall be delivered to the jobsite and placed to the depth specified in the designated area as soon as possible after mixing. Compaction of the soil-fly ash materials shall be completed as quickly as possible after placement, especially with mixtures containing Class C fly ash.

F. Mixing In-Place:
1. During the in-place mixing operation, fly ash shall be placed on the prepared subgrade. If an activator is used, the activator is then placed on top of the fly ash, and the materials are then mixed together with a rotary pulvamixer.
2. The full depth of the treated subgrade shall be mixed with a rotary pulvamixer which utilizes a direct hydraulic drive. Fly ash shall not be left exposed for more than 90 minutes after application. The mixing machine shall make two coverages.
3. Water shall be added through use of a pulvamixer equipped with a spray bar in the mixing drum capable of applying sufficient quantities of water to achieve the required moisture content of the soil-fly ash mixture. The system shall be capable of being regulated to the degree as to maintain moisture contents within the range specified in the mix design.
4. Required moisture contents shall be established based on laboratory tests with the site soils and specific fly ash to be used for the treatment. Final moisture content of the mix, immediately prior to compaction, shall be in accordance with ASTM D 698 and shall be within 2% above or below the optimum moisture content for maximum density of the mix.
5. If moisture contents exceed the specified limits, additional fly ash may be added to lower the moisture content to the required limits. Lowering moisture contents by aeration following the addition of the fly ash shall not be permitted.
6. If the soil-fly ash mixture contains clods greater than 1 1/2 inch in size, they shall be reduced in size by additional pulverization.
7. The thickness of the fly ash treated material shall be determined by depth checks taken randomly by the ENGINEER. When the base thickness is deficient by more than 1/2 inch, correct such areas in a manner satisfactory to the ENGINEER, at no additional cost.

G. Placement:
1. For plant-mixed soil and fly ash, the materials shall not be placed in layers that are less than 4 inches or greater than 8 inches in compacted thickness. The material shall be spread in loose layers that are approximately 2 inches greater in thickness prior to compaction than the desired compacted thickness.
2. For in-place mixtures of soil and fly ash the maximum compacted thickness of each lift shall not exceed 8 inches. Where greater thickness of stabilized soil is required, the upper layer of existing, suitable soil shall be stockpiled until the remaining depth is no greater than 10 inches at the base of the stabilized area. The top of the excavated surface shall be prepared for application of fly ash as specified in this Section.
3. For stabilized sections greater than 8 inches in compacted thickness, each layer beneath the top lift shall have the top surface of the underlying layer scarified approximately 1/4 to 1/3 of the depth of the lower lift prior to placing the next lift.

H. Compaction:
1. Compaction of the soil-fly ash mixture shall begin immediately after mixing of the fly ash and shall be completed within 90 minutes following incorporation of fly ash. Compaction of the mixture shall continue until the entire depth of mixture is uniformly compacted to the specified density using sheepsfoot or padfoot rollers.
2. A test for both density and moisture content of the soil-fly ash mixture shall be taken for each 2,500 sf of material placed. The field density of the compacted mixture shall be at least 95% of the maximum density of laboratory specimens prepared from samples taken from material in-place. The laboratory specimens shall be compacted and tested in accordance with ASTM D 698. The moisture content shall be within 2% of optimum, as determined in the mix design.
3. The field density of the compacted mixture shall be at least 95% of the maximum density. Acceptance testing may be accomplished using a nuclear gauge in accordance with ASTM D 6938 using the Direct Transmission Method. Calibration and operation of the gauge shall be in accordance with the requirements of the Manufacturer. The operator of the nuclear gauge shall show evidence of training and experience in the use of the instrument. The gauge shall be standardized daily in accordance with ASTM D 6938.
4. Irregularities, depressions, or weak spots which develop shall be corrected immediately by scarifying the areas affected, adding or removing material as required, and remixing and re-compacting. The surface of the course shall be maintained in a smooth condition, free from undulations and ruts, until other Work is placed thereon, or the Work is accepted.
5. In addition to the requirements specified for density, the full depth of the material shown on the Drawings shall be compacted to the extent necessary to remain firm and stable under construction equipment. After each section is completed, tests will be made by the ENGINEER. If the material fails to meet the density requirements, it shall be reworked to meet these requirements.
6. Throughout the entire operation, the shape of the course shall be maintained by blading, and the surface upon completion shall be smooth and shall be in accordance with the typical section shown on the Drawings and to established lines and grades. If the material, due to any reason or cause, loses the required stability, density, and finish before the Work is accepted, it shall be reprocessed, re-compacted, and refinished at the sole expense of the CONTRACTOR. Reprocessing shall follow the same pattern as the initial stabilization including the addition of fly ash.

I. Finishing:
1. After compaction of fly ash treated subgrade, it shall be brought to the required lines and grades in accordance with the typical sections. The surface of finished treated material after compaction shall be the established graded plane.

2. The finished surface shall not vary by more than 1/2 inch when tested with a 16-foot straightedge applied in two perpendicular directions. Any variations in excess of this tolerance shall be corrected, at no additional cost, in a manner satisfactory to the ENGINEER.
3. Finish the completed section by rolling with a pneumatic or suitable roller sufficiently light to prevent hairline cracking. The finished surface of the fly ash treated subgrade shall be in a smooth condition free from rutting, bump, or dips.
4. Keep the surface of each compacted layer of treated material moist until covered by a subsequent layer of treated material or curing seal.
5. If loose edges are left, then remixing 4 inches into the previous day's compacted zone may be required provided that the method and equipment is acceptable to the ENGINEER.

J. Final Curing:
1. After placing and compacting the stabilized material, it shall be properly cured to protect against drying and to assist in the development of in-place strength. Where specified or shown on the Drawings, a coal tar emulsion seal coat shall be applied to the top surface of the base. Apply at least two applications uniformly to the top (final) layer of treated material, each at a rate of 0.10 to 0.11 gal/sy of surface.
2. Apply curing seal as soon as possible after completion of final rolling, before temperature falls below 40°F and within 24 hours of placement.
3. The performance of the stabilized material is dependent on the development of in-place strength following placement, compaction, and curing. Vehicles shall not be permitted to traverse the stabilized layer until it has achieved at least 350 psi compressive strength, in-place.

3.4 REPAIRS

A. Repairs shall be made to areas of the stabilized section when the surface is rutted or uneven, the material is loose (uncemented) or yields under pressure less than 75% of the 7-day design compressive strength, shows signs of pumping under equipment traffic loading, or is not to specified grade.
B. Repairs shall ensure restoration of a uniform surface and durability of the portion repaired and provide a continuous surface and level of support with the surrounding stabilized area that did not require repair.
C. Areas requiring repair shall be excavated to a depth of at least 12 inches to firm, stable material. If the soil at the bottom of the repair excavation is unstabilized soil, it shall be scarified to a depth of a minimum of 8 inches and re-compacted prior to placing the new mixture.
D. If the repair excavation does not penetrate through the stabilized layer, and the material below is firm and stable, the surface shall be cleared of any loose material, and the surface lightly roughened to enable a bond between the in-place material and the repair section.

3.5 PROTECTION

A. Maintain the completed soil-fly ash base in good condition, as to grade, crown, and cross-section until the surface course is constructed. Irregularities or other defects that may occur shall be immediately repaired by the CONTRACTOR at the CONTRACTOR's expense.
B. Maintain the fly ash treated subgrade in good condition until the completion of the Project. In the event of fly ash treated subgrade failure or damage during construction, remove and replace the damaged portion of material or repair as necessary.
C. After the fly ash treated course has been finished as specified herein, the surface shall be protected against rapid drying by one of the following methods for a period of not less than 3 days or until the overlying base material or the structure is placed.
   1. Apply an emulsified asphalt coating.
   2. Maintain in a thorough and continuously moist condition by sprinkling.
   3. Apply a 2 inch layer of earth on the completed course and maintain in a moist condition.
D. Keep traffic off surfaces freshly treated with bituminous material.
E. Provide warning signs and barricades so that traffic will not travel over freshly treated surfaces. Do not permit equipment or traffic on treated material until subgrade stability is assured.
F. Maintain the finished surface until Work has been completed.
G. Provide drainage during the entire period of construction to prevent water from collecting or standing on the area to be stabilized.

3.6 QUALITY CONTROL

A. The ENGINEER will perform QC testing of the treated subgrade.
B. The ENGINEER will perform the following QC tests:
   1. Water soluble sulfate testing in accordance with CDOT CP-L2013 prior to fly ash application. If sulfate testing indicates concentration more than 0.2%, then in-place material shall be removed to the extents determined by the ENGINEER.
   2. Compressive strength; minimum strength shall be 350 psi at 7 days.
   3. Moisture density curve in accordance with ASTM D 698.
   4. Field moisture content and density testing in accordance with ASTM D 6938; minimum of 95% of maximum dry density and +1% to +2% of optimum moisture content in accordance with ASTM D 698 and firm and unyielding surface.
   5. The thickness of the fly ash treated subgrade shall be determined by depth tests or cores taken at intervals so that each test shall represent no more than 2,500 sf. The CONTRACTOR shall replace, at its expense, the soil/fly ash material where borings are taken for test purposes.

6. At final compaction, the fly ash and water content for each course of subgrade treatment shall be in accordance with the following tolerances relative to the mix design:
   a. Fly ash: +0% to 0.5%.
   b. Water: -1% to +2%.

C. Provide access and assistance for the OWNER's QC testing.

END OF SECTION

SECTION 31 37 00
RIPRAP AND SOIL RIPRAP

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for riprap.
- B. Related Sections:
  1. SECTION 31 23 13 – SUBGRADE PREPARATION

1.2 REFERENCES
- A. ASTM International (ASTM):
  1. C 136 – Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
  2. C 535 – Standard Test Method for Resistance to Degradation of Large-Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
  3. D 7012 – Standard Test Method for Compressive Strength and Elastic Moduli of Intact Rock Core Specimens under Varying States of Stress and Temperatures
- B. Colorado Department of Transportation (CDOT):
  1. Standard Specification for Road and Bridge Construction
- C. Mile High Flood District (MHFD):
  1. Urban Storm Drainage Criteria Manual
  2. Technical Specifications
  3. Figure MD-13B, Soil Riprap Typical Details

1.3 SCHEDULING AND SEQUENCING
- A. Prior to placing riprap bedding or riprap, complete subgrade preparation as specified in SECTION 31 23 13.

1.4 SUBMITTALS
- A. Shop Drawings: The description and location of proposed sources of riprap bedding and riprap.
- B. Quality Control Submittals:
  1. Test results:
     - a. Riprap and soil riprap: Provide certified results prior to importing to the Work site and during production at the request of the ENGINEER at least 14 days prior to placement in Work.
       - 1) Gradation.
       - 2) Abrasion resistance: In accordance with ASTM C 535.
       - 3) Unconfined compressive strength: In accordance with ASTM D 7012.
     - b. Riprap bed course material: Provide certified results in accordance with ASTM C 136 prior to importing to the Work site and during production at the request of the ENGINEER at least 14 days prior to placement in Work.
  2. Qualifications:
     - a. A minimum of 3 years of documented experience in the Work of this Section and the documented successful completion of three projects of similar size using the proposed riprap under similar service conditions.
     - b. Approved by the Manufacturer.
- C. Administrative Submittals: Trip tickets showing the source, type, and weight of each load of material delivered to the site.

1.5 QUALITY ASSURANCE
- A. Riprap and Soil Riprap Source: A quarry producing riprap and performing satisfactorily on other projects for a minimum of 3 years.

PART 2 PRODUCTS

2.1 MATERIALS
- A. Bed Course Material: Imported; in accordance with CDOT Standard Specification for Road and Bridge Construction, Section 703.07, and free of deleterious materials.
- B. Riprap:
  1. Imported; in accordance with CDOT Standard Specification for Road and Bridge Construction, Section 506.02 for the d50 stone size shown on the Drawings.
  2. Import from the same source and similar lithologic rock type and color; recycled concrete rubble or other man-made materials are not allowed.
  3. Gradation: Smaller pieces shall generally fill voids between larger pieces without excess or deficiency of one or more sizes of stone.
- C. Soil Riprap:
  1. Imported; in accordance with MHFD Urban Strom Drainage Criteria Manual, Chapter 8.2.2; type as shown on the Drawings, see Figure 8-34.
  2. The bulk density for the boulder shall be 1.3 ton/cy or greater.

PART 3 EXECUTION

3.1 INSTALLATION
- A. Bed Course Material:
  1. Place over the prepared foundation to the lines and grades shown on the Drawings.
  2. No mechanical compaction is required; however, work bedding as necessary to distribute material and eliminate detrimental voids; avoid overworking or long pushes that result in the segregation of particle sizes.
  3. Grade the surface free from irregularities and to ±0.2 foot from the established grade.
  4. Place and grade in a manner that avoids subgrade disturbance; do not push material down-slope.

B. Placing Riprap on Bed Course Material:
   1. In accordance with CDOT Standard Specification for Road and Bridge Construction, Section 506.03, except as modified herein.
   2. Place to the lines, grades, and thicknesses shown on the Drawings.

C. Soil Riprap:
   1. Place in accordance with MHFD Urban Storm Drainage Criteria Manual, Chapter 8.2.2, Figure 8-34 and MHFD Figure MD-13B.
   2. In accordance with MHFD Technical Specifications, Section 31 37 00 3.02.C.

END OF SECTION

SECTION 31 73 00
TUNNEL GROUTING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for tunnel grouting.

1.2 REFERENCES

A. American Petroleum Institute (API):
   1. 13A – Specification for Drilling Fluids Materials

B. ASTM International (ASTM):
   1. C 144 – Standard Specification for Aggregate for Masonry Mortar
   2. C 150 – Standard Specification for Portland Cement
   3. C 494 – Standard Specification for Chemical Admixtures for Concrete
   4. C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
   5. C 827 – Standard Test Method for Change in Height at Early Ages of Cylindrical Specimens from Cementitious Mixtures

1.3 DEFINITIONS

A. Contact Grouting: The controlled injection of fluid grout at the interface between tunnel liner plates or casing pipe and the ground.

1.4 SUBMITTALS

A. Pre-Construction:
   1. A detailed description of the grouting operation including:
      a. Procedures for monitoring grout placement and controlling pressures.
      b. Grout material and properties.
      c. Grout mix design including fluidizers, accelerators, and other additives.
      d. Grout material properties including density, viscosity, bleeding, shrinkage, expansion, and set time.
      e. The Grout Manufacturer’s instruction. Mixing and installation instructions including data on water volume, workability, setting times, and temperatures.
   2. The proposed method of verifying that voids have been successfully grouted.

B. Construction:
   1. Grout logs; within 1 day of grouting, submit field logs containing as a minimum:
      a. A description of injection points using stationing along the tunnel and degrees clockwise looking up station from the crown.
      b. The volume of grout take at each injection point.
      c. The maximum sustained pressure at each injection point.
      d. Grout time for each hole from beginning to end of injection.
      e. Grout sequence and stages, both longitudinal to and in a cross-section of the tunnel.
      f. Grout equipment and setup including, as a minimum, mixers, pumps, agitators, circulation or deliver circuit, and gauges.
      g. Grout mix pumped.

1.5 QUALITY ASSURANCE

A. Performance Requirement: Determine contact grouting equipment, materials, and methods subject to the limitations specified herein and elsewhere in the Contract Documents. Ensure that the tunnel’s final lining, utilities, and other facilities are not damaged by contact grouting operations.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Dry Pack Mortar:
   1. Sika Corporation, SikaRepair 223
   2. Williams Form Engineering Corporation, Wil-X Cement Grout, mixed with sand

2.2 MATERIALS

A. Grout:
   1. Stable colloidal suspension of cement, bentonite, water, fluidifier, and admixtures. Sand may be added provided the grout is demonstrated to have suitable flow characteristics; it may also be used to fill voids at the locations specified.
   2. Design the grout mix to achieve the material properties specified, to grout the tunnel and anticipated ground conditions, and to be compatible with the grouting equipment.
   3. Adjust the grout mix as necessary to address different tunnel and ground conditions.
   4. Unconfined compressive strength: Minimum 200 psi at 28 days; minimum 20 psi in 1 day.
   5. Adjust the w/cm of the grout as necessary to fill voids within the zone of grout influence; however, at all times the grout shall have a w/cm of between 1 to 1 and 3 to 1 by volume and a bentonite content of no more than 2%. No hole shall be completed with a w/cm above 1 to 1 by weight.
   6. Grout shall not show shrinkage when tested in accordance with ASTM C 827.
   7. Grout components and the handling and storage of grout components including, but not limited to, cement, fly ash, bentonite, pozzolons, admixtures, and water shall be as specified in this Section and as recommended by the Manufacturer.
   8. Store bulk cement and fly ash in suitable moisture-proof enclosures. Cement and fly ash that have become caked or lumpy shall not be used.

9. Store sand in a manner that prevents segregation and the inclusion of foreign materials. The bottom 6 inches of sand piles in contact with the ground shall not be used.

B. Cement: In accordance with ASTM C 150, Type II, with less than 1% retained on the No. 200 sieve.

C. Fly Ash: In accordance with ASTM C 618.

D. Admixtures:

1. Grout admixtures shall be compounds possessing characteristics which will increase the flowability of the grout mixture, assist in dispersal of the cement grains, retard or accelerate the set time, minimize bleed voids in grout, and neutralize the setting shrinkage of the grout.
2. In accordance with ASTM C 494 and compatible with grout materials, including other admixtures.
3. Approved by the ENGINEER prior to use.

E. Fluidifier:

1. Fluidifier holds the solid constituents of the grout in colloidal suspension and is compatible with the cement, sand, gravel, and water used in the grouting program.
2. Fluidifier contains an expansive shrinkage compensator. Fluidifier shall not contain bentonite and other clay-like substances.
3. Approved fluidifiers: Calcium ligno-sulfonate and sodium ligno-sulfonate.
4. Storage: Furnish fluidifier in sealed containers and protect from moisture. Material that has become caked due to moisture adsorption will be rejected.

F. Dry Pack Mortar: A specially-proportioned mixture of Type II portland cement, sand, quick-setting admixture, and water, or an approved, commercially-manufactured mortar.

G. Water: Water used in drilling grout holes and preparing grout shall be potable, clean, and free from sewage, oil, acid, alkali, chlorides, salts, organic materials, and other impurities.

H. Bentonite: Pulverized or powdered premium grade natural sodium cation bentonite in accordance with API 13A with a minimum yield of 90 barrels per ton.

I. Sand: In accordance with ASTM C 144.

2.3 FABRICATION

A. Grout Ports: Locate 2 inch standard IP threaded pipe half couplings for contact grouting a minimum of every 4 feet along the pipeline alternating spring line and top of pipe.

PART 3 EXECUTION

3.1 GENERAL

A. The purpose of contact grouting is to fill voids completely behind tunnel liner plates and casing pipe to result in firm contact between the ground and the structural elements of the tunnel.

3.2 INSTALLATION

A. Equipment:

1. Controls and instrumentation:
   a. Grout flow: At the grout injection point, provide suitable valves and accurate pressure gauges so the pressure and grout flow at the grout holes may be monitored and regulated by increasing or decreasing the flow in the grout return line.
   b. Volume of grout: Provide means for accurately determining the amount of grout injected into each hole.
   c. Stop valves: Provide suitable stop, check, or ball valves at the collar of the hole for use in maintaining pressure as required until the grout has set.

B. Contact Grouting:

1. Inject contact grout through grout ports in liner plates or casing pipe to fill the annular space between the tunnel and the excavated ground.
2. Grouting behind liner plates shall follow as soon as practicable after liner plates are erected. At the end of a Work shift or when Work is interrupted for any reason, no liner plates shall be left ungrouted. Grouting shall follow progressively with each adjacent set of holes.
3. Grouting behind casing pipe shall immediately follow the jacking of casing pipe into its final position.
4. Grouting shall be performed over the entire 360 degree circumference of the tunnel.
5. Vent air and fluids (e.g., water, grout, and slurry) through the upper holes. Continue grouting until grout appears in the next set of grout holes which shall be kept open during grouting to permit the release of air and water.

C. Mixing and Injection of Grout:

1. Grout materials shall be free of lumps when put into the mixer and the grout mix constantly agitated. Screen grout before entering the pump. Grout shall flow unimpeded and shall completely fill voids. Grout that has not been injected after 90 minutes of mixing shall not be used.
2. Make connections for injecting grout at each grout fitting of the pipe as shown on the approved Shop Drawings at each grout connection. The injection of grout during any stage of grouting shall be performed continuously, filling the spaces and voids, and avoiding the disturbance of grout that has taken initial set. The grouting process shall be operated and controlled so that grout will be delivered uniformly and steadily.
3. Grouting shall progress from the grout hole in the sequence shown on the approved Shop Drawings.
4. Maintain grout injection pressure so as not to heave or deform the ground surface or leak grout onto the ground surface. Grout injection pressure shall be determined by the CONTRACTOR but in no case shall pressure exceed 1 psi per vertical foot of over burden cover.
5. Maintain grout injection pressure so as not to deform liner plates or casing pipe.

6. After the grouting of any grout pipe is finished, pressure shall be maintained by means of a ball or check valve or other suitable device until the grout has set to the extent that it will be retained in the hole.
7. After removing the packer or grout pipe, fill any void left with dry pack mortar. Replace grout plugs in the pipe at the completion of grouting. Dry pack mortar shall be used to fill any recesses.

3.3 PROTECTION

A. Take necessary precautions to protect and preserve the interior of the tunnel from damage. Any damage to the lining caused by or occurring during the grouting operations shall be repaired by a method approved by the ENGINEER at no additional cost to the OWNER. Minimize grout spills and clean-up immediately after grouting.

3.4 QUALITY CONTROL

A. Perform Work in the presence of the ENGINEER. Provide notification to the ENGINEER, in writing, 1 day in advance of the start of a grouting operation.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for aggregate base course.

1.2 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):
   1. M 147 – Standard Specification for Materials for Aggregate and Soil-Aggregate Subbase, Base, and Surface Courses

B. ASTM International (ASTM):
   1. C 535 – Standard Test Method for Resistance to Degradation of Large-Sized Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine
   2. D 75 – Standard Practice for Sampling Aggregates
   3. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
   4. D 4643 – Standard Test Method for Determination of Water Content of Soil and Rock by Microwave Oven Heating
   5. D 6913 – Standard Test Methods for Particle-Size Distribution (Gradation) of Soil Using Sieve Analysis
   6. D 6938 – Standard Test Method for In-Place Density and Water Content of Soil and Soil-Aggregate by Nuclear Methods (Shallow Depth)

C. Colorado Department of Transportation (CDOT):
   1. Standard Specification for Road and Bridge Construction

1.3 DEFINITIONS

A. Compaction:
   1. Ratio, in percent, of as-compacted field dry density to laboratory maximum dry density as determined in accordance with ASTM D 698.
   2. Verification that the proper ASTM D 698 Proctor Curve is being used for the individual test may require collecting a soil sample from the location of the test for running of a one-point Proctor Test to correlate to the full Proctor Curve.
   3. Apply corrections for oversize material to as-compacted field dry density or maximum dry density, as determined by the ENGINEER.

B. Completed Course: Course or layer ready for the next layer or next phase of Work, free from irregularities with a smooth, tight, even surface, true rolling, and cross-section.

C. Fines: Materials passing No. 200 sieve as determined in accordance with ASTM D 6913.

D. Lift: The loose, uncompacted, layer of material.

E. Moisture Content: In-place moisture content of fill material being compacted in accordance with ASTM D 4643.

F. Optimum Moisture Content: Moisture content in accordance with ASTM D 698.

1.4 SUBMITTALS

A. Samples:
   1. Imported material taken at the source and collected in accordance with ASTM D 75.
   2. Specified material from each source: minimum of 30 lbs of each.
   3. Clearly mark to show the source of the materials intended use and include gradation, if applicable.

B. Quality Control Submittals:
   1. Manufacturer’s data sheets for compaction equipment.
   2. Certified test results and the name and location of the source for each imported material.

C. Submit a gradation analysis from the production of imported material

1.5 QUALITY ASSURANCE

A. Notify the ENGINEER in writing when:
   1. The native or import material directly below the aggregate base course is properly prepared and ready for OWNERs QA testing. Minimum of 24 hours’ notice required.
   2. The final grade of aggregate base course is properly compacted and ready for OWNERs QA testing. Minimum of 24 hours’ notice required.
   3. Fill material deviates from the Contract Documents.
   4. Fill is about to be placed on a prepared subgrade or when fill operations are resumed after a period of inactivity.
   5. The initial sampling of the imported material source is to be conducted or the importing of material to the site is to begin.

B. Environmental Requirements: Do not place aggregate base course if material is frozen or if the surface upon which material is to be placed is frozen.

PART 2 PRODUCTS

2.1 MATERIALS

A. Aggregates:
   1. In accordance with CDOT Standard Specification for Road and Bridge Construction, Section 703, including the following:
      a. Aggregates for bases shall be crushed stone, crushed slag, crushed gravel, natural gravel, or crushed reclaimed concrete.
      b. Los Angeles wear test shall be less than 50% in accordance with ASTM C 535. The liquid limit shall be less than or equal to 30; the plasticity index shall not exceed 6.0.

B. Gradations:

Table 1	
Sieve Designation	Percentage by Weight Passing Square Mesh Sieves
	CDOT Class 6
1 inch	100
3/4 inch	95 to 100
No. 4	30 to 65
No. 8	25 to 55
No. 200	3 to 12

C. For pavement, curb and gutter, and sidewalks within the ROW, meet the more stringent requirements of the AHJ and this Section.

PART 3 EXECUTION

3.1 PREPARATION

A. Foundation:
1. The foundation shall be considered to be the finished earth subgrade, subbase course, or base course upon which any subbase, base, or surface course is to be constructed.
2. Preparation shall consist of the Work necessary to restore, correct, strengthen, or prepare the foundation to a condition suitable for applying and supporting the intended course.
3. The top 6 inches of topsoil shall be stripped within the area to be aggregate surfaced.
4. The upper 12 inches of subgrade shall be scarified and compacted to a minimum of 98% compaction in accordance with ASTM D 698.
5. On-site material may be used for compacted fill for aggregate base course if approved by the ENGINEER.
6. The foundation shall be prepared and constructed to have a uniform density. It shall be brought to the required alignment and cross-section with equipment and methods adapted for that purpose. Upon completion of shaping and compacting operations, the foundation shall be smooth, at the required density, and at the proper elevation and contour to receive aggregate base course.
7. Holes, ruts, and other depressions in the foundation shall be filled with materials similar to those existing in the foundation. High places shall be excavated and removed to the required line, grade, and section.
8. Areas of yielding or unstable material shall be excavated and backfilled with stabilization rock as determined by the ENGINEER. Base course material shall not be placed on a foundation that is soft, spongy, or covered by ice or snow. Base course shall not be placed on a dry or dusty foundation where the existing condition would cause rapid dissipation of moisture from the base course material and hinder or preclude its proper compaction. Apply water to dry foundations and rework and compact as necessary.
9. The ENGINEER will direct the CONTRACTOR to make minor adjustments in the finish grade from that shown on the Drawings as may be necessary or desirable to maintain the characteristics of a stabilized foundation by minimizing the amount of cutting into or filling.

B. Earth Subgrade:
1. When the foundation is an earth subgrade it shall be prepared by removing vegetation, excavating and removing materials, filling depressions, scarifying, shaping, moisture content, and smoothing and compacting to meet the required grade, section, moisture content, and density.
2. Stones greater than 3 inches shall be removed.

3.2 INSTALLATION

A. Aggregate base course shall be constructed to the width and section shown on the Drawings.

B. Material shall be installed in maximum lifts of 8 inches. Where hand-operated tampers or similar equipment is used for compaction, maximum lifts shall be 4 inches.

C. Each layer shall be constructed as far in advance of the successive layer as directed by the ENGINEER. The Work shall proceed from the point nearest the point of supply of aggregate so that hauling equipment travels over the previously placed material. Hauling equipment shall be routed as uniformly as possible over portions of the previously constructed courses or layers of the base course.

D. The material shall be deposited on the soil foundation or on the previously placed layer in a manner that minimizes segregation and facilitates spreading to a uniform layer of the required section. In the event that blending of materials is necessary to provide the required gradation and properties of the material, and is done in the roadway, the same shall be accomplished by mixing aggregate and blending material by means of blade graders, discs, harrows, or other equipment to effect a uniform distribution and gradation throughout the finished mixture. Excessive mixing and grading that causes segregation between the course and fine materials is prohibited.

E. Equipment:
1. Equipment shall be capable of performing the Work required by this Section. Inadequate equipment shall be replaced or supplemented.
2. Improperly used equipment shall be cause for rejection of Work if, in the opinion of the ENGINEER, the Work fails to meet the requirements of this Section.
3. Equipment used for compaction shall be the rolling type, the vibratory type, or a combination thereof and be of sufficient capacity to meet the compaction requirements herein.

F. Compaction:
1. After a layer or course is placed and spread to the required thickness, width, and contour, it shall be compacted. If the material is too dry to readily attain the required density, it shall be uniformly moistened to the degree necessary for proper compaction.
2. Compaction of each layer shall continue until the required density listed herein is reached. The surface of each layer shall be maintained during compaction operations in such a manner that a uniform texture is produced and aggregates are firmly keyed.
3. In areas where proper compaction is not obtainable due to the segregation of materials, excess fines, or other deficiencies in aggregate, it shall be reworked as necessary or the material shall be removed and replaced with aggregates as specified in this Section.
4. The surface of each layer shall be kept true and smooth.
5. Where permitting jurisdiction does not stipulate compaction requirements for aggregate base course, place aggregate base course within 2% of optimum moisture content and compact to a minimum of 98% compaction in accordance with ASTM D 698.
6. Compact each lift to a minimum compaction as specified herein determined in accordance with ASTM D 6938.

G. Mixing:
1. Mix aggregate by one of the following methods:
   a. Stationary plant method:
      1) Aggregate base course and water shall be mixed in an approved mixer.
      2) After mixing, the aggregate shall be transported to the Work site while it contains the proper moisture content. It shall then be placed on the roadbed by means of an approved spreader.
   b. Travel plant method: After the material for each layer has been placed through an aggregate spreader or window-sizing device, it shall be uniformly mixed by a traveling mixing plant.
   c. Road mix method: After material for each layer has been placed, it shall be mixed while at optimum moisture content by motor graders or other approved equipment until uniform.

END OF SECTION

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SECTION 32 11 24
RECYCLED ASPHALT AGGREGATE

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for recycled asphalt aggregate.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 32 11 23 – AGGREGATE BASE COURSE

1.2 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):

1. T 30 – Standard Method of Test for Mechanical Analysis of Extracted Aggregate
2. T 180 – Standard Method of Test for Moisture-Density Relations of Soils Using a 10-lb Rammer and 18-in Drop

1.3 SUBMITTALS

A. Samples: 30 lbs of processed recycled asphalt pavement.

B. Qualifications: Provide documentation showing laboratory and personnel certifications for the AASHTO T 30 and T 180 test method.

C. Quality Control Submittals: Laboratory tests.

D. The CONTRACTOR’s QC test reports for AASHTO T 30 and T 180 tests conducted at the frequency required herein.

1.4 WARRANTY

A. As specified in SECTION 01 60 00.

PART 2 PRODUCTS

2.1 MATERIALS

A. Recycled Asphalt Pavement Gradations:

1. The processed recycled asphalt pavement shall be 100% passing the 1 1/4-inch sieve. The aggregate obtained from the processed recycled asphalt pavement shall be 100% passing the 1-inch sieve.

B. Recycled Blend Pavement:

1. Non-paved roadways shall be a blend of 50% recycled asphalt pavement and 50% aggregate base course as specified in SECTION 32 11 23, unless otherwise noted.

PART 3 EXECUTION

3.1 PREPARATION

A. As specified in SECTION 32 11 23.

3.2 INSTALLATION

A. As specified in SECTION 32 11 23, except as modified herein.

B. Mix aggregate by one of the following methods:

1. Stationary plant method:
    a. Aggregate base course, recycled asphalt pavement, and water shall be mixed in an approved mixer.
    b. After mixing, the blended recycled asphalt pavement aggregate shall be transported to the Work site while it contains the proper moisture content. It shall then be placed on the roadbed by means of an approved spreader.
2. Travel plant method: After the material for each layer has been placed through an aggregate spreader or window-sizing device, it shall be uniformly mixed by a traveling mixing plant.
3. Road mix method: After the material for each layer has been placed, it shall be mixed while at optimum moisture content by a reclaimer or other approved equipment until uniform. Motor graders are not an acceptable mixing procedure.
4. Material shall be compacted to a minimum of 95% in accordance with AASHTO T 180.
5. Compact material in minimum lifts of 8 inches.

3.3 QUALITY CONTROL

A. Control of recycled asphalt pavement gradation in accordance with AASHTO T 30.

1. Frequency: 1/1000 tons of processed recycled asphalt pavement material (minimum three tests).

B. Compaction testing in accordance with AASHTO T 180.

1. Frequency: A minimum of one test every 250 lf of roadway or every 5,000 sf of prepared grade surface.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for asphalt paving.

1.2 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):
   1. M 208 – Standard Specification for Cationic Emulsified Asphalt
B. ASTM International (ASTM):
   1. D 2950 – Standard Test Method for Density of Bituminous Concrete in Place by Nuclear Methods
C. Colorado Department of Transportation (CDOT):
   1. Colorado Procedure 44 – Standard Method of Test for Bulk Specific Gravity and Percent Relative Compaction of Compacted Bituminous Mixtures Using Saturated Surface-Dry Specimens
   2. Colorado Procedure 81 – Standard Method of Test for Density and Percent Relative Compaction of HMA Pavement by the Nuclear Method
   3. Standard Specification for Road and Bridge Construction
D. Metropolitan Government Pavement Engineers Council (MGPEC):
   1. Pavement Design Standards and Construction Specifications Manual

1.3 SUBMITTALS

A. Quality Control Submittals:
   1. Certificates of compliance for the following materials:
      a. Aggregate: Gradation.
      b. Asphalt for binder: Type and grade.
      c. Prime coat: Type and grade of asphalt.
      d. Tack coat: Type and grade of asphalt.
      e. Mixes: Conforms to job-mix formula.
   2. Test results:
      a. Mix design:
         1) Aggregate gradation.
         2) Asphalt content.
         3) Stability number.
      b. Asphalt concrete cores:
         1) Permeability.
         2) Density.
      c. Uncompacted mix:
         1) Asphalt content.
         2) Aggregate gradation.
      d. Asphalt cement for binder.
   3. CDOT ROW pavement:
      a. Proposed mix designs shall have been used on a CDOT roadway within the previous year.
      b. Signed and approved CDOT Form 43 for any asphalt mix design proposed.
B. QUALITY ASSURANCE
   1. Materials and installation shall be in accordance with the CDOT Standard Specification for Road and Bridge Construction, Section 401.
   2. Local jurisdiction requirements:
      a. Paving requirements shall be in accordance with the AHJ.
         1) Jurisdictional requirements shall govern when in conflict with the Contract Documents.
         2) Any pavement in the CDOT ROW will require a polymer mix for the top lift.
      b. When local permitting jurisdiction does not have asphalt requirements or specifications, the requirements of the MGPEC Pavement Design Standards and Construction Specifications Manual shall control.
      c. The guidelines herein are provided to assist the CONTRACTOR in understanding specific requirements of the local jurisdiction; however, it is the CONTRACTOR's responsibility to confirm these requirements.

1.4 SITE CONDITIONS

A. Hot mix asphalt shall be placed only on properly constructed surfaces that are free from water, snow, and ice. The mixtures shall be placed in accordance with the temperature limitations of the following table and only when weather conditions permit the pavement to be properly placed and finished as determined by the ENGINEER:

Placement Temperature Limitations		
Compacted Layer Thickness (T) (Inches)	**Air and Surface Temperature Minimum (°F)**	
	Top Layer of Pavement	**Layers Below Top Layer**
$T \leq 2$	60	50
$2 < T \leq 3$	50	40
$T > 3$	50	40

   1. Air temperature is taken in the shade.
   2. Surface is defined as the existing base on which the new pavement shall be placed.

PART 2 PRODUCTS

2.1 MATERIALS

A. General: At a minimum, materials and mixes shall be in accordance with the CDOT Standard Specification for Road and Bridge Construction Sections 702 and 703, and the MGPEC Pavement Design Standards and Construction Specifications Manual.

B. Hot mix asphalt shall not contain more than 20% recycled asphalt pavement in the top lift of pavement, or 25% recycled asphalt pavement for the intermediate or bottom lifts.

C. Mix Design:

1. Use Grade S for bottom and intermediate lifts and grade SX for top lift.
2. For pavement located on DW property or in local jurisdictions where specified requirements are not defined, use the following minimum requirements based on traffic loading:

Traffic Loading, Total 18 Kip ESALs Over Design Life (20 years)	Superpave Compactor Design Gyrations	Hveem Stability (for grade S or SX)	Binder Grade
Low Traffic	$N_{design} = 75$	N/A	PG 58-28
High Traffic	$N_{design} = 75$	28 min.	PG 64-22

3. Lift thickness shall be 2 1/2 inches to 4 inches for bottom and middle lifts and 1 1/2 inches to 3 inches for top lift.

D. The minimum temperature of the asphalt mixture when discharged from the mixer and when delivered for use are as follows:

Asphalt Grade	Minimum Discharged Temperature	Minimum Delivered Temperature
PG 58-28	275°F	235°F
PG 64-22	290°F	235°F
PG 76-28	320°F	280°F

1. Delivered mix temperature shall be measured behind the power screed.
2. The maximum mix discharge temperature shall not exceed the minimum discharge temperature by more than 30°F.

E. Tack Coat: Emulsified asphalt shall be Grade CSS-1h and in accordance with AASHTO M 208, except the penetration test valve requirements of the residue shall be 40 to 120.

PART 3 EXECUTION

3.1 GENERAL

A. Provide the labor, materials, and equipment required to complete Work.

B. Grading SX shall be used unless otherwise shown on the Drawings or as required by the AHJ.

3.2 PREPARATION

A. Asphalt Removal:

1. Asphalt shall be saw cut or removed with pneumatic chisels for full depth leaving the remaining asphalt with a straight, vertical edge.
2. Any asphalt to remain that is loosened or damaged by the CONTRACTOR shall be removed and replaced at the CONTRACTOR's expense.
3. Removed asphalt shall be disposed of legally and in a responsible manner.

3.3 INSTALLATION

A. Tack Coat:

1. Preparation:
   a. Surface preparation shall include work necessary to provide a smooth, dry, uniform surface. Work shall include patching, brooming, shaping to the required grade and section, and compaction and removal of unstable corrugated areas.
   b. The edges of existing pavements adjacent to new pavement or overlays shall be cleaned to permit the adhesion of bituminous materials.
   c. Existing edges to be matched shall be cut.
2. Application:
   a. Bituminous material shall be applied by a pressure distributor in a uniform and continuous spread. Care shall be taken so the application of bituminous material at the junctions of spreads is not in excess of the quantity. Excess material shall be removed or distributed as directed. Skipped areas or deficiencies shall be corrected. Bituminous material shall not be placed on any surface where traffic will travel on freshly applied material.
   b. Unless otherwise shown on the Drawings, asphalt shall be applied at a minimum rate of 0.10 gallon/sy. Do not place more tack coat than is necessary for the day's operation. Traffic not essential to the Work shall be kept off the tack coat.

B. Placement and Compaction:

1. Spreading and finishing shall be in accordance with the CDOT Standard Specification for Road and Bridge Construction, Section 401.16 or the local jurisdiction, whichever is more stringent.
2. Compaction:
   a. In accordance with the CDOT Standard Specification for Road and Bridge Construction, Section 401.17 or the local jurisdiction, whichever is more stringent.

b. After the bituminous mixture is spread, struck off, and the surface irregularities adjusted, it shall be thoroughly and uniformly compacted by rolling.
c. The surface shall be rolled when the mixture is in the proper condition and when rolling does not cause undue displacement, cracking, or shoving.
d. The roller provided shall be sufficient to obtain the required compaction while the mixture is in a workable condition.
e. Field density determinations shall be made in accordance with CDOT Colorado Procedure No. 44 or No. 81.
f. Compaction shall begin immediately after the mixture is placed and be continuous until the required density is obtained.
g. Any displacement occurring as a result of reversing the direction of a roller or from other causes shall be corrected immediately by the use of rakes and the addition of fresh mixture when required. In rolling, do not displace the line and grade of the edges of the bituminous mixture.
h. Pavement shall be compacted to a density of 92% to 96% of the daily theoretical maximum specific gravity in accordance with the CDOT Standard Specification for Road and Bridge Construction, Section 401.17.
i. When the mixture contains unmodified asphalt cement (PG 58-28 or PG 64-22) or modified asphalt cement (PG 58-34), and the surface temperature falls below 185°F, further compaction effort shall not be applied.
j. When the mixture contains modified asphalt cement (PG 76-28, PG 70-28, or PG 64-28) and the surface falls below 230°F, further compaction effort shall not be applied.
k. In places inaccessible to the rollers, the mixture shall be thoroughly compacted with hand or mechanical tampers. On depressed areas, a trench roller or cleated compression strips under the roller to transmit compression to the depressed area may be used.
l. Any mixture that becomes loose and broken, mixed with dirt, or is in any way defective shall be removed and replaced with new, hot mixture that shall be compacted to conform with the surrounding area.

C. Connections with Existing Facilities:
1. Where asphalt pavement connects to an existing roadway surface or other facility, modify the existing roadway profile to produce a smooth riding connection.
2. Modifying existing surfaces: Burn or chip existing paved surfaces to provide neat lines and surfaces. Allow for sufficient depth of removal to reinstall a minimum thickness of 1 inch of asphalt.
   a. Neat lines: Lines straight and edges vertical.
   b. Edges of neat line cuts: Paint with a tack coat prior to placing pavement.
   c. Sealing neat line: After the placement of pavement by painting with liquid asphalt or emulsified asphalt, cover immediately with clean, dry sand.
3. Paint edges of contact surfaces (curbs and manhole frames) before laying pavement with a tack coat or paving asphalt cement to provide watertight joints. Do not stain adjacent surfaces not intended to be coated.

D. Joints:
1. Offset the edge of each layer a minimum of 6 inches so that joints are not directly over those in the underlying layer.
2. Form transverse joints by cutting back on the previous day's run to expose the full vertical depth of the layer.
3. For patches in roadways labeled as moratorium streets by the AHJ, infrared of seems and/or use of T-joints where new asphalt meets existing asphalt may be required.

E. Joint Compaction:
1. Place the top or wearing layer as continuously as possible.
2. Pass the roller over the unprotected end of the freshly laid mixture only when the laying of the layer is discontinued long enough to permit the mixture to become chilled.
3. Cut back the previously compacted mixture when Work is resumed to produce a slightly beveled edge for the full thickness of the layer.
4. Cut away waste material and lay new mix against the fresh cut.

F. Tolerances:
1. Conduct measurements for conformity with crown and grade immediately after initial compression. Correct variations immediately by the removal or addition of materials and by continuous rolling.
2. Tolerance measurements:
   a. Completed surface of top or wearing layer: Uniform texture, smooth, and uniform to crown and grade.
   b. The completed surface shall not vary more than 1/8 inch from the lower edge of the 10-foot straight edge placed on the surface parallel to the centerline.
   c. The transverse slope of the completed surface shall not vary more than 1/4 inch in 10 feet from the rate of the transverse slope shown on the Drawings.
   d. The finished grade shall not vary more than 0.02 feet.
3. Correct deviations in excess of the specified tolerances by adding asphalt concrete mixture to low places or removing material from high places.
4. The wearing surface shall be removed and replaced to achieve a satisfactory finish surface if the surface of the completed pavement deviates by more than twice the specified tolerances.

G. Equipment:
1. Hot bituminous asphalt: Application equipment shall be in accordance with the CDOT Standard Specification for Road and Bridge Construction, Section 401.16.
2. Tack coat:
   a. Equipment shall be capable of uniformly heating and applying bituminous material.

b. The distributor and the equipment shall be capable of uniformly distributing bituminous material at an even temperature and uniform pressure on variable widths of surface up to 15 feet in width at readily determined and controlled rates from 0.05 to 2.0 gallons/sy.
c. The allowable variation from any specified rate shall not exceed ±0.02 gallon/sy.
d. Distributor equipment shall include a tachometer, pressure gauges, accurate volume measuring devices or a calibrated tank, and a thermometer for measuring temperatures of tank contents.
e. Distributors shall be equipped with a power unit for the pump and full circulation spray bars that are laterally and vertically adjustable.

H. Traffic Control:
1. Minimize inconvenience to traffic and keep vehicles off freshly treated or paved surfaces to avoid the pickup and tracking of asphalt.
2. Meeting federal, state, and local requirements for traffic control.

3.4 RESTORATION

A. Pavement Markings, Signing, and Traffic Signal Conduit:
1. Restore or replace any existing pavement markings, signing, traffic signal conduit, or other traffic control devices that may be covered, removed, or damaged during construction.
2. Replace in accordance with site-specific standards of the AHJ.

3.5 QUALITY CONTROL

A. Testing:
1. Hot mix asphalt:
a. An extraction test is required for each hot mix placed to verify the bitumen content and aggregate gradation and when materials of the job-mix formulas change.
b. An immersion compression test is required for the first day's construction and when materials of the job-mix formulas change. Replace test sections as required.
c. Retain a qualified consultant to perform density testing in accordance with ASTM D 2950. The frequency of the CONTRACTOR’s QC testing shall meet the requirements of the permit they are working under or one test per lift every 200 lf or every 5,000 sf per lift; whichever is more stringent.

B. Control of Line and Grade: Provide and maintain intermediate control, independent of the underlying base, to meet finish surface grades and the minimum thickness.

END OF SECTION

SECTION 32 17 23
PAVEMENT MARKING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for pavement marking.

1.2 REFERENCES

A. Colorado Department of Transportation (CDOT):
   1. M&S Standard Plans
   2. Standard Specification for Road and Bridge Construction

1.3 SEQUENCING AND SCHEDULING

A. Schedule painting so markings have sufficient time to dry prior to opening lanes to traffic in accordance with the traffic control plan.

1.4 SUBMITTALS

A. Product Data: Paint.

B. Shop Drawings:
   1. Description of proposed methods for removal of drips, overspray, improper markings, paint and thermoplastic material tracked by traffic, and existing markings.
   2. Pavement marking layout plan.

C. Quality Control Submittals:
   1. Manufacturer's certificate of compliance for products specified in this Section.
   2. Equipment list: Proposed equipment to be used, including descriptive data.

1.5 QUALITY ASSURANCE

A. Construction Requirements: In accordance with CDOT Standard Specification for Road and Bridge Construction, Section 627.

PART 2 PRODUCTS

2.1 MATERIALS

A. Epoxy Pavement Marking Material: CDOT Standard Specification for Road and Bridge Construction, Section 713.19.

B. Glass Beads: CDOT Standard Specification for Road and Bridge Construction, Section 713.08.

C. Paint: CDOT Standard Specification for Road and Bridge Construction, Section 708.05.

D. Pavement Marking Tape: CDOT Standard Specification for Road and Bridge Construction, Section 713.15.

E. Pavement Primer: CDOT Standard Specification for Road and Bridge Construction, Section 708.07.

F. Preformed Plastic Material: CDOT Standard Specification for Road and Bridge Construction, Section 713.13.

G. Raised Pavement Marker: CDOT Standard Specification for Road and Bridge Construction, Section 713.18.

H. Pavement Marking Tape (Removable): CDOT Standard Specification for Road and Bridge Construction, Section 713.16.

I. Thermoplastic Marking Material: CDOT Standard Specification for Road and Bridge Construction, Section 713.12.

PART 3 EXECUTION

3.1 GENERAL

A. Provide, apply, and remove temporary pavement marking in accordance with the Contract Documents.

B. Place pavement markings in accordance with the following requirements, CDOT M&S Standard Plans, S-627-1, or jurisdictional requirements.

3.2 PREPARATION

A. Cleaning:
   1. Thoroughly clean surfaces to be marked before the application of pavement marking material.
   2. Remove dust, dirt, and other granular surface deposits by sweeping, blowing with compressed air, rinsing with water, or a combination thereof.
   3. Completely remove rubber deposits, surface laitance, existing paint markings, and other coatings adhering to pavement with scrapers, wire brushes, sand blasting, approved chemicals, or mechanical abrasion.
   4. Scrub areas of old pavement affected with oil or grease with several applications of trisodium phosphate solution or other approved detergent or degreaser, and rinse thoroughly after each application.
   5. After cleaning, oil-soaked areas shall be sealed with cut shellac to prevent bleeding through the new paint.
   6. When water is used for cleaning, allow pavement surfaces to dry prior to striping or marking.
   7. Re-clean surfaces when Work is stopped due to rain.

B. Layout of Markings: Unless previously applied markings are present to serve as a guide, layout markings in advance of paint application.

3.3 APPLICATION

A. Paint:
   1. General:
      a. Thoroughly mix pigment and vehicle together prior to application and keep thoroughly agitated during application.
      b. Do not add thinner.
      c. Apply to clean, dry surfaces, and only when air and pavement temperatures are above 40°F and less than 95°F. Maintain paint temperature within these same limits.
      d. Provide guidelines and templates to control paint application.
      e. Take special precautions in marking numbers, letters, and symbols.
      f. Apply paint only to unfrozen, dry, and clean pavement surfaces.
      g. Edges of markings shall be clearly outlined.

2. Rate of application:
   a. Apply paint in two coats at a uniform rate of 105 to 115 sfpgpc without running or spattering.
   b. Apply pigmented binder evenly to the pavement area at a rate of 105 sfpg, ±5 sf.
   c. Nonreflective markings: Apply paint evenly to the pavement surface at a rate of 105 sfpg, ±5 sf.
3. Drying:
   a. Provide the maximum drying time of paint to prevent undue softening of bitumen, pickup, displacement, or discoloration by tires or traffic.
   b. If there is a delay in drying or markings, discontinue painting operations until the cause is determined and corrected.

3.4 PROTECTION

A. Protect markings from traffic until paint is completely dry.

B. Protect surfaces from disfiguration by paint spatters, splashes, spills, or drips.

3.5 CLEANING

A. Remove paint spatters, splashes, or drips.

B. Ensure asphalt surfaces and striping are left clean and fresh at time of demobilization.

END OF SECTION

SECTION 32 31 13
CHAIN LINK FENCES AND GATES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for chain link fences and gates.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE
3. SECTION 28 00 00 – SECURITY SYSTEMS

1.2 REFERENCES

A. American National Standards Institute/Underwriters Laboratories of Canada/Underwriters Laboratories (ANSI/CAN/UL):

1. 325 – Standard for Door, Drapery, Gate, Louver, and Window Operators and Systems

B. ASTM International (ASTM):

1. B 117 – Standard Practice for Operating Salt Spray (Fog) Apparatus
2. B 221 – Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
3. D 523 – Standard Test Method for Specular Gloss
4. D 714 – Standard Test Method for Evaluating Degree of Blistering of Paints
5. D 1654 – Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
6. D 2244 – Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
7. D 2794 – Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
8. D 3359 – Standard Test Methods for Measuring Adhesion by Tape Test
9. F 2200 – Standard Specification for Automated Vehicular Gate Construction

C. Colorado Department of Transportation (CDOT):

1. M&S Standard Plans
2. Standard Specification for Road and Bridge Construction

1.3 SUBMITTALS

A. Product Data: Submit the Manufacturer's descriptive literature for fence and gate installations.

B. Certificates: Submit the Manufacturer's certifications that chain link fence and component materials meet specified requirements.

1.4 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Aluminum Cantilever Gate:

1. Ameristar Fence Products, Inc., Ameristar TransPort LINK gate system
2. No substitutes

B. Gate Drive Operator:

1. Chamberlain, Elite Heavy Duty Model SL3000UL1HPH, 120 V, single-phase

2.2 MATERIALS

A. Fence and Gate:

1. Provide standard chain link fence complete with barbed wire guard in accordance with CDOT Standard Specification for Road and Bridge Construction. Fabric height shall be 96 inches. Chain link fabric may be reused if serviceable in the opinion of the ENGINEER.
2. Chain link fencing materials, including gates, shall be in accordance with CDOT Standard Specification for Road and Bridge Construction, Section 607 and Section 710.
3. Provide pipe posts, accessories, concrete footings, and other materials required for fence erection.

B. Concrete: Concrete for post footings shall be Class B as specified in SECTION 03 30 00.

C. Aluminum Cantilever Gate:

1. The Manufacturer shall supply a total industrial ornamental aluminum cantilever gate system (specify with extended uprights for barb wire or without extended uprights). The system shall include all components including tracks, uprights, bracing, pickets, hardware, fittings, and fasteners. The gate schedule shall include the following additional information for each cantilever gate included in the scope of the Work: Opening (specify nominal opening size range in feet) and gate posts (specify size and shape of posts). Chain link fabric and barb wire are not provided by Ameristar.
2. The materials used for cantilever gate framing (e.g., uprights, diagonal braces, and pickets or pales) and rails shall be manufactured in accordance with ASTM B 221 aluminum, designation 6063-T-6, with a yield strength of 25,000 psi, a tensile strength of 30,000 psi, and a standard mill finish.
3. Material for diagonal bracing and uprights shall be 2 inch square by 1/4-inch aluminum. The design of the top and bottom enclosed track shall conform to the Manufacturer's 5 inch by 2 inch Fast-Trak system. Material for chain link infill shall be in accordance with the Contract Documents.

4. Internal roller truck assembly shall be self-aligning swivel ball-and-socket type running on four bearing wheels. Internal roller truck assembly shall be affixed to the hanger bracket by means of a 5/8 inch diameter industrial grade rod end/center bolt with a minimum static load rating of 10,000 lbs. Attachment of the center bolt to the truck body shall be by means of a swivel joint to ensure equivalent and consistent loading on bearing wheels and internal track surfaces throughout the travel of the gate.

D. Gate Operator and Sensors: The operator shall include the required interface connections for access keypads, reflective photo beam detector and accessories. The operator shall be mounted on a metal pedestal as shown on the Drawings.

2.3 FABRICATION

A. Enclosed track, uprights, and diagonal bracing shall be predrilled and labeled for easy assembly; components shall be pre-cut to specific lengths.

B. Top and bottom rail extrusions shall be mechanically fastened to vertical uprights and reinforced with diagonal braces as shown on the Drawings.

C. If color coating is required, the manufactured components shall be subjected to the Ameristar thermal stratification coating process (high-temperature, in-line, multi-stage, and multi-layer) including, at a minimum, a six-stage pretreatment/wash and an electrostatic spray application of a polyester finish. The topcoat shall be a no-mar TGIC polyester powder coat finish with a minimum thickness of 2 mils. The color shall be black. The stratification-coated framework shall be capable of meeting the performance requirements for each of the following quality characteristics:

Coating Performance Requirements		
Quality Characteristics	**ASTM Test Method**	**Performance Requirements**
Adhesion	D 3359 – Method B	Adhesion (retention of coating) over 90% of test area (tape and knife test)
Corrosion Resistance	B 117, D 714, and D 1654	Corrosion resistance over 3,500 hours (scribed in accordance with ASTM D 1654; failure mode is accumulation of 1/8 inch coating loss from scribe or medium #8 blisters)
Impact Resistance	D 2794	Impact resistance over 60 in/lb (forward impact using 0.625-inch ball)
Weathering Resistance	D 2244 and D 523 (60°Method)	Weathering resistance over 1,000 hours (failure mode is 60% loss of gloss or color variance of more than three delta-E color units)

PART 3 EXECUTION

3.1 ERECTION

A. Fence and Manual Gate:

1. Construct fences in accordance with CDOT Standard Specification for Road and Bridge Construction and CDOT M&S Standard Plans for chain link fence.
2. Before erecting fences, clear and remove brush, ground surface irregularities, and other obstacles that may interfere with proper erection.
3. Set posts in concrete to the depth shown on the Drawings, plumb and in alignment.
4. Provide one tension or stretcher bar for the end post and two for each corner and pull post.
5. Install top rails as shown on the Drawings.
6. Clean and repair damaged galvanizing.

B. Aluminum Cantilever Gate:

1. New gate installations shall be laid out by the CONTRACTOR in accordance with the Contract Documents.
2. Hardware shall be installed in accordance with the Ameristar installation instructions. Ameristar cantilever gates shall be installed in accordance with ASTM F 2200 and ANSI/CAN/UL 325.
3. Gate stops shall be installed on each track in accordance with ASTM F 2200.
4. Set posts in concrete to the depth and diameter shown on the Drawings, plumb and in alignment.
5. Install mesh fabric and barb wire on gate frame.

C. Gate Operator: Install gate operator and reflective photo bean detector as shown on the Drawings and as recommended by the Manufacturer. Connect chain drive and adjust for a fully operational gate. Power and security connections are to be performed by the approved Subcontractor and as specified in SECTION 28 00 00.

3.2 CLEANING

A. Clean the site of excess materials. Post-hole excavations shall be scattered uniformly away from posts.

END OF SECTION

SECTION 32 31 19
ORNAMENTAL METAL FENCING SYSTEM

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for ornamental metal fencing systems.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE
3. SECTION 31 01 01 – SITE RESTORATION AND CLEANUP

1.2 REFERENCES

A. American National Standards Institute/Underwriters Laboratories of Canada/Underwriters Laboratories (ANSI/CAN/UL):

1. 325 – Standard for Door, Drapery, Gate, Louver, and Window Operators and Systems

B. ASTM International (ASTM):

1. A 653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
2. B 117 – Standard Practice for Operating Salt Spray (Fog) Apparatus
3. B 221 – Standard Specification for Aluminum and Aluminum-Alloy Extruded Bars, Rods, Wire, Profiles, and Tubes
4. D 523 – Standard Test Method for Specular Gloss
5. D 714 – Standard Test Method for Evaluating Degree of Blistering of Paints
6. D 822 – Standard Practice for Filtered Open-Flame Carbon-Arc Exposures of Paint and Related Coatings
7. D 1654 – Standard Test Method for Evaluation of Painted or Coated Specimens Subjected to Corrosive Environments
8. D 2244 – Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
9. D 2794 – Standard Test Method for Resistance of Organic Coatings to the Effects of Rapid Deformation (Impact)
10. D 3359 – Test Standard Test Methods for Measuring Adhesion by Tape Test
11. F 2200 – Standard Specification for Automated Vehicular Gate Construction
12. F 2408 – Standard Specification for Ornamental Fences Employing Galvanized Steel Tubular Pickets
13. F2453/F2453M – Standard Specification for Welded Wire Mesh Fence Fabric

1.3 SUBMITTALS

A. Manufacturer's literature.

B. Shop Drawings.

C. Warranty Documentation:

1. Sample warranty.
2. Warranty.

1.4 QUALITY ASSURANCE

A. Genesis Style System Description for Panels, Posts, and Manual Gates: The system shall be two-rail with all components including panels, posts, quad-flare finials, gates, and hardware.

B. Qualifications:

1. A minimum of 5 years of documented experience in the Work of this Section.
2. Approved by the Manufacturer.

1.5 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

1.6 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the ornamental metal fencing system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Panels, Posts, and Manual Gates:

1. Ameristar Fence Products, Inc., Montage II, Welded and Rackable Ornamental Steel, Genesis Style
2. Ameristar Fence Products, Inc., Aegis II, Industrial Ornamental Steel, Genesis Style
3. Ameristar Fence Products, Inc., WireWorks Plus, commercial welded wire architectural fence
4. Cochrane USA, ClearVu welded wire fence

B. Industrial, Ornamental, Electrically Operated Cantilever Gate:

1. Ameristar Fence Products, Inc., Ameristar TransPort II gate system with welded wire or pickets as specified on the Drawings
2. No substitutes

C. Gate Drive Operator:

1. Chamberlain, Elite Heavy-Duty Model SL3000UL1HPH, 120 V, single-phase

2.2 MATERIALS

A. Panels, Posts, and Manual Gates:

1. Steel fence panels and posts in accordance with ASTM A 653 with a minimum yield strength of 45,000 psi and a minimum hot-dip galvanized zinc coating weight of 0.90 oz/ft^2, coating designation G90, or .60 oz/ft^2, coating designation G-60 for architectural welded wire fence systems.
2. Pickets shall be 1 inch square by 14 gauge tubing. Rails shall be steel channel, 1 3/4 inch square with a minimum 14 gauge thickness. Fence and gate posts shall meet the requirements shown in Table 3A.

3. Steel wire mesh fence panels shall be welded by resistance welding in accordance with ASTM A 185 using 6 gauge (0.192 inch) pre-galvanized steel wire welded at each crossing to form rectangles. Vertical 6 gauge wires shall be spaced at 2 inches; horizontal 6 gauge wires shall be spaced at 6 inches. The cold rolled wire shall have a tensile strength of at least 70,000 psi and 74,000 psi weld shear strength. Wire strand shall be galvanized before welded (GBW), 0.050 oz/sf zinc coating in accordance with ASTM A 641.

B. Cantilever Gates:

1. Materials used for cantilever gate framing (uprights, diagonal braces, and pickets or pales) shall be manufactured in accordance with ASTM B 221 aluminum, designation 6063-T-6, with a yield strength of 25,000 psi, a tensile strength of 30,000 psi, and a standard mill finish. Rails shall be manufactured in accordance with ASTM B 221 aluminum, Alloy 6063-T-6, with minimum yield strength of 25,000 psi, a tensile strength of 30,000 psi, and a standard mill finish.
2. Material for diagonal bracing and uprights shall be 2 inch square by 1/4-inch aluminum. The design of the top and bottom enclosed track shall conform to the Manufacturers 5 inch by 2 inch Fast-Trak system. Material for pickets shall be 1 inch by 1/8-inch wall aluminum.
3. Internal roller truck assembly shall be self-aligning, swivel ball-and-socket type running on four bearing wheels. Internal roller truck assembly shall be affixed to the hanger bracket by means of a 5/8 inch diameter industrial-grade rod end/center bolt with a minimum static load rating of 10,000 lbs. Attachment of the center bolt to the truck body shall be by means of a swivel joint to ensure equivalent and consistent loading on bearing wheels and internal track surfaces throughout the travel of the gate.
4. Pickets shall be fitted with quad flare finials as shown on the Drawings.

C. Gate Operator and Sensors: The operator shall include the required interface connections for access keypads, reflective photo beam detector and accessories. The operator shall be mounted on a metal pedestal as specified on the Drawings.

2.3 FABRICATION

A. Panels, Posts, and Manual Gates:

1. Pickets, rails, panels, and posts shall be pre-cut to specified lengths. Rails shall be pre-punched to accept pickets. See Table 2A & Table 2B for post sizing requirements based on specified height and gate width where applicable.
2. Pickets shall be inserted into the pre-punched holes in the rails and shall be aligned to standard spacing using a specially calibrated alignment fixture. The aligned pickets and rails shall be joined at each picket-to-rail intersection by Ameristar's proprietary fusion welding process.
3. Manufactured panels and posts shall be coated by an inline electrode position coating (E-Coat) process consisting of a multi-stage pretreatment/wash with zinc phosphate, followed by a duplex application of an epoxy primer and an acrylic topcoat. The minimum cumulative coating thickness of epoxy and acrylic shall be 2 mils. The color shall be black. Coated panels and posts shall be capable of meeting the performance requirements for each quality characteristic shown in Table 1. Picket coating performance criteria shall be in accordance with of ASTM F 2408.
4. The manufactured Montage II and Aegis II fence system shall be capable of meeting the vertical load, horizontal load, and infill performance requirements for industrial weight fences in accordance with ASTM F 2408.
5. Ornamental fence gates: Swing gates shall be fabricated using 1 3/4 inch by 14 gauge Forerunner double channel rail, 2 inch square by 11 gauge gate ends, and 1 inch square by 14 gauge pickets. Gates that exceed 6 feet in width shall have a 1 3/4 inches square by 14 gauge intermediate upright. Rail and upright intersections and picket and rail intersections shall be joined by welding. Gusset plates shall be welded at each upright to rail intersection. Cable kits shall be provided for additional bracing for gate leaves over 6 feet.
6. Architectural welded wire fence gates: Swing gates shall be fabricated using 2 inch by 12 gauge square rails and gate ends. Gates that exceed 6 feet in width shall have a 2 inch square by 12 gauge intermediate upright. Rail, upright, and gate end intersections shall be joined by welding. Steel gussets, 1/4 inch by 2 inch, shall be welded at each rail to the gate end intersection and rail to intermediate intersections (four gussets per gate bay). Gusset shall be punched to accept gate trussing cable and turnbuckle. See Table 2B for gate post sizing.

B. Cantilever Gates:

1. Pickets, enclosed track, uprights, and diagonal bracing shall be predrilled and labeled for easy assembly; components shall be pre-cut to specified lengths.
2. Top and bottom rail extrusions shall be mechanically fastened to vertical uprights and reinforced with diagonal braces as shown on the Drawings.
3. Manufactured components shall be subjected to the Ameristar thermal stratification coating process, high-temperature, in-line, multi-stage, and multi-layer including, at a minimum, a six-stage pretreatment/wash and an electrostatic spray application of a polyester finish. The topcoat shall be a no-mar TGIC polyester powder coat finish with a minimum thickness of 2 mils. The color shall be black. The stratification-coated framework shall be capable of meeting the performance requirements for each of the following quality characteristics.

Table 1
Coating Performance Requirements

Quality Characteristics	ASTM Test Method	Performance Requirements
Adhesion	D 3359 – Method B	Adhesion (retention of coating) over 90% of test area (tape and knife test)
Corrosion Resistance	B 117, D 714, and D 1654	Corrosion resistance over 3,500 hours (scribed per ASTM D 1654; failure mode is accumulation of 1/8 inch coating loss from scribe or medium #8 blisters)

Table 1 Coating Performance Requirements		
Quality Characteristics	**ASTM Test Method**	**Performance Requirements**
Impact Resistance	D 2794	Impact resistance over 60 in/lb (forward impact using 0.625-inch ball)
Weathering Resistance	D 822, D 2244, and D 523 (60˚ Method)	Weathering resistance over 1,000 hours (failure mode is 60% loss of gloss or color variance of more than three delta-E color units)

PART 3 EXECUTION

3.1 PREPARATION

A. New installation shall be laid out by the CONTRACTOR in accordance with the Contract Documents.

3.2 INSTALLATION

A. Fence Post: Spaced in accordance with Table 3A and Table 3B, ±1/2 inch. For installations that need to be be raked to follow sloping grades, the post spacing dimension shall be measured along the grade. Fence panels shall be attached to posts with brackets supplied by the Manufacturer. Posts shall be set in concrete bases having a minimum depth of 42 inches. In some cases, local restrictions on freezing weather conditions may require greater depth. Material requirements for concrete bases shall be as specified in SECTION 31 01 01 and SECTION 03 30 00. Post setting by other methods such as plated posts or grouted core-drilled bases are permissible only if shown by engineering analysis to be sufficient in strength for the intended application.

B. Gate:

1. Manual gates: Gate posts shall be spaced in accordance with the Manufacturer's Shop Drawings, dependent on standard out-to-out gate leaf dimensions, and the gate hardware selected. Type and quantity of gate hinges shall be based on the application, weight, height, and number of gate cycles. The Manufacturer's gate drawings shall identify the necessary gate hardware required for the application. Gate hardware shall be provided by the Gate Manufacturer and shall be installed in accordance with the Manufacturer's instructions.
2. Cantilever gates:
   a. New cantilever gate installations shall be laid out by the CONTRACTOR as shown on the Drawings.
   b. Hardware shall be installed in accordance with the Manufacturer's instructions. Transport cantilever gates shall be installed in accordance with ASTM F 2200 and ANSI/CAN/UL 325.
   c. Gate stops shall be installed on each track in accordance with ASTM F 2200.
   d. Gate post shall be spaced in accordance with the specified gate elevation. Non-gate and gate weight supporting posts shall be set in concrete bases as shown on the Drawings. Concrete shall meet the Class B mix design as specified in SECTION 03 30 00. Post setting by other methods, plated posts or grouted core-drilled bases, are permissible only if shown by engineering analysis to be sufficient in strength for the intended application.
3. Gate operator: Install gate operator and photo sensors as shown on the Drawings and as recommended by the Manufacturer. Connect chain drive and adjust for a fully operational gate. Power and security connections are to be performed by the approved Subcontractor.

Table 2A Minimum Sizes for Montage II Posts			
Fence Posts	**Panel Height**		
2 1/2 inch by 12 gauge	Up to and including 6 foot		
3 inch by 12 gauge	Over 6 foot up to and including 8 foot		
Gate Leaf	**Gate Height**		
	Up to and including 4 foot	**Over 4 foot up to and including 6 foot**	**Over 6 foot up to and including 8 foot**
Up to 4 foot	2 1/2 inch by 12 gauge	3 inch by 12 gauge	3 inch by 12 gauge
4 foot 1 inch to 6 foot	3 inch by 12 gauge	4 inch by 11 gauge	4 inch by 11 gauge
6 foot 1 inch to 8 foot	3 inch by 12 gauge	4 inch by 11 gauge	6 inch by 3/16 inch
8 foot 1 inch to 10 foot	4 inch by 11 gauge	6 inch by 3/16 inch	6 inch by 3/16 inch
10 foot 1 inch to 12 foot	4 inch by 11 gauge	6 inch by 3/16 inch	6 inch by 3/16 inch
12 foot 1 inch to 14 foot	4 inch by 11 gauge	6 inch by 3/16 inch	6 inch by 3/16 inch
14 foot 1 inch to 16 foot	6 inch by 3/16 inch	6 inch by 3/16 inch	6 inch by 3/16 inch

Table 2B Minimum Sizes for WireWorks Plus Posts	
Fence Posts	**Panel Height**
2 inch square by 16 gauge	Up to 6 foot
2 1/2 inch square by 16 gauge	8 foot

Table 2B
Minimum Sizes for WireWorks Plus Posts

Gate Leaf	**Gate Height**	
	Up to and including 6 foot	**Over 6 foot up to and including 8 foot**
Up to 4 foot	2 1/2 inch by 12 gauge	3 inch by 12 gauge
4 foot 1 inch to 6 foot	3 inch by 12 gauge	3 inch by 12 gauge
6 foot 1 inch to 10 foot	4 inch by 11 gauge	6 inch by 3/16 inch
10 foot 1 inch to 16 foot	6 inch by 3/16 inch	6 inch by 3/16 inch

Table 3A
Post Spacing By Bracket Type

Span	For Classic, Genesis, and Majestic 8 foot nominal (92 5/8-inch rail)					
Post Size (inches)	2 1/2	3	2 1/2	3	2 1/2	3
Bracket Type (inches)	Industrial Universal 2.5 (BB302) 3 (BB303)		Industrial Flat Mount (BB301)		Industrial Swivel (BB304)*	
Panel Type: Montage II						
Post Settings (inches) ±1/2 inch o.c.	96	96 1/2	96	96 1/2	*96	*96 1/2
Panel Type: Aegis II						
Post Settings (inches) ±1/2 inch o.c.	96	96 1/2	96	96 1/2	97 1/2	98

*Note: When using BB304 swivel brackets on one or both ends of a panel installation, provide spacing between the post and the adjoining pickets to meet applicable codes. This may require trimming one or both ends of the panel. When using the BB301 flat-mount bracket for the invincible style, the rail may need to be drilled to accommodate the rail to the bracket attachment.

Table 3B
WireWorks Plus Post Spacing

Span	WireWorks Plus	
Post Size (inches)	2	2 1/2
Post Settings (inches) ±1/4 inch o.c.	96 1/2	96 1/2

C. Maintenance:
1. When cutting or drilling rails or posts, adhere to the following steps to seal the exposed steel surfaces:
   a. Remove metal shavings from the cut area.
   b. Apply zinc-rich primer to thoroughly cover cut edge and drilled hole; let dry.
   c. Apply two coats of custom finish paint matching fence color; failure to seal exposed surfaces in accordance with this Section will negate the warranty. Ameristar spray cans or paint pens shall be used to prime and finish exposed surfaces; paint pens are recommended to prevent overspray. Use of non-Ameristar parts or components will negate the Manufacturer's warranty.

3.3 CLEANING
A. Clean the Work site of excess materials. Post-hole excavations shall be scattered uniformly away from posts.

END OF SECTION

SECTION 32 31 23
PLASTIC FENCES AND GATES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for plastic fences and gates.

1.2 REFERENCES

A. ASTM International (ASTM):

1. A 123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products

1.3 SUBMITTALS

A. Product Data: The Manufacturer's technical data for fence fabric, steel posts, ties, and tension wire.

B. Shop Drawings.

PART 2 PRODUCTS

2.1 MATERIALS

A. PP Safety Fence Fabric:

1. Diamond mesh pattern with smooth top and bottom edge.
2. Mesh size: Approximately 1 1/2 inch by 1 3/4 inch.
3. Fabric height: 4 feet or 6 feet as shown on the Drawings.

B. Metal Fence Post:

1. Material: Studded tee post rails weighing a minimum 1 1/4 lbs/ft.
2. Finish: Baked green enamel, hot-dipped galvanized in accordance with ASTM A 123.
3. Anchor plate: Securely swaged on the tee post studs.
4. Vinyl cap: Premolded to fit over top of tee post.

C. Wire:

1. Tension wire: 0.177 inch, type II, zinc-coated (galvanized).
2. Wire fasteners: Preformed clips for attaching to tee post.

PART 3 EXECUTION

3.1 GENERAL

A. Provide labor, tools, equipment, and Work necessary for, or incidental to, the supply and construction of a safety grid fence as shown on the Drawings.

B. Perform clearing and grubbing as necessary to construct the fence to the required grade and alignment.

C. Components shall not infringe upon adjacent property lines.

3.2 PREPARATION

A. Alignment Breaks:

1. At locations where breaks in a run of fencing are required, at intersections with existing fences, or at a ditch, canal, or channel crossing, appropriate adjustments in fence alignment and fence post spacing shall be made to satisfy the requirements for the type of closure shown on the Drawings or the conditions encountered.
2. Provide gates for vehicle or pedestrian access as required and adequate fastening to allow opening and closing to secure the affected area.

3.3 INSTALLATION

A. Post tops shall be set to the required grade and alignment.

B. Fence posts shall be spaced at a maximum of 8 feet for 4 foot high fabric and 10 feet for 6 foot high fabric. Posts shall be embedded 2 feet into compacted soil.

C. Stretch fabric between end posts or at intervals of 100 feet at a maximum, whichever is less. Pull fabric taut with the bottom 1 inch to 2 inches above the ground line. Weave the tension wire through the top diamond pattern. Attach tension wire to post and turnbuckle until taut. Wire clip tension wire to tee posts. Wire clip fabric to tee post at 1 foot spacing from tension wire to bottom of fabric. Place a vinyl cap on tee posts.

D. Splices in the fabric shall be made at a post.

E. Posts and fabric shall be flush at the top of the post.

F. For gate sections use top and bottom tension wires attached to an independent metal post. Secure independent post at open end with a top and bottom wire loop to the line post.

3.4 PROTECTION

A. Protect the fence during construction.

B. Damage to the fence shall be repaired within 8 hours to the satisfaction of the ENGINEER.

END OF SECTION

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SECTION 32 31 26
WIRE FENCES AND GATES

PART 1 GENERAL

1.1 SUMMARY

- A. Section includes general information, products, and execution for wire fences and gates.
- B. Related Sections:
  1. SECTION 03 30 00 – CAST-IN-PLACE CONCRETE

1.2 REFERENCES

- A. ASTM International (ASTM):
  1. A 53 – Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
  2. A 121 – Standard Specification for Metallic-Coated Carbon Steel Barbed Wire
  3. A 307 – Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength
  4. A 702 – Standard Specification for Steel Fence Posts, Hot Wrought
- B. Colorado Department of Transportation (CDOT):
  1. Standard Specification for Road and Bridge Construction

1.3 SUBMITTALS

- A. Product Data: Submit the Manufacturer's descriptive literature for fence and gate installations.
- B. Certificates: Submit the Manufacturer's certifications that chain link fence and component materials meet specified requirements.

PART 2 PRODUCTS

2.1 MATERIALS

- A. Barbed Wire:
  1. Zinc-coated barbed wire: In accordance with ASTM A 121, Class 1.
     - a. Line wire: Two strands of No. 12 1/2 gauge.
     - b. Barbs:
       - 1) Number of points: 4.
       - 2) Spacing: 5 inches.
- B. Metal End and Line Posts:
  1. Line posts:
     - a. In accordance with ASTM A 702.
     - b. 6-foot studded T-posts painted green.
     - c. Weight: 1.33 lbs/ft.
  2. End posts: 2-inches round galvanized steel.
- C. Hardware for End and Line Posts: In accordance with CDOT Standard Specification for Road and Bridge Construction, M-607-2.
- D. Metal Gates:
  1. Type: Five-rail, 1 5/8-inches galvanized steel tube gate.
  2. Frame: Galvanized tubular steel in accordance with ASTM A 53.
  3. Design:
     - a. To fit the opening between the gate posts and be able to swing through an arc of 90 degrees inward and 90 degrees outward.
     - b. Fabricate with steel vertical steel braces.
  4. Height: Minimum 50 inches. Gates of greater height are acceptable provided they do not extend above the top of the gate posts.
  5. Width: As shown on the Drawings.
  6. Fittings:
     - a. Furnish complete with galvanized fittings designed for use with the type of gate and gate posts provided.
     - b. Furnish with hasp for padlock.
- E. Wood Posts and Braces:
  1. General:
     - a. Cut from sound timber.
     - b. Free from bark and protruding knots.
     - c. Straight: Free from sweep exceeding 1.67% of post length, not to exceed a maximum of 2 inches; free from multiple crooks. Acceptable crooks may be in one place only.
     - d. Free from loose or unsound knots, shakes greater than 1/3 post thickness, splits longer than post thickness, or other defects that would render them unfit structurally for the purpose intended.
     - e. Dry and seasoned: Small surface seasoning checks are acceptable.
     - f. Square or rectangular posts and braces:
       - 1) Rough sawn, S4S or S2S.
       - 2) Free of heart center.
  2. Untreated wood posts and braces:
     - a. Species: Cedar or redwood.
     - b. Posts: Sawn or hewn.
       - 1) Nominal size: Not less than 8 inches by 8 inches.
  3. Bracing: Sawn or hewn:
     - a. Nominal size: Not less than 4 inches by 4 inches.
- F. Lag Bolts: In accordance with ASTM A 307, galvanized.

G. Concrete: Concrete for post footings shall be Class B as specified in SECTION 03 30 00.

PART 3 EXECUTION

3.1 PREPARATION:

A. Establish locations of fence lines, gates, and terminal posts.

B. Notify the ENGINEER after locations of fence lines, gates, and terminal posts are staked and before proceeding with fence installation.

3.2 INSTALLATION

A. Metal End, Gate, Corner, and Intermediate Posts:

1. Set metal posts in concrete.
    a. Set end posts at the beginning and end of the fence not terminating at the gates.
    b. Set corner posts at angle points in the fence alignment where the deflection angle between adjoining panels of fence is 5 degrees or more for metal line posts and 15 degrees or more for wood line posts or as shown on the Drawings.
    c. Space intermediate end posts between end and corner posts a maximum of 1,000 feet apart.
    d. Minimum post embedment depth: 32 inches with 4 inches of concrete fill to bottom of hole.
2. Place and tamp concrete around posts and braces after they are in proper position and are securely restrained from movement.
3. Strike off concrete to a reasonably smooth surface slightly above ground level. Crown each surface to drain away from the post or the brace.
4. Wait for concrete to cure for at least 7 days before subjecting posts and braces to stress or strain, unless otherwise authorized by the ENGINEER.

B. Line T-Post Spacing:

1. Maximum 10 feet. Set posts on the lines and grades established or install at the typical spacing as shown on the Drawings. Face post studs on the outside of the fence alignment.
2. Line T-posts that are set by driving shall be free of damage when in place. Remove any post which is twisted or bent and replace with a new post.

C. Barbed Wire:

1. Draw barbed wire tight with come-a-long and securely attach to the posts.
    a. Terminate barbed wire at each end post, gate post, corner post, and intermediate end post.
    b. Wrap each line of barbed wire around the terminating post and splice it to itself with at least four turns.
    c. Securely fasten each line of barbed wire at each metal line T-post with 11 gauge galvanized wire fasteners.
2. In the final position, barbed wire shall be tight and free from sag.
3. In crossing gullies, ditches, and abrupt depressions where the bottom line of the fence as normally constructed leaves an unfenced opening beneath it exceeding 12 inches in height, add an additional line of barbed wire, so that there are no side openings or bottom openings exceeding 12 inches in dimension at any point along the fence.
4. Fence condition upon completion: Straight between corners.
    a. Posts: Vertical and firmly set.
    b. Braces, fittings, and fixtures: Tight and firm.

D. Vertical Fence Stays: Install two equal distance between posts. Twist wire to permit weaving into horizontal fence wires to provide rigid spacing.

E. Gate:

1. Install the gate post at the location shown on the Drawings and in accordance with the CDOT Standard Specification for Road and Bridge Construction.
2. Set gate posts plumb in the concrete at each end of each gate opening.
3. Allow concrete to cure for a minimum of 7 days before hanging the gate.
4. Adjust hinges as required to allow the gate to open and close freely without dragging on the road surface.

F. Wood Post Installation:

1. Set posts with the large end down, plumb, and in good line on the side on which the wires are to be fastened as follows:
    a. Set the posts at full depth. Do not cut off the bottoms to avoid rock removal or additional excavation.
    b. Cut the butt end of the post square.
    c. Diameter of post holes: Minimum 6 inches larger than the diameter of the posts.
    d. Minimum embedment depth: 40 inches.
2. After posts are placed and aligned, backfill holes with Class B concrete. Mound concrete or provide excess earth fill around the post to provide drainage away from the post.
3. Where anchors are on the bottom of the corner, the brace, or the gate posts, attach by notching the post and predrilling the pilot hole then installing a lag bolt to anchor in place. Lag bolts shall penetrate the receiving post a minimum of 4 inches.

END OF SECTION

SECTION 32 32 23
SEGMENTAL RETAINING WALLS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for segmental retaining walls.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 31 23 23 – FILL

1.2 REFERENCES

A. ASTM International (ASTM):

1. C 140 – Standard Test Methods for Sampling and Testing Concrete Masonry Units and Related Units
2. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
3. D 1248 – Standard Specification for Polyethylene Plastics Extrusion Materials for Wire and Cable
4. D 3034 – Standard Specification for Type PSM Poly(Vinyl Chloride) (PVC) Sewer Pipe and Fittings

1.3 SUBMITTALS

A. Product Data: Geotextile.

B. Quality Control Submittals:

1. Certificates: Submit the Manufacturer's certifications two weeks prior to the start of Work stating that SRW units and geosynthetic reinforcement are as specified in this Section. If the height from the top of the wall to the bottom of the footing is greater than 4 feet or supporting a surcharge, the calculations shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

1.4 QUALITY ASSURANCE

A. Qualifications:

1. A minimum of 5 years of documented experience in the Work of this Section.
2. Approved by the Manufacturer.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Check materials upon delivery to ensure the specified type and grade of materials and the proper color and texture of SRW units are supplied.

B. Store and handle materials in accordance with the Manufacturer's instructions and as specified in SECTION 01 60 00.

C. Prevent excessive mud, wet concrete, epoxies, and like materials that may affix themselves from coming in contact with SRW materials.

D. Protect materials from damage. Damaged materials shall not be used into the retaining wall.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Geogrids:

1. Fortrac

2.2 MATERIALS

A. SRW Units:

1. Machine-formed portland cement concrete blocks specifically designed for retaining wall applications.
2. Color: As shown on the Drawings.
3. Face finish: As shown on the Drawings.
4. Unit height: As shown on the Drawings.
5. Units (not including aggregate fill in unit voids) shall provide a minimum weight of 78 psf per wall face area.
6. Units shall have a minimum depth (front face to rear) to height ratio of 1.5 to 1.
7. Units shall be sound and free of cracks and defects that would interfere with the proper placement of the unit or impair the strength or permanence of the structure. Units with cracking or excessive chipping shall not be used.
8. Concrete used to manufacture units shall have a minimum 28 day compressive strength of 3,000 psi and a maximum moisture absorption rate, by weight, of 8% as determined in accordance with ASTM C 140. Compressive strength test specimens shall conform to the saw cut coupon provisions in accordance with ASTM C 140, except the coupon shall be taken from the least dimension of the unit of a size and shape representing the geometry of the unit as a whole.
9. Units molded dimensions shall not differ more than ±1/8 inch from that specified, except height which shall be ±1/16 inch as measured in accordance with ASTM C 140.

B. Units shall be interlocked with connection pins. Pins shall consist of glass-reinforced nylon made for use with the units supplied.

C. Geosynthetic reinforcement shall consist of geogrids or geotextiles manufactured as a soil reinforcement element.

1. Manufacturers of geosynthetic reinforcement shall have demonstrated construction of similar sizes and types of SRWs on previous projects.
2. The type, strength, and placement location of the reinforcing geosynthetic shall be as determined or as shown on the Drawings.

D. Leveling pad material shall consist of CDOT Class 6 aggregate base course and be a minimum of 8 inches in depth.

E. Drainage aggregate shall be angular, clean stone, or granular fill that meets the following gradation.

Sieve Size	Percent Passing (Volume)
1 inch	100
3/4 inch	75 to 100
No. 4	0 to 60
No. 40	0 to 50
No. 200	0 to 5

F. Drainage Pipe: Perforated or slotted PVC or corrugated HDPE pipe wrapped with a geotextile fabric to function as a filter and manufactured in accordance with ASTM D 3034 and ASTM D 1248.

G. Reinforced Soil:
1. Reinforced soil material shall be free of debris. The reinforced material shall consist of the inorganic NRCS soil types: GP, GW, SW, SP, and SM meeting the following gradation.
2. The maximum particle size of GP, no fines, shall not exceed 3/4 inch unless geosynthetic strength is reduced to account for additional installation damage from larger particles.
3. The plasticity of the fine fraction shall be less than 20.
4. Reinforced soil material shall meet the following gradation:

Sieve Size	Percent Passing (Volume)
4 inches	100
No. 4	20 to 100
No. 40	0 to 60
No. 200	0 to 35

PART 3 EXECUTION

3.1 PREPARATION

A. Following excavation, foundation soil shall be examined by the ENGINEER to ensure actual strength meets or exceeds the assumed design bearing strength. Soils that fail to meet the required strength shall be removed and replaced with infill soils as directed.

B. Foundation soil shall be proof-rolled and compacted to 95% of maximum density as determined by ASTM D 698 at a moisture content within 2% of optimum, and inspected by the ENGINEER prior to the placement of leveling pad materials.

3.2 INSTALLATION

A. Design:
1. For constructability considerations, vertical spacing between geosynthetic layers shall not exceed 2 feet.
2. Each layer of geosynthetic reinforcement shall be designed with 100% continuous coverage parallel to the length of the wall. Gapping between horizontally adjacent layers of geosynthetic (partial coverage) is not allowed.

B. Excavation:
1. Excavate to the lines and grades shown on the Drawings; take precautions to minimize over-excavation. Over-excavation shall be filled with compacted fill as specified in SECTION 31 23 23 at the CONTRACTOR's expense.
2. Verify the location of existing structures and utilities prior to excavation. Ensure surrounding structures are protected from the effects of wall excavation. Provide excavation support if required.

C. Leveling Pad: Place as shown on the Drawings. The leveling pad shall extend laterally at least 6 inches from the toe and heel of the lowermost SRW unit.

D. SRW Units:
1. Install SRW units to the proper elevation and orientation shown on the Drawings and in general accordance with the Manufacturer's instructions.
2. The first course of units shall be placed on the leveling pad. Units shall be leveled side-to-side, front-to-rear, and with adjacent units. Align to ensure contact with the leveling pad. Alignment may be done by means of a string line or offset from base line to the back of the units. Gaps shall not be left between the fronts of adjacent units.
3. Voids within the units shall be filled with granular drainage aggregate and excess debris cleaned from the top of the units.
4. The next course of units shall be placed on top of the lower course of units.
5. Where pins are utilized, connection shall be installed through the pin holes of each upper course unit into the receiving slots in the lower course units. Pins shall be fully seated in the pin slot below. Units shall be pushed forward to remove looseness in the unit-to-unit connection. Level and alignment of the units shall be checked and corrected if necessary before proceeding.
6. The layout of curves and corners shall be installed in accordance with the Drawings and the Manufacturer's installation guidelines. Walls meeting at corners shall be interlocked by overlapping successive courses.
7. These procedures shall be repeated to the extent of wall height.
8. The wall face cant shall not differ more than ±2 degrees from that specified.

E. Geosynthetic Reinforcement:
1. Install geosynthetic reinforcement at the proper elevation and orientation shown on the Drawings. Verify that orientation is correct in accordance with the Manufacturer's instructions.

2. Lay horizontally on compacted fill and on top of concrete SRW units at the elevations shown on the Drawings. Embedment in the SRW units shall be in accordance with the Manufacturer's instructions. The highest strength direction shall be perpendicular to the wall face.
3. Layers shall be one continuous piece for the entire embedment length. Overlap in the design strength direction perpendicular to the wall face is not permitted. Horizontally adjacent sections shall be butted in a manner to ensure 100% coverage after placement.
4. A minimum of 6 inches of backfill is required prior to the operation of tracked vehicles over reinforcement. Rubber tire equipment may pass directly over reinforcement at speeds less than 5 mph; keep turning to a minimum.
5. In tension and free of wrinkles prior to the placement of fill. Nominal tension shall be applied and secured in place with staples, stakes, or by hand-tensioning until reinforcement is covered by 6 inches of fill.

F. Drainage:
1. Drainage aggregate shall be installed to the line, grades, and sections shown on the Drawings. Drainage fill shall be placed to the minimum thickness shown on the Drawings between and behind units.
2. Collection pipes shall be installed to maintain the gravity flow of water outside the reinforced soil zone. Collection pipe shall daylight along a slope at an elevation lower than the lowest point of the pipe within the aggregate drain.

G. Backfill:
1. Reinforced backfill shall be placed as shown on the Drawings in the maximum compacted lift thickness of 10 inches and compacted to 95% of maximum density in accordance with ASTM D 698 at a moisture content within 2% of optimum. Backfill shall be placed and spread in such a manner as to eliminate wrinkles and eliminate the movement of geosynthetic reinforcement and SRW units.
2. Only hand-operated compaction equipment is allowed within 3 feet of the front of the wall face. Compaction within 3 feet behind the wall face shall be achieved by using a lightweight mechanical tamper, plate, or roller.
3. At the end of each day's operation, slope the last level of backfill away from the wall facing to direct water runoff away from the wall face.
4. At completion of wall construction, backfill shall be placed level with the final top of the wall elevation. If final grading, paving, landscaping, and storm drainage installation adjacent to the wall is not placed immediately after wall completion, provide temporary surface drainage to ensure water runoff is not directed at the wall and not allowed to collect or pond behind the wall until final construction adjacent to the wall is complete.

H. SRW Caps:
1. Properly align and glue SRW caps to underlying units with Manufacturer recommended, flexible, high-strength concrete adhesive. Rigid adhesive and mortar shall not be used.
2. Overhang the top course of units by 3/4 inch to 1 inch; a slight variation in overhang is allowed to correct alignment at the top of the wall.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for irrigation systems.

B. Related Sections:
   1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
   2. SECTION 33 19 13 – WATER METERS FOR SERVICE LINE INSTALLATIONS
   3. SECTION 31 23 33 – TRENCH BACKFILL
   4. SECTION 33 05 31.26 – POLYVINYL CHLORIDE PIPE FOR TRANSMISSION AND DISTRIBUTION

1.2 REFERENCES

A. ASTM International (ASTM):
   1. A 536 – Standard Specification for Ductile Iron Castings
   2. B 62 – Standard Specification for Composition Bronze or Ounce Metal Castings
   3. B 584 – Standard Specification for Copper Alloy Sand Castings for General Applications
   4. C 33 – Standard Specification for Concrete Aggregates
   5. D 256 – Standard Test Methods for Determining the Izod Pendulum Impact Resistance of Plastics
   6. D 638 – Standard Test Method for Tensile Properties of Plastics
   7. D 648 – Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
   8. D 698 – Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3 (600 kN-m/m^3))
   9. D 790 – Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
   10. D 792 – Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement
   11. D 1784 – Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
   12. D 2239 – Standard Specification for Polyethylene (PE) Plastic Pipe (SIDR-PR) Based on Controlled Inside Diameter
   13. D 2241 – Standard Specification for Poly(Vinyl Chloride) (PVC) Pressure-Rated Pipe (SDR Series)
   14. D 2464 – Standard Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
   15. D 2466 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
   16. D 2467 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
   17. D 2564 – Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
   18. F 477 – Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

B. Colorado Department of Transportation (CDOT):
   1. Standard Specification for Road and Bridge Construction

C. Manufacturers Standardization Society (MSS):
   1. SP-80 – Bronze Gate, Globe, Angle, and Check Valves

D. National Fire Protection Association (NFPA):
   1. 70 – National Electrical Code (NEC)

E. NSF International/American National Standards Institute (NSF/ANSI):
   1. 61 – Drinking Water System Components – Health Effects

1.3 SUBMITTALS

A. Product Data: Include information on the meter, backflow preventer, controller, valves, flow sensor, pipes, and pipe fittings.

B. Quality Control Submittals: Qualifications of the Systems Manufacturer and the systems installer.

C. Warranty Documentation:
   1. Sample warranty.
   2. Warranty

D. Material Submittals:
   1. Provide, tag, and box the following special tools for shipment and storage:

Quantity	Description
1	Manual drain key
1	Gate valve key
6	Sprinkler nozzles for each type used
1	Quick coupler key and hose swivels
1	Sprinkler adjusting tool

1.4 QUALITY ASSURANCE

A. Qualifications:
   1. CONTRACTOR: Coordinate installation with other trades on the Work.
   2. Systems Supplier: Regularly engaged in the distribution of irrigation systems.
   3. Systems Installer qualifications:
      a. A minimum of 5 years of documented experience in the Work of this Section.
      b. Approved by the Manufacturer.

4. Field superintendent: On-site daily; provide at least one Maxicom certified installer during the installation of Maxicom related equipment.

1.5 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

1.6 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the irrigation system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Meters:
   1. Type A, 3 inches or larger: As specified in SECTION 33 19 13
   2. Type B: 2 inches or smaller: As specified in SECTION 33 19 13
   3. RP BFPAs:
      a. Type A: In accordance with Standard Detail 33283
      b. Type B: In accordance with Standard Detail 32054

B. Valves:
   1. Master valve:
      a. Superior, 3200
   2. Isolation valves:
      a. Type A, Matco, 10RT
      b. Type B, Matco, 513
   3. Drain valves:
      a. Matco, 513
   4. Drain Check Valves:
      a. Rain Bird, Seal-A-Matic (SAM)
   5. Quick-coupling valves:
      a. Rain Bird, 44-RC
   6. Angle valve:
      a. Buckner, VBM
   7. Ball valve:
      a. Spears, PVC True Union
   8. Electric control valve:
      a. Rain Bird PEB Series

C. Dripline Filter:
   1. Netafim Techfilter with Triflurex incorporated into the replaceable disk

D. Dripline Pressure Regulator:
   1. Netafim high flow series

E. Dripline Pipe:
   1. Netafim Techline CV

F. Fittings:
   1. Dripline fittings:
      a. Netafim 17 mm
   2. Mainline fittings:
      a. Harco Deep Bell
      b. Schedule 40 PVC
      c. Schedule 80 PVC

G. Flow Sensing:
   1. Flow sensor: Rain Bird, FS Series

H. Controllers:
   1. HydroPoint WeatherTRAK ET Pro3 two-wire/conventional
   2. HydroPoint WeatherTRAK LC+

I. Valve and Utility Boxes:
   1. Box and cover: Carson, Brooks Plastics, with thermoplastic construction in accordance with ASTM D 256, ASTM D 638, ASTM D 648, ASTM D 790, and ASTM D 792

J. Wire Splice:
   1. 3M, DBY direct-bury splice kit

K. Solvent Primer:
   1. Weld-on

L. Control Wire:
   1. Paige P70 72D (red/black) – two-wire 12 gauge solid copper AWG and UL/UF approved

M. Decoder:
   1. HydroPoint WeatherTRAK two-wire single valve, WT2W-SVD-11

N. Lightning Surge Protection:
   1. HydroPoint WeatherTRAK WT2W-LSP

2.2 MATERIALS

A. Meter: As specified in SECTION 33 19 13.

B. Backflow Preventer: The RP BFPA shall be approved by the Foundation for Cross-Connection Control and Hydraulic Research at the University of Southern California.

C. Pipe Zone: As specified in SECTION 31 23 33.

D. Valve Box Base: 3/4-inch crushed rock, CDOT Standard Specification for Road and Bridge Construction Size No. 7, free from dirt, clay balls, and organic material.

E. Valves:

1. Master valve:
   a. Normally closed.
   b. Brass body.
   c. EPDM rubber parts.
   d. 24 VAC solenoid.
2. Isolation valve:
   a. Type A:
      1) 200 psi CWP.
      2) Full port flow.
      3) Epoxy-coated CI, internal and external.
      4) Vulcanized encapsulated resilient wedge.
      5) Serviceable in-line.
      6) Wrench nut, 2 inches.
      7) Replaceable disc.
   b. Type B:
      1) 200 psi WOG.
      2) Non-rising stem.
      3) Full port flow.
      4) Solid wedge.
      5) Cross handle.
      6) In accordance with MSS SP-80 and ASTM B 62.
3. Drain valves:
   a. 200 psi WOG.
   b. Non-rising stem.
   c. Full port flow.
   d. Solid wedge.
   e. Cross handle.
   f. In accordance with MSS SP-80 and ASTM B 62.
4. Quick-coupling valves:
   a. The valve shall be a two-piece type, constructed of heavy duty cast brass in accordance with ASTM B 584, 81-3-7-9 type.
   b. Self-closing, yellow thermoplastic cover with an optional locking cover.
   c. Corrosion-resistant SST spring.
   d. Operating range: 10 gpm to 125 gpm, 5 psi to 125 psi.
   e. The valve design shall be compatible with the valve coupler key and hose swivels.
   f. Hose swivel, Rain Bird SH-1: 1 inch female pipe thread by 3/4 inch male hose thread.
   g. Valve key, Rain Bird 44-K: 1 inch.
5. Angle valve:
   a. Heavy duty cast brass.
   b. Cross handle.
   c. Incorporate a free-rotating seat disc assembly and a rising flow control stem to minimize pressure loss through the valve.
   d. The valve seat disc shall use replaceable seat washers.
   e. The flow control stem and seat disc assembly shall be removable from the valve body without removing the body from the pipeline.
6. Ball valve:
   a. PVC Type 1 Cell Classification 12454-B.
   b. Valves shall have a double stop PP handle.
   c. Union nuts shall have buttress threads.
   d. Valve components shall be replaceable.
   e. Full Schedule 80 bore opening.
   f. The seal carrier shall stop flow in either direction.
7. Electric control valve:
   a. Durable glass-filled nylon construction.
   b. The valve shall have internal and external manual open/close (internal and external bleed) for manually opening and closing the valve without electrically energizing the solenoid.
   c. The valve shall house a fully encapsulated one-piece solenoid. The solenoid shall have a captured plunger with a removable retainer and a leverage handle. The 24 VAC 50/60 Hz solenoid shall open with 19.6 VAC

minimum at 200 psi. At 24 VAC, average current shall not exceed 0.41 A. Average holding current shall not exceed 0.28 A.

d. The valve's construction shall provide for internal parts to be removable from the top of the valve without disturbance to the valve installation.

F. Pressure Regulator:
1. Plastic sealed unit, field replaceable.
2. Built-in indicator pops out when proper outlet pressure is achieved.

G. Pipe:
1. Mainline, Type A:
   a. Class 200RT PVC, SDR 21 semi-rigid, Type I, in accordance with ASTM D 1784, ASTM D 2241, and NSF/ANSI 61.
   b. Class 200RT with molded in place gasket in accordance with ASTM D 2564.
2. Mainline, Type B: Class 200BE PVC, SDR 21 semi-rigid, Type I, in accordance with ASTM D 1784, ASTM D 2241, and NSF/ANSI 61.
3. Lateral lines – PE pipe: 100 psi, NSF/ANSI 61, PE 3408, in accordance with ASTM D 2239.
4. Dripline – 17 mm dripline, 0.9 gph emitter flow rate, 12 inch emitter spacing.

H. Fittings:
1. Mainline fittings, Type A: DI, Grade 65-45-12 in accordance with ASTM A 536. Fittings shall have deep bell push-on joints with gaskets meeting ASTM F 477.
2. Mainline fittings, Type B: PVC Type 1, Schedule 80, in accordance with ASTM D 1784, ASTM D 2464, and ASTM D 2467.
3. Valve and lateral fittings:
   a. PVC Type 1, Schedule 40 in accordance with ASTM D 1784 and ASTM D 2466.
   b. PVC Type 1, Schedule 80 in accordance with ASTM D 1784, ASTM D 2464, and ASTM D 2467.
4. Dripline fittings: 17 mm, high pressure rated, UV-resistant, barbed fittings.

I. Sleeves:
1. Sidewalks: Schedule 40 PVC, in accordance with ASTM D 1784, semi-rigid, Type I, ASTM D 2466.
2. Roadways: Schedule 80 PVC, Type 1, in accordance with ASTM D 1784, ASTM D2464, and ASTM D 2467 and as specified in SECTION 33 05 31.26.

J. Flow Sensing:
1. Flow sensor:
   a. In-line PVC tee sensor with a non-magnetic, spinning impeller.
   b. Electronics housing: Glass-filled PPS.
   c. Shaft: Tungsten carbide.
   d. Electrical connections: Two single conductor #18 AWG leads.

K. Control Wiring:
1. Conventional controller:
   a. Type: #14 gauge solid AWG and UL/UF approved.
   b. Control wiring color: Red.
   c. Common wires: White.
   d. Spare control wires: Yellow, those left in valve boxes shall be located at zone x-x and clearly identified by a marking tag at the controller.
2. Two-wire controller:
   a. Paige P70 72D (red/black) 12 gauge solid copper wire, AWG and UL/UF approved.

L. Controller:
1. Conventional controller – HydroPoint WeatherTRAK ET Pro3. Model number as identified on the Drawings.
2. Two-wire controller – HydroPoint WeatherTRAK ET Pro3. Model number as identified on the Drawings.
3. HydroPoint WeatherTRAK LC+. Model number as identified on the Drawings.

M. Valve and Utility Boxes:
1. Cluster control valve box: Carson, Brooks Plastics, Model 2436-18 (without quick-coupler) or Model 3636-18 (with quick-coupler).
2. Single control valve box: Carson, Brooks Plastics, Model 1324-15.
3. Isolation valve box: Carson, Brooks Plastics, Model 910.
4. Drain valve box: Carson, Brooks Plastics, Model 910.
5. Splice box: Carson, Brooks Plastics, Model 1017-12.

N. Sprinklers:
1. Gear-driven rotor: As shown on the Drawings. Pop-up with radius and arc adjustments, SST riser, and a SAM drain check valve.
2. Spray head: As shown on the Drawings. Pop-up with UV-resistant plastic construction SAM and a PRS.

O. Accessories: SST worm-gear clamps with a 3/8 inch wide SST hex head screw.

PART 3 EXECUTION

3.1 INSTALLATION

A. Excavation and Backfill:
1. Trenching and installation of the irrigation system shall not occur until finish grades are attained and the ENGINEER's approval received.

2. Excavation:
   a. Unclassified.
   b. Minimum depth:
      1) Mainline, from finish grade to top of pipe: 24 inches.
      2) Laterals, from finish grade to top of pipe: 18 inches.
      3) Wiring: Constant side next to mainline.
   c. Width:
      1) Mainline: Excavate with a minimum of 4 inches on the sides of piping.
      2) Laterals: Excavate to the narrowest practicable width to perform connections.
   d. Bottom: Reasonably true to grade and free of protruding stones, roots, and other undesirable material. Uniformly slope to low points at a minimum of 3 inches per 100 feet.
   e. Avoid existing interference and utilities by adjusting the grade of the mainline. Provide the necessary fittings and excavation to make the adjustment.
3. Backfill:
   a. Pipe base material: Place and firmly compact squeegee sand, 10% passing at 3/8-inch sieve, 3% passing at No. 200 sieve, in accordance with ASTM C 33, to 3 inches in depth to provide a uniform, solid foundation for mainline pipe. Maintain 3 inches of depth over piping and compact to 95% of maximum density in accordance with ASTM D 698 at a moisture content within 2% of optimum.
   b. Place backfill in layers that do not exceed 6 inches and thoroughly compact each layer up to finished grade.
   c. Install poly marker tape and tracer wire as shown on the Drawings.
   d. Settling that occurs during the warranty period shall be repaired at the CONTRACTOR's expense, including damage to other items affected by settling.
   e. Remove excess material and debris from areas disturbed on-site.

B. Gasketed Pipe:
1. Cut the pipe squarely; bevel the plain end. The bevel shall be 15 degrees and 3/4 inch long. Measure the bell depth; mark the pipe for reference. In cold weather, allow 1/2 inch clearance between the end of pipe and the bell stop for future pipe expansion.
2. Clean debris from the bell area of the fitting. Seat the gasket completely in the groove and ensure there are no raised areas.
3. Lubricate the gasket and the plain end of the pipe with lubricant supplied by the Pipe Manufacturer.
4. Align the pipe with the fitting; push together by hand with pry bars on the end of the fitting or with two pry bars using the lugs on the fitting. Insert until the reference line mark is even with the edge of the fitting bell.

C. Plastic Pipe:
1. Plastic pipe shall not be installed when temperatures are below 40°F.
2. Use the Manufacturer's recommended sealant for threaded pipe connections.
3. Lay the pipe on the prepared base and snake it from one side of trench to the other to provide for subsequent thermal expansion and contraction.
4. After the successful completion of hydrostatic pressure testing and with the approval of the ENGINEER, begin backfill activities.
5. Pipe installed under hardscapes (walks, curbs, pavement) shall be inside PVC sleeves.

D. Solvent Weld Cement and Primers: Use the type recommended by the Pipe and Fittings Manufacturers.

Pipe Size (excluding Schedule 80) (Inches)	Solvent Primer	Solvent Cement
Up to 2	P-68 purple	710
2 to 6	P-70 purple	705
6 to 12	P-75 aqua-blue	711

E. Thrust Blocking:
1. Provide thrust blocks at changes in size or direction. Bends, reducers, plugs, and the opposite side of tee branches require thrust blocks.
2. The 100 psi sizing pressure, the size and type of fitting, and the soil conditions on-site will determine the size of the thrust block.
3. Soil type determined by the ENGINEER.
4. Thrust block sizing: Block Size (sf) = $\frac{\text{Table 1 Value}}{\text{Table 2 Value}}$

Table 1: Thrust/100 Table (Pounds per 100 psi)				
Size (Inches)	**Tees/Plugs**	**90˚**	**45˚**	**22.5˚**
2	363	513	259	141
2 1/2	531	751	379	207
3	788	1,114	562	307
4	1,302	1,841	928	508
6	2,822	3,990	2,012	1,101
8	4,783	6,763	3,410	1,865

Table 2: Soil Bearing Capacity	
Soil Type	**Safe Bearing Load (lbs/sf)**
Soft Clay	1,000
Sand	2,000
Sand and Gravel	3,000
Sand and Gravel Cemented with Clay	4,000
Hard Pan	10,000

F. Irrigation Line Clearances:
   1. Same trench: Minimum 6 inches horizontal clearance.
   2. Crossing lines: Minimum 2 inches vertical clearance.
   3. Other utilities: Minimum 24 inches clearance in any direction.

G. Sleeves:
   1. Utilize the following sleeve sizes unless otherwise noted on the Drawings:

Pipe Diameter or Wire Bundle Diameter	Minimum Required Sleeve Diameter (Inch PVC)
3/4 inch to 1 1/4-inch pipe	1 to 2
1 1/2 inch to 2-inch pipe	2 to 4
2 1/2 inch to 3-inch pipe	4 to 6
4 inch to 6-inch pipe	6 to 8
1 to 25 control wires	1 to 2
26 to 75 control wires	2 to 4

   2. Depth of sleeve:
      a. Mainline: 24 inches from finish grade to top of pipe; extend 2 feet past hardscape.
      b. Laterals: 18 inches from finish grade to top of pipe; extend 2 feet past hardscape.
   3. Sleeved pipe shall be installed on a compacted or non-disturbed subgrade.
   4. Wrap ends with a 3 foot length of Typar type landscape fabric. Duct tape landscape fabric to the sleeve.
   5. Install mainline, lateral pipe, and control wires if applicable. Snug fabric around piping; duct tape to prevent backfill material from entering the sleeve.
   6. Backfill and compact as outlined for trench excavations.

H. Valves and Valve Boxes:
   1. Control valves: Install in a single or clustered configuration as shown on the Drawings; verify with the ENGINEER prior to installation.
   2. Isolation valves: Install with brick foundation and gravel sump as shown on the Drawings.
   3. Valve boxes: Install on brick foundations and gravel sump as shown on the Drawings.
      a. Lawn areas: Set cover flush with finish grade.
      b. Mulched areas: Set flush with the top of the mulch.

I. Drain Valves:
   1. Pit excavation and preparation:
      a. Install valves on brick foundation with gravel sump as shown on the Drawings.
      b. Excavate 3 feet below the mainline.
      c. Excavate the pit diameter to contain a minimum of 3 cubic feet of crushed rock.
      d. Place Typar type landscape fabric into the hole and install rock on top of fabric. The installed rock shall be completely covered with fabric to prevent the infiltration of fines.
   2. Install as shown on the Drawings.

J. System Drainage:
   1. Drain valves: Locate at the points shown on the Drawings.
   2. Slope lines to ensure the entire system is effectively drained to the drain valves.

K. Sprinklers:
   1. Sprinkler heads shall be adjusted vertically to be flush with finish grade.
   2. Install heads on double swing joint or swing pipe assemblies. Use Teflon type pipe compound or the Manufacturer's recommended compound for the threaded sprinkler connection.
   3. The angle of the swing joints relative to lateral lines shall be between 15 degrees and 45 degrees.
   4. Install with the spacing shown on the Drawings. Vary the arrangement of heads to avoid trees, shrubs, and other obstacles with the approval of the ENGINEER.
   5. Locate a minimum of 2 inches from walkways, drives, paths, curbs, and paved areas.
   6. Tighten nozzles on pop-up spray heads after installation. Adjust sprinklers for proper coverage and discharge rate.

L. Wiring:
   1. Low-voltage:
      a. The installation of the wiring bundle shall be to one side and as close as possible to the mainline.
      b. Leave a 24-inch coil of wire in each valve box and make connections with 3M DBY splice connectors.
      c. The connection between the controller and the control valves shall be #12 (two-wire) or #14 UL/UF wire.

d. Direct-bury splices shall not be permitted unless contained in a splice box.
e. Control wire color: Red.
f. Common wire: White.
g. Spare wires: Yellow.
h. Ground wires at the controller: Green.
i. Two-wire control and common color: Red and black.

2. High-voltage: Electrical wiring shall be installed in accordance with the Manufacturer's instructions and NFPA 70.

M. Controller:
1. Packaged wall-mounted controller assembly: Make the necessary connections to control wiring, electrical supply, grounding, rain can, and network lines.
2. Install in accordance with the Manufacturer's instructions.
3. Verify controller assembly with the ENGINEER; grounding shall provide a resistance of 10 ohms or less.

N. Flushing: Flush the mainline before the installation of control valves; flush laterals before the installation of nozzles.

3.2 QUALITY CONTROL

A. Testing and Inspection:
1. The mainline to be tested shall be backfilled as specified prior to testing.
2. Close angle and ball valves at control valve locations.
3. Isolate the mainline from the backflow preventer.
4. Testing shall be performed after the mainline is properly filled, flushed, and purged of air.
5. The hydrostatic pressure test shall not be performed on solvent welded pipeline and pipe joints for a minimum of 2 days after installation.
6. Test the mainline pipe to 1 1/4 times the maximum working pressure. Typically test at 100 psi, measured at the highest point of the section being tested, for a period of 2 hours. Allowable pressure drop shall be a maximum of 5 psi as determined by:
   a. Gasketed pipe: $L = \frac{SD(\sqrt{P})}{148,000}$

      Where:

      L = Allowable leakage (gph)
      S = Length of pipe tested (ft)
      D = Nominal diameter of pipe (in)
      P = Test pressure (psi)

   b. Solvent weld pipe: L = 0
7. Test lateral lines by zone under normal operating pressure until approved by the ENGINEER.
8. Remove and replace defective piping; perform testing until pressure supply pipes are watertight.
9. In accordance with the Manufacturer's instructions. Central control operation and grounding specifications shall be approved by the Manufacturer's services technician and the ENGINEER before acceptance of the system.

B. System Balancing: Adjust flow controls and PRVs to the required sprinkler head pressure; adjust heads for alignment and coverage. The approval of the ENGINEER is required prior to planting.

END OF SECTION

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SECTION 32 91 00
PLANTING PREPARATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for planting preparation.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 32 92 00 – TURF AND GRASSES

1.2 REFERENCES

A. Environmental Protection Agency (EPA):

1. 40 CFR Part 503 – Standards for the Use or Disposal of Sewage Sludge

1.3 SEQUENCING AND SCHEDULING

A. Plant Deliveries: Notify the ENGINEER in writing at least 3 days in advance of each delivery.

B. Planting Season: May 1 to October 1.

C. Plant trees and shrubs after final grades are established and before seeding and sodding installations.

D. Phase landscaping to occur after irrigation or other hardscape installations (if applicable).

1.4 SUBMITTALS

A. Product Data: Labels and data sheets.

B. Samples: Representative of stockpiled or imported soil and amendment.

C. Quality Control Submittals: Products Supplier list.

1.5 QUALITY ASSURANCE

A. Qualifications: Material Suppliers shall be licensed distributors of the products.

1.6 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

PART 2 PRODUCTS

2.1 MATERIALS

A. Fertilizer:

1. Sod areas:
   a. Commercial, uniform in composition, free-flowing, suitable for application with equipment designed for that purpose; application rates: 5.6 lbs/1,000 sf.
   b. Mix: Diammonium phosphate (18-46-0).
      1) N: 18%.
      2) P_2O_5: 46%.
   c. Fertilizer shall be of neutral character, dry, pelletized or granular, uniform in composition, free-flowing, and thoroughly mixed by the Manufacturer.
2. Seed areas:
   a. Biosol Forte.
      1) Nutrient ratio: 7 to 2 to 1.
      2) Application rate: 1,500 lbs/acre.
      3) pH level: 6 to 8.
3. Material previously opened, caked, segregated, exceeding the expiration date of application, or otherwise damaged shall not be used.
4. Fertilizer shall be in compliance with federal, state, and local regulations. Fertilizer applied over water-containing structures shall be approved by the ENGINEER.

B. Soil Amendment:

1. Organic compost:
   a. Free from lumps, stones, foreign matter, mineral matter, and any composition harmful to plant life.
   b. Composted material with a carbon/nitrogen ratio from 20 to 1 to 30 to 1.
   c. Acidity and alkalinity range: pH 6.0 to 8.0.
   d. Particle size: Pass through a 1/2-inch sieve.
   e. Soluble salt content: Maximum of 2.5 dS/m.
   f. Moisture content: 35% to 55%.
   g. Stability: Stable to highly stable.
   h. Trace elements/heavy metals: In accordance with EPA 40 CFR Part 503 exceptional quality concentration limits.
   i. Organic matter content: Minimum 250 lbs/cy to 300 lbs/cy with a bulk density of 1,000 lbs/cy.
   j. Application rate: Depth of 1 inch (approximately 4 cy/1,000 sf).

C. Topsoil: Natural, friable, sandy-loam, obtained from well-drained areas, free from objects larger than 1 1/2 inches, subsoil, roots, grass, weeds, foreign matter, hazardous or toxic substances, and deleterious materials that may be harmful to plant growth or hinder grading, planting, or maintenance.

D. Mulch:

1. Stone mulch:
   a. Multi-colored washed river rock: 4 inches to 6 inches.
   b. Multi-colored washed river rock: 1 1/2 inch.
   c. Multi-colored washed river rock: 3/4 inch.
   d. Crushed granite: 3/4 inch.
      1) Color: Mountain granite.

e. Crushed granite: 1 1/2 inch.
   1) Color: Mountain granite.
f. Pea gravel: 3/8 inch.

2. Wood mulch: Mulch shall consist of shredded red cedar tree trimmings and be free from litter, leaves, boards, and trash.

E. Erosion Control Blanket:
1. Straw, straw/coconut, or coconut fibers stitched into or between 100% biodegradable nettings woven from lightweight, high strength jute yarn.
2. Slope and durability:
   a. Less than 3 to 1, 10 month: Straw matrix bonded with biodegradable thread to a single fiber net.
   b. 3 to 1, 10 month: Straw matrix stitch bonded with biodegradable thread between two natural fiber nets.
   c. 3 to 1 to 2 to 1, 18 month: 70% straw matrix, 30% coconut matrix stitch bonded with biodegradable thread between 2 natural fiber nets.
   d. Greater than 2 to 1, 24 month: Coconut matrix stitch bonded with biodegradable thread between two natural fiber nets.

PART 3 EXECUTION

3.1 PREPARATION

A. Scarify compacted subgrade to a 6 inch depth. Remove stones over 2 1/2 inches, sticks, roots, rubbish, and other extraneous material.

B. Establish rough grades to receive amendment and fertilizer at an appropriate level to meet final grade after placement, tilling, and compaction.

C. Limit preparation to areas that will receive placements within 2 days after subgrade preparation.

3.2 INSTALLATION

A. Soil Amendment:
1. Do not place amendment when subsoil or topsoil is frozen, excessively wet, or when it is otherwise detrimental to Work.
2. Spread compost evenly over the area to be sodded. Add specified fertilizer at the application rate on subgrade to be seeded or sodded. To thoroughly mix soil components, till to a depth of 6 inches.
3. Uniformly distribute to within 1/2 inch of final grade. Fine grade the surface to eliminate rough or low areas; maintain levels, profile, and contours. Hand rake areas inaccessible to machine grading. Compact with a roller to 75% of maximum density at a moisture content within 2% of optimum.
4. Remove stones exceeding 3/4 inch, roots, sticks, debris, and foreign matter during and after placement.
5. Remove surplus subsoil from the site. Grade the stockpile area as necessary and place in a condition acceptable for planting or seeding.

B. Mulching:
1. Washed river rock: Spread 3/4-inch rock over landscape fabric to an average depth of 3 inches in areas shown on the Drawings. For dry stream beds, add 1 1/2 inch and 4 inch to 6-inch rock at edges as shown on the Drawings. Finish with a narrow, undulating path of pea gravel down the center of the stream bed.
2. Red cedar mulch: Apply mulch over landscape fabric to a depth of 3 inches after planting is complete. Spread evenly over the designated area and keep neatly contained within edging.
3. Crushed granite: Spread 3/4-inch rock over landscape fabric to an average depth of 3 inches in areas shown on the Drawings.

C. Erosion Control Blanket:
1. Complete SECTION 32 92 00 prior to installing blankets.
2. Beginning at the top of the slope, place the blanket in a 6 inch deep by 6 inch wide trench with approximately 12 inches of blanket extending beyond the up-slope portion of the trench. Anchor the blanket by using a row of staples/stakes approximately 12 inches apart in the bottom of the trench. Backfill and compact the trench after stapling. Apply seed to the compacted soil and fold the remaining 12 inch portion of the blanket over the seed and the compacted soil; secure with a row of staples/stakes spaced approximately 12 inches apart across the width of the blanket.
3. Roll blankets down the slope. Blankets will unroll with the appropriate side against the soil surface. Blankets shall be securely fastened to the soil surface by the placement of staples or stakes in the locations shown in the Manufacturer’s staple pattern guide. When using the optional Dot System, staples/stakes shall be placed through the colored dots corresponding to the appropriate staple pattern.
4. The edges of parallel blankets shall be stapled with 2 inches to 5 inches of overlap depending on the blanket type.

3.3 PROTECTION

A. Protect existing materials found on-site, above and below grade. Locates for buried utilities and structures are required before excavation. Temporary fencing shall be used to protect plant material in vulnerable locations. Repair damage caused by the execution of this Section.

END OF SECTION

SECTION 32 92 00
TURF AND GRASSES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for turf and grasses.

B. Related Sections:

1. SECTION 32 31 23 – PLASTIC FENCES AND GATES
2. SECTION 32 91 00 – PLANTING PREPARATION
3. SECTION 32 93 00 – PLANTS

1.2 REFERENCES

A. Code of Federal Regulations (CFR):

1. 7 CFR Part 201 Federal Seed Act (FSA)

B. Colorado Department of Agriculture:

1. Weed Free Forage Act, Title 35, Article 27.5, CRS

1.3 DEFINITIONS:

A. Maintenance Period: Begin maintenance immediately after each area is planted (seed, sod, or sprig) and continue throughout the 1 year warranty period.

B. Satisfactory Stand:

1. A section of grass with bare spots no larger than 3 sf.
2. Uniform seed germination covering 80% of the area seeded.

C. Replacement Area: Areas disturbed by the activities of the CONTRACTOR.

1.4 SEQUENCING AND SCHEDULING

A. Before beginning the Work of this Section, complete planting as specified in SECTION 32 93 00 and prepare subgrade as specified in SECTION 32 91 00.

B. Complete the Work described herein within 10 days of the completion of soil preparation.

C. Notify the ENGINEER in writing at least 3 days in advance of each material delivery and at the start of seeding activity.

D. Seed and Sod Installation: March 15 to June 15; September 1 to October 15.

1.5 SUBMITTALS

A. Product Data: Seed and sod labels and data sheets.

B. Quality Control Submittals:

1. Certifications: Seed analysis, germination rate, and inoculation; certify that each lot of seed was tested within 6 months of the date of delivery by a certified seed testing laboratory. Include with certification:
   a. The name and address of the laboratory.
   b. The date of the test.
   c. The lot number for each seed specified.
   d. Test results: Name; percentages of purity and of germination; weed content for each kind of seed provided.
   e. The proportions of each kind of seed.

C. Administrative Submittals: Sod load tickets.

D. Warranty Documentation:

1. Sample warranty.
2. Warranty.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Seed: Provide in standard containers with the seed name, lot number, net weight, percentages of purity, germination, and the hard seed and maximum weed seed content clearly marked for each container of seed; keep dry during storage.

B. Hydroseeding Mulch: Mark the air dry weight on the package of wood fiber mulch.

C. Sod:

1. Deliver sod on pallets properly loaded on vehicles with the root system protected from exposure to sun, wind, and heat. Label with botanical and common names of each grass species in accordance with the 7 CFR Part 201 FSA. Sod damaged by poor handling or improper storage shall not be used.
2. Protect from dehydration, contamination, freezing, and heat. Keep stored sod moist and under shade or covered with moistened burlap.
3. Stack no more than 2 feet deep.
4. Sod rolls shall not be dropped from carts, trucks, or pallets.
5. Do not deliver more sod than can be installed within 2 days.

D. Fertilizer:

1. Deliver inorganic or chemical fertilizer to the Work site in its original, unopened container bearing the Manufacturer's guaranteed chemical analysis, name, trade name, trademark, warranty, and conformance to state law.
2. Material shall be inspected upon arrival at the Work site.
3. Immediately remove unacceptable material from the Work site.

1.7 SITE CONDITIONS

A. Perform Work under favorable weather and soil moisture conditions as determined by acceptable local practice.

1.8 WARRANTY

A. Warranty for 1 year full growing season (April 1 through October 31) following the Substantial Completion date for the satisfactory performance and installation of the turf and grasses system and associated appurtenances.

PART 2 PRODUCTS

2.1 MATERIALS

A. Fertilizer: Commercial, as specified in SECTION 32 91 00.

B. Water: Free of substances harmful to plant growth.

C. Sod: Colorado grown Kentucky Bluegrass blend having a healthy, vigorous root system. The blend shall contain a minimum of three improved varieties of which at least one is an aggressive type.

D. Seed:

1. Fresh, clean new-crop seed in compliance with the tolerance for purity and germination established by the AOSA.
2. Seeds of legumes: Inoculated with a pure culture of nitrogen-fixing bacteria prepared specifically for legume species in accordance with the Manufacturer's instructions.
3. Weed free with a purity of 99%.
4. Germination shall exceed 85%.
5. Seeding mixtures shall be applied at a PLS rate per acre as follows:
   a. Type 1 – native mix:

Common Name (Grasses)	Scientific Name	Cultivar	Percentage of Mix	PLS Lbs/Acre (drill)	PLS Lbs/Acre (broadcast)
Western Wheatgrass	Pascopyrum smithii	Arriba	30	12	24
Thickspike Wheatgrass	Elymus lanceolatus	Critana	10	4	8
Streambank Wheatgrass	Elymus lanceolatus	Sodar	10	4	8
Green Needlegrass	Nassella viridula	Lodorm	5	2	4
Blue Grama	Bouteloua gracilis	Hachita	20	8	16
Sideoats grama	Bouteloua curtipendula	Vaughn	10	4	8
Little Bluestem	Schizachyrium scoparium	Pastura	5	2	4
Yellow Indiangrass	Sorghastrum nutans	Cheyenne	5	2	4
Switchgrass	Panicum virgatum	Nebraska 28	5	2	4
		TOTAL	100	40	80

   b. Type 2 – cover crop:

Common/Scientific Name	Variety		Percentage of Mix	PLS Lbs/Acre (drill)	PLS Lbs/Acre (broadcast)
Quickguard	Triticum aestivum x Secale cereale		100	10	20
		TOTAL	100	10	20

6. Compensate for the percentage of purity and germination by providing sufficient additional seed to equal the specified PLS product. The formula for determining the quantity of PLS: Pounds of Seed (Bulk) x Purity x Germination = Pounds of PLS.

E. Straw:

1. Certified under the Colorado Department of Agriculture Weed Free Forage Certification Program and inspected as regulated by the Weed Free Forage Act, Title 35, Article 27.5, CRS. Each certified weed free mulch bale shall be identified by one of the following:
   a. One of the ties binding the bale shall consist of blue and orange twine.
   b. The bale shall have a regional Forage Certification Program tag indicating the Regional Forage Certification Program Number.
2. Do not unload certified weed free mulch bales or remove their identifying twine, wire, or tags until the ENGINEER has inspected and accepted them.
3. Straw in a stage of decomposition (discolored, brittle, rotten, or moldy) or old, dry mulch which breaks in the crimping process will not be accepted.

F. Hydromulching – Wood Cellulose Fiber Mulch:

1. Specially processed wood fiber containing no growth or germination inhibiting factors.
2. Organic green dye to facilitate the inspection of material placement.
3. Manufactured such that after addition and agitation in slurry tanks with water, the material fibers shall become uniformly suspended to form a homogenous slurry.
4. When hydraulically sprayed on the ground, the material shall allow moisture absorption and percolation.

G. Tackifier:

1. Derived from natural, organic plant sources containing no growth or germination inhibiting materials.
2. Capable of hydrating in water.
3. Readily blendable with other slurry materials.

4. Natural guar, organic polysaccharide containing no additives.
5. Coverage rate of 40 lbs/acre.

H. Fence: Seeded and sodded areas shall be protected against damage from pedestrian or vehicle traffic as specified by the ENGINEER; fence material shall be clearly visible and suitable for deterring traffic as specified in SECTION 32 31 23.

PART 3 EXECUTION

3.1 GENERAL

A. Areas disturbed by the CONTRACTOR's operation such as, but not limited to, earthwork, construction, construction traffic, and the storage of equipment or materials shall be restored to existing condition.

3.2 PREPARATION

A. Prepare subgrade as specified in SECTION 32 91 00.
B. Seed by evenly spreading fertilizer over the area at a rate of 1,500 lbs/acre.
C. Sod by evenly spreading 1 1/3 inches of compost over the area.
D. Till in thoroughly to a minimum depth of 6 inches.
E. Grade areas to a smooth, even surface with loose, uniformly fine texture.
F. Roll to compact. Rake to remove ridges, fill depressions, and meet finish grades.
G. Limit Work to areas to be planted within the immediate future.
H. Remove debris, stones larger than 3/4 inch, and other objects that may interfere with planting and maintenance operations.
I. Restore prepared areas to the specified condition if eroded or otherwise disturbed after preparation and prior to planting.

3.3 INSTALLATION

A. Seeding:
1. Start seeding within 3 days of the completion of soil preparation.
2. Hydroseed slopes steeper than 3 to 1. Flatter slopes shall be drill seeded. Mechanical seeding may be used where weight or access of machinery is a problem.
3. Mechanical: Broadcast seed in two different directions and compact the seeded area with a cultipacter or roller.
4. Sow seed at a uniform rate: Type I, 1 lb/1,000 sf.
5. Use a rangeland drill type seeder with a packer wheel.
6. Broadcasting is only allowed in areas too small to use a rangeland drill type seeder. Where seed is broadcast, increase the seeding rate by 100%.
7. Broadcast seed shall be raked in or covered with a minimum of 1/4 inch of soil.

B. Sodding:
1. Lay sod on dry soil.
2. Lay with the longest dimension parallel to contours and in continuous rows.
3. Tightly butt the ends and the sides of sod together. Stagger and compact vertical joints between sod strips by rolling so that sod is incorporated with the ground surface. Ensure tight joints between adjacent pieces. Ensure sod is not stretched or overlapped.
4. Add topsoil along exposed edges to match adjacent grade. Feather topsoil out approximately 1 foot from the edge of the sod. Broom screened topsoil over the entire sodded area to fill voids; do not smother sod.
5. Roll when soil and sod are moist. Roll sod lightly as soon as possible after it is laid. The roller shall weigh 100 lbs to 160 lbs/ft/roller. Delay rolling until just prior to the second watering.
6. Assure that finished areas of sod are graded such that positive drainage of storm and irrigation water will occur and ponding of water is minimized.
7. Thoroughly water sod immediately after laying to a depth sufficient to thoroughly wet the underside of the new sod strips and the soil below the sod.
8. Maintain a spongy, wet surface for 7 days then begin to lessen the water requirement.

C. Hydroseeding:
1. Application rate: 2,500 lbs/acre plus two times the seed application requirements.
2. Apply on moist soil after free surface water has drained away.
3. Prevent drift and displacement of the mixture into other areas.
4. Upon application, allow moisture absorption and percolation into the ground.

D. Hydromulching:
1. Apply immediately upon the seed being drilled.
2. Apply wood cellulose fiber uniformly at a rate of 2,500 lbs/acre.
3. Apply uniformly across the surface of the soil in the designated area.
4. Mix tackifier at a rate of 40 lbs/acre with wood cellulose fiber or in accordance with the Manufacturer's instructions.
5. Apply water with fine spray after mulching to saturate the top 2 inches of the soil; repeat daily as required to keep the 2-inch profile moist during the 14 to 30 day germination period.

E. Straw Mulching:
1. After seeding has been completed or when required for erosion control, hay or straw shall be uniformly applied, with no bare soil showing, at a rate of 2 tons/acre. It shall be crimped in with a crimper or other approved equipment. The ENGINEER may order hand-crimping on areas where mechanical methods cannot be used.
2. The seeded area shall be mulched and crimped within 4 hours after seeding. Areas not mulched and crimped within 4 hours after seeding or prior to precipitation or damaging winds on-site shall be reseeded with the specified seed mix at the CONTRACTOR's expense prior to mulching and crimping.

3.4 QUALITY CONTROL

A. Sod materials shall be subject to inspection and acceptance. Prior to acceptance, the ENGINEER reserves the right to reject sod materials if, in the ENGINEER's opinion, the materials fail to meet the requirements herein.

B. Inspection Control:
   1. Inspection control is primarily for quality; however, other requirements shall not be waived even though visual inspection results in acceptance. Notify the ENGINEER in writing 2 days in advance of the intended sod farm prior to cutting for inspection. Inspection at the growth site shall not rule out the right of rejection at the Work site.
   2. Promptly remove rejected sod from the Work site.
   3. The ENGINEER will periodically inspect during sodding, at its completion, and at the end of the warranty period.

C. Sod Standards:
   1. Sod shall be healthy, thick turf having undergone a program of regular fertilization, mowing, and weed control that is free of objectionable weeds and uniform in green color, leaf texture, and density. It shall have a healthy, vigorous root system and when inspected be free of disease, nematodes, pests, and pest larvae.
   2. Each piece of sod shall have a sandy-loam soil base that will not break, crumble, or tear during sod installation.
   3. Thickness: Minimum 3/4 inch, excluding top growth and thatch.
   4. Thatch: Not to exceed 1/2 inch uncompressed.
   5. Size: Cut in 18 inch wide strips within 1 day of delivery.

D. Unconditionally guarantee a satisfactory stand of grasses in locations seeded throughout the entire warranty period.

E. Eight weeks after seeding is complete and upon written notice from the CONTRACTOR, the ENGINEER will, within 15 days of receiving the notice, determine if a satisfactory stand is established.

F. If a satisfactory stand is not established, the ENGINEER will make another determination following the next growing season after receiving written notice from CONTRACTOR.

G. Maintenance:
   1. Seed maintenance includes:
      a. Keeping the surface moist to establish a satisfactory stand.
      b. Repairing washouts by filling with topsoil, fertilizing, seeding, and mulching.
      c. Replacing mulch wherever and whenever it is washed or blown away.
      d. Weed control.
      e. Repairing and maintaining fences until a satisfactory stand of grass is established.
      f. Reseeding unsatisfactory areas, or portions thereof, immediately at the end of the maintenance period if a satisfactory stand is not established.
      g. Reseeding or replanting during the next planting season if the scheduled end of maintenance period falls after consistent ground freeze.
      h. Reseeding or replanting the entire area if a satisfactory stand does not develop by July 1 of the following year.
   2. Sod maintenance includes:
      a. The maintenance period shall begin immediately after each area is sodded and shall continue until the Substantial Completion date or a minimum of 30 days, whichever is later. During this time, water, mow, spray, weed, aerate, fertilize, and perform related work as necessary to ensure that sodded areas are in a vigorous growing condition.
      b. Providing supervision, labor, material, and equipment to maintain turf areas.
      c. Ensuring materials are as specified in this Section.
      d. Initial watering shall begin when Work is complete and the irrigation system is operable under full control.
      e. Watering sod sufficiently to moisten subsoil at least 4 inches deep in a manner that does not cause erosion or damage to adjacent finished surfaces. Water shall be free of substances harmful to plant growth.
      f. Providing water from an underground sprinkler system, quick-couplers, or other source.
      g. Mowing and trimming around trees (keeping mulch in saucers and beds), walls, fences, etc., and maintaining turf at 2 1/2 inches to 3 inches in height; do not remove more than 1/3 of grass leaf in a single mowing; remove grass clippings from pavement areas.
      h. Resodding spots larger than 1 sf not having a healthy, uniform stand of grass.
      i. Weed control as required using selective herbicides approved by the ENGINEER.
      j. Final acceptance:
         1) At the end of the warranty period, the ENGINEER will, upon written notice of end of the warranty period, inspect the Work for final acceptance. Ensure the written request is received at least 10 days before the anticipated date for final inspection.
         2) The ENGINEER will inspect and approve repairs and replacements.
         3) Sod areas will be accepted when:
            a) Roots are thoroughly knit to the soil.
            b) There is an absence of visible joints.
            c) Each area shows a uniform stand of specified grass in a healthy condition that is free of weeds, diseases, and other visible imperfections.
            d) At least 30 days have elapsed since the completion of the Work under this Section.

3.5 PROTECTION

A. As determined by the ENGINEER, erect a temporary fence, as specified in SECTION 32 31 23, around each newly seeded or sodded area as shown on the Drawings.

END OF SECTION

SECTION 32 93 00
PLANTS

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for plants.
- B. Related Sections:
  1. SECTION 32 91 00 – PLANTING PREPARATION

1.2 REFERENCES
- A. American National Standards Institute (ANSI):
  1. Z60.1 – American Standard for Nursery Stock
- B. Colorado Nursery Act (CNA):
  1. Title 35, Article 26, Section 111, CRS 1973
- C. Hortus Third, 1976 (Plant Encyclopedia)

1.3 DEFINITIONS
- A. Shade and Flowering Trees:
  1. In size grading B&B shade trees, caliper takes precedence over height.
  2. In size grading B&B small and flowering trees, height shall take precedence up to 6 feet, and then caliper takes precedence.
  3. In size grading bare root and container trees, height shall take precedence up to 6 feet for small and flowering trees and 8 feet for shade trees, and then caliper takes precedence.
  4. Caliper of the trunk shall be taken 6 inches above the ground up to and including 4 inch caliper size. Larger sizes shall be measured 12 inches above the ground.
  5. The minimum size allowable for that grade shall include plants from that size up to, but not including, the next larger grade size.
- B. Deciduous shrubs, coniferous evergreens, and broadleaf evergreens: The size shall be the minimum size allowable for that grade, including plants from that size up to, but not including, the next larger grade size.
- C. Perennial Plants: Graded by plant size and container size. Plant size refers to the minimum size for a specific grade.

1.4 SEQUENCING AND SCHEDULING
- A. Plant Deliveries: Notify the ENGINEER in writing a minimum of 3 days in advance of each delivery.
- B. Planting Season: May 1 to October 1.
- C. Plant trees and shrubs after final grades are established and before seeding or sodding installations.
- D. Phase landscaping to occur after irrigation system installation or other hardscape installations.

1.5 SUBMITTALS
- A. Product Data: For the manufactured products specified.
- B. Quality Control Submittals:
  1. Products Supplier list.
  2. Complete soil nutrient test, if applicable.
  3. Qualifications for Suppliers and landscape installers.
  4. Watering schedule.
- C. Contract Closeout Submittals: O&M instructions for the care and maintenance of each type of plant material.
- D. Warranty Documentation:
  1. Sample warranty.
  2. Warranty.

1.6 QUALITY ASSURANCE
- A. Qualifications:
  1. A minimum of 5 years of documented experience in the Work of this Section.
  2. Approved by the Manufacturer.
- B. Material Suppliers: Products shall meet industry standards for type and quality; nursery stock shall be in accordance with ANSI Z60.1 and CNA, Title 35.

1.7 DELIVERY, STORAGE, AND HANDLING
- A. Cover plants during shipment with a tarpaulin or other suitable covering to minimize desiccation.
- B. B&B Plants: Wrap each ball firmly with burlap; securely bind burlap with twine, cord, or wire; drum lace balls 30 inches or more in diameter.
- C. Store plants in a designated staging area. If B&B stock are not installed within 8 hours, provide mulch or excavated soil in the staging area to cover the bottom 2/3 of the root ball. Maintain plant watering requirements until installation occurs.

1.8 WARRANTY
- A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the plants and associated appurtenances.
- B. In accordance with the accepted submittal on the care and maintenance of plants and as follows:
  1. Maintain by watering, pruning, cultivating, and weeding as required for healthy growth. Restore planting saucers.
  2. Tighten and repair stake and guy supports and reset trees and shrubs to proper grades or vertical position as required.
  3. Restore or replace damaged wrappings. Spray to keep trees and shrubs free of insects and disease as required.
  4. Maintenance includes providing temporary protection fences as required.
  5. Provide the watering schedule to the ENGINEER.

6. Guarantee workmanship and installed materials; provide for removal and replacement with new, like genus/species plants with those transplanted or newly planted plants found defective, dead, or not in a vigorous, thriving condition within the 1-year period after the Substantial Completion date.

PART 2 PRODUCTS

2.1 MATERIALS

A. Trees, Shrubs, and Groundcover:
   1. Provide the quantity, size, genus, species, and variety of trees and shrubs indicated on the plant list. Grade and sizing shall be in accordance with ANSI Z60.1.
   2. Nomenclature (names of plants) shall be in accordance with Hortus Third.
   3. Quality and size:
      a. Nursery-grown, with the habit of growth normal for the species.
      b. Sound, healthy, vigorous, and free from insects, disease, and injury.
      c. Equal to or exceeding the measurements specified in the plant list.
      d. The root system of container-grown plants shall be well developed and well distributed throughout the container such that roots visibly extend to the inside face of the container.
      e. Pruning shall only occur upon approval of the ENGINEER.
      f. Size, canes, and spread in accordance with ANSI Z60.1 for the kind and type of plants required.
      g. B&B plants shall have a firm, intact ball of earth encompassing enough of the fibrous and feeding root system to enable full plant recovery.
      h. Meet the minimum spread height to ball requirements in accordance with ANSI Z60.1.
      i. Container-grown plants shall be self-established root systems sufficient to hold earth together after removal from the container.
      j. Stock shall be grown in delivery containers for 6 months to 2 years.
   4. Label each tree and shrub of a variety with a securely attached waterproof tag bearing the legible designation of the botanical and common names.

B. Guying, Staking, and Wrapping:
   1. Steel T-posts: Length as required.
   2. Guy wires: 12 gauge galvanized steel.
   3. Anchors: As required.
   4. Tree tie strap: Nylon strap with grommets.
   5. Tree wrapping material: Approved paper tree wrap.
   6. Burlap: Of first quality, a minimum 8 ounces in weight and between 6 inches and 10 inches in width.

C. Planting Soil – Volumetric Mix: 1/2 excavated pit soil with 1/2 approved compost as specified in SECTION 32 91 00.

D. Fertilizer: Complete, granular, timed release, 18% N-7% P-10% K.

PART 3 EXECUTION

3.1 GENERAL

A. Protect existing on-site materials above and below grade. Locates for buried utilities and structures are required before excavation. Temporary fencing shall be used to protect plant material in vulnerable locations. Repair damage caused by the execution of this Section.

3.2 PREPARATION

A. Locate new plantings by staking positions as shown on the Drawings.

B. Planting, except ground cover, shall not be located within 18 inches of pavements, pedestrian pathways, and structures.

C. Notify the ENGINEER in writing if utility, drainage, or irrigation lines prohibit exact placement. Adjust as required.

D. Planting Soil: Delay the mixing of amendments and fertilizer if planting will not follow within 2 days. For pit backfill, mix compost with excavated soil at the required rate as specified in this Section and backfill immediately upon placement.

E. Plants: Place on undisturbed existing soil or well-compacted backfill.

F. Trees and Shrubs:
   1. Pits, beds, and trenches: Excavate with vertical and scarified sides.
   2. B&B trees: 16 inches plus root ball width, as shown on the Drawings.
   3. B&B shrubs: 12 inches plus root ball width, as shown on the Drawings.
   4. Container-grown stock: Excavate as specified for B&B shrubs; adjust for size of container width and depth.
   5. Compact planting soil in the bottom of the pit before placing plant material.

G. Planting:
   1. Plant trees before planting surrounding shrubs and ground covers. Adjust plants with the most desirable side facing toward the prominent view (e.g., sidewalk, building, or street).
   2. B&B plants: Place in the pit by lifting and carrying by the ball; do not lift the plant by its branches or trunk; remove plastic or wire basket in its entirety from the root ball; set straight and in the pit center with the top of the root ball 2 inches above adjacent finish grade.
   3. Container-grown plants: Remove containers and slash the edges of root balls from top to bottom at least 1 inch deep. For 1 gallon and 5 gallon containers, keep the top of the plant 1/2 inch above finish grade; larger containers shall be planted in accordance with the requirements for B&B plants.

H. Backfilling: Use planting soil mix for B&B plants:
   1. Partially backfill the pit to support the plant; remove burlap and binding from the sides and tops; do not pull burlap from under the balls.
   2. Compact in 6-inch lifts and when excavation is approximately 2/3 full, water thoroughly before placing the remainder of the backfill to eliminate air pockets.

3. Finish backfilling the pit sides.
4. The top of the root ball shall not be covered with soil; form a saucer above existing grade completely around the outer rim of the plant pit.

I. Guying, Staking, and Wrapping:
1. Support trees immediately after planting to maintain plumb position.
2. Support deciduous trees over 1 inch in caliper and upright evergreen trees with three guys equally spaced. Wires shall be tightened firmly.
3. Install tree wrap between October 1 and May 1, then remove wrapping.
4. Begin wrapping at the bottom of the trunk and spiral upwards to the first set of branches; fasten securely with staple or tape.

J. Fertilizer:
1. Spread timed release fertilizer on the soil around the base of trees, shrubs, and perennials.
2. The rate of application shall be in accordance with the Manufacturer's recommendation.

K. Pruning and Repair: After planting, prune in accordance with standard horticultural practice to preserve the natural character of the plant with the approval of the ENGINEER. Remove dead wood, suckers, and broken or badly bruised branches. Use clean, sharp tools. Do not prune main leaders.

L. Pest and Weed Control: Integrated pest and weed management practices shall apply. Submit pesticide/herbicide applications in writing to the ENGINEER for approval prior to use conforming to the OWNER's water quality approved chemicals list.

END OF SECTION

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SECTION 32 94 00
PLANTING ACCESSORIES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for planting accessories.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT

1.2 SUBMITTALS

A. Product Data: Labels and data sheets.

B. Samples: Representative of specified material.

C. Quality Control Submittals: Products Supplier list.

1.3 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00 and as identified herein:

1. Deliver materials to the site in the Manufacturer's original, unopened containers and packaging with labels clearly identifying the product name and the Manufacturer.
2. Store materials in a clean, dry area protected from weather in accordance with the Manufacturer's instructions.
3. Protect materials during handling and installation to prevent damage.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURES

A. Steel Edging:

1. COLMET
2. Dura-Edge

2.2 MATERIALS

A. Landscape Fabric:

1. Fabric: Fuzzy surface on one side.
2. Material: Black woven PP.
3. Fabric weight: 4.7 oz/sy.
4. Thickness: 28 mils.
5. Burst: 275 psi.
6. UV resistance: 70%.

B. Steel Edging:

1. Brown powder-coated steel, 12 gauge: 4 inch by 10-foot sections with stake slots.
2. Steel stakes: Four per piece.

C. Ornamental Boulders:

1. Utilize Colorado moss rock or granite boulders as shown on the Drawings.
2. Boulders shall be the approximate length and width shown on the Drawings allowing a minimum of 2 feet of visible height after being set.

PART 3 EXECUTION

3.1 INSTALLATION

A. Landscape Fabric:

1. Install material fuzzy side up.
2. Fabric shall follow the contours of the area being covered; keep taut and pin.
3. Planting soil shall not be allowed to contaminate the mulch on top of the landscape fabric.
4. Fabric shall be cut to the outside perimeter of plant watering saucers.

B. Steel Edging:

1. The top of the mulch, the edging, and the finish grades shall be flush.
2. Install in a smooth continuous line without bends or kinks.
3. Anchor at slotted points, four per piece, and lock sections together.

C. Ornamental Boulders:

1. Consult with the ENGINEER for the orientation of boulders before placement.
2. Excavate a 6 inch to 8 inch deep cut slightly larger than the boulder. Obtain the correct orientation from the ENGINEER and ease boulders into place; do not drop the boulder from a bucket and attempt to correct by rolling or spinning.
3. Backfill and compact around the boulder to the grades shown on the Drawings.

END OF SECTION

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SECTION 33 01 10.54
CLEANING IN-PLACE CAST IRON PIPE

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for cleaning in-place cast iron pipe.

B. Related Sections:

1. SECTION 31 23 33 – TRENCH BACKFILL
2. SECTION 33 01 10.83 – CEMENT-MORTAR LINING IN-PLACE CAST IRON PIPE

1.2 SUBMITTALS

A. Product Data: Cleaning equipment

B. Quality Control Submittals:

1. Statement of Qualification: Equipment Operator.

1.3 QUALITY ASSURANCE

A. Qualifications:

1. A minimum of 5 years of documented experience in the Work of this Section.
2. Approved by the Manufacturer.

B. Take every precaution during pipe cleaning operations to safeguard individuals from injury and property from damage. Immediately notify the ENGINEER in the event of injury or damage.

PART 2 PRODUCTS

2.1 MATERIALS

A. The equipment used for pipe cleaning shall be designed and manufactured to prevent damage to existing pipe, joints, fittings, and valves.

PART 3 EXECUTION

3.1 GENERAL

A. Furnish labor, trucks, equipment, cleaners, and squeegees to mechanically clean pipelines.

B. Operate cleaning equipment and be responsible for any damage to pipe that occurs during cleaning.

C. Protect pipe ends from damage due to cable or rod abrasion. Install steel rollers or guards on pipe ends whenever steel cable is being pulled through the pipe.

D. Mechanically clean the interior of pipe. Remove corrosion and chemical deposits, loose and deteriorated remains of old coating materials, oil, and grease. Ensure there are no remaining accumulations of water, dirt, and debris. Clean pipe to a degree suitable for the proper application of CML as specified in SECTION 33 01 10.83.

E. Clean the pipeline using the cable attached drag cleaning method. Cleaning equipment provided by the CONTRACTOR shall be dedicated to potable water main use only; it shall not have been previously used for other purposes.

F. Provide video inspection of the cleaned pipe.

G. Re-clean pipe found to be inadequately cleaned. An ENGINEER-determined second video inspection may be required prior to lining to verify the effectiveness of cleaning.

3.2 PREPARATION

A. Accessing the Pipeline:

1. Access the pipeline by saw cutting the pipe perpendicular to the axis of the pipe. Remove a 3 foot to 5 foot long piece of the pipe, preferably with a joint in the middle of the section. When removing a section of pipe for access, do not cut the pipe within 2 feet of any joint that is to remain.
2. Any removed piece of pipe, fitting, or appurtenance shall be replaced with new material unless it is specifically authorized by the ENGINEER to be reinstalled.
3. During construction, cover open pipe with plastic caps. Add plywood and wedge tight to prevent unauthorized access into the pipeline.

B. Dewatering the Pipeline:

1. Cut the pipe and remove the remaining water after the OWNER has taken the pipeline out of service.
2. If there is water flowing in the pipeline of sufficient quantity as to prevent installation of the lining, locate and identify the source of the leak(s) and notify the ENGINEER.
3. Stop leaks coming from service taps. Leaks coming from sideline valves will be stopped by the OWNER by reworking the valve(s). If this does not stop the leak, replace the sideline valve as directed.

C. Obstructions:

1. Obstructions to the passage of the cleaning tool due to bends, reducers, stays, or other fittings not shown on the Drawings may require additional openings. A fitting with a different inside dimension from the main water main is not considered an obstruction. Excavate, fill, and patch as specified in SECTION 31 23 33.
2. Costs resulting from obstructions shall be paid in accordance with the General Conditions.

END OF SECTION

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SECTION 33 01 10.82
ABANDONMENT OF EXISTING WATERLINES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for the abandonment of existing waterlines.

1.2 SUBMITTALS

A. Product Data: Specification and data sheets, including set times and strength characteristics for abandonment grout material.

B. Special Procedure Submittals:

1. Sequence and length of the waterlines to be abandoned.
2. Methods and materials to isolate the waterlines to be abandoned.
3. Means and method to demonstrate that the abandoned waterlines are filled with abandonment grout material.
4. Grout volumes used.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Low Density Cellular Concrete:

1. Mearlcrete

2.2 MATERIALS

A. Abandonment Grout Material:

1. Flowing characteristics that will fill, with no space at the crown for the defined limits, the waterline to be abandoned.
2. Initial set time of less than 1 day.
3. Compressive strength, 28 day: 100 psi, minimum.
4. Shrinkage shall not exceed 1% of the abandoned waterline diameter. Does not cause damage to the surroundings while filling the waterline, while setting, or after setting.
5. Cement and sand type mixture with good flowing characteristics, a low-density cellular concrete, or a fly ash based mixture.

PART 3 EXECUTION

3.1 RESTORATION

A. Promptly repair damage caused to adjacent facilities by the abandonment operation as directed by the ENGINEER and at no cost to the OWNER.

B. Remove debris resulting from the abandonment operation. Upon the Substantial Completion date, remove materials, equipment, waste, and debris of every sort and leave the site clean and orderly.

C. Restore the surface area to a condition compatible with the adjacent areas and in accordance with the Contract Documents.

D. Abandonment of Pipelines:

1. Complete new waterline Work including the installation, testing, and transfer of services before beginning abandonment Work.
2. Access the waterline through excavated access pits.
3. Isolate the reaches to be abandoned by the installation of bulkheads; control and monitor the amount of abandonment grout or material installed.

3.2 QUALITY CONTROL

A. Provide test cylinders and testing to demonstrate the strength and set time for abandonment grout material.

B. Additional testing may be provided by the OWNER.

C. Site Safety:

1. Execute the abandonment with means that will prevent damage and injury to adjacent structures and prevent interference with the use of and safe and free passage to and from adjacent areas or structures.
2. The closing or obstructing of roadways, railways, sidewalks, or passageways adjacent to the Work by the abandonment operation is not permitted without the written permission of the ENGINEER. Erect and maintain barriers and lights around the work area, as required. Provide alternate routes around closed or obstructed traffic ways.

END OF SECTION

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SECTION 33 01 30.83
CEMENT-MORTAR LINING IN-PLACE CAST IRON PIPE

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for cement mortar lining of in-place cast iron pipe.
- B. Related Sections:
  1. SECTION 33 01 10.54 – CLEANING IN-PLACE CAST IRON PIPE

1.2 REFERENCES
- A. American Water Works Association (AWWA):
  1. C602 – Cement-Mortar Lining of Water Pipelines in Place – 4 In. (100 mm) and Larger
- B. ASTM International (ASTM):
  1. C 40 – Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
  2. C 143 – Standard Test Method for Slump of Hydraulic-Cement Concrete
  3. C 150 – Standard Specification for Portland Cement
  4. C 494 – Standard Specification for Chemical Admixtures for Concrete
  5. C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
  6. E 11 – Standard Specification for Woven Wire Test Sieve Cloth and Test Sieves
- C. NSF International/American National Standards Institute (NSF/ANSI):
  1. 61 – Drinking Water System Components – Health Effects

1.3 SEQUENCING AND SCHEDULING
- A. Clean the pipelines as specified in SECTION 33 01 10.54.
- B. CML after the pipe has been cleaned and its condition approved by the ENGINEER.

1.4 SUBMITTALS
- A. Product Data:
  1. CML equipment.
  2. Admixtures.
  3. Cement-mortar mix NSF/ANSI 61 approval.
- B. Quality Control Submittals:
  1. Mix design: Submit prior to CML pipe.
  2. Statement of Qualification: Cement-mortar equipment operator.

1.5 QUALITY ASSURANCE
- A. CI Pipe:

Main Size (Inches)	CML Thickness (Inches)
6	3/16
8	3/16
10	3/16
12 to 23	1/4
24 and larger	5/16

- B. Tolerances: +1/8 inch, -1/16 inch.
- C. Guarantee the minimum Hazen-Williams C-value based on the nominal diameter of the pipeline; the OWNER will perform tests.

Main Size (Inches)	C-Value
6	100
8	110
10	115
12	120
14 to 20	125
Larger than 20	130

PART 2 PRODUCTS

2.1 MATERIALS
- A. Cement-Mortar Design:
  1. Composition: Cement, sand, and water that are well-mixed and of such consistency as to produce a dense, homogeneous lining that will adhere firmly to the pipe surface.
  2. Proportions:
     - a. One part of portland cement to one to one and a half parts of sand by volume.
     - b. Determine exact proportions by the characteristics of the sand used.
     - c. Pozzolanic material, if used, shall be substituted for a part of the portland cement in a proportion of one part pozzolanic material to five parts portland cement by volume.
     - d. Admixtures, if used, shall be in accordance with the Manufacturer's recommendations.
  3. Water content: The minimum quantity that produces a workable mixture with full allowance made for moisture collecting on the interior of pipe surfaces.
  4. Mixing: Long enough to obtain maximum plasticity. Use mortar before initial set.

B. Portland Cement: ASTM C 150, Type I or II.

C. Pozzolanic Material and Admixtures:

1. May be used only upon prior approval of the ENGINEER in accordance with ASTM C 618, Type C, F, or N.
2. Admixtures in accordance with ASTM C 494 may be used, at the option of the CONTRACTOR, provided the ratio of admixture to portland cement does not exceed that used in the ASTM C 494 qualification tests.
3. No admixtures shall be used that would have a deleterious effect on potable water flowing in the pipe after the CML has been placed.

D. Sand:

1. Inert granular material.
2. Grains shall be strong, durable, and uncoated.
3. Well-graded; pass a No. 16 mesh screen with no more than 5% passing the No. 100 sieve; sieve sizes shall be in accordance with ASTM E 11.
4. Free from injurious amounts of dust, clay, lumps, shale, soft or flaky particles, mica, loam, oil, alkali, or other deleterious substances.
5. The total weight of such substances shall not exceed 3% of the combined weight of the substances and the sand that contains them.
6. In addition, limitations shall apply to specific substances as follows:

Substance	**Maximum Allowable % By Weight**
Shale	1
Clay Lumps	1
Mica and deleterious substances (other than shale and clay lumps)	2

7. Shall not show a color value darker than the referenced standard color solution prepared in accordance with ASTM C 40.

E. Water shall be clean and free from injurious amounts of mud, oil, organic material, or other deleterious substances.

PART 3 EXECUTION

3.1 GENERAL

A. Furnish and apply CML for CI mains as shown on the Drawings. Remove debris prior to lining; ensure the pipeline is clean and dry enough to apply CML effectively.

3.2 INSTALLATION

A. Equipment:

1. Produce a smooth surface.
2. Only machines that have successfully placed CML similar to that herein specified, have been in service, and have proved satisfactory for the diameters specified, in the opinion of the ENGINEER, will be acceptable. Equipment used shall be in good operating condition and shall be subject to the approval of the ENGINEER.
3. Provide personnel trained in the use of the equipment for its operation; on-the-job trainees are not be acceptable.
4. Equipment used shall be dedicated to potable water service only; it shall not have been previously used for other purposes.

B. Machine Application:

1. Preparation: Clean pipe as specified in SECTION 33 01 10.54.
2. Application:
   a. One course application of the cement-mortar shall be placed in an uninterrupted continuity by a centrifugal machine that projects the mortar against the wall of the pipe, with minimum rebound and with sufficient velocity to cause the mortar to be densely packed and adhere in place.
   b. Sand pockets or lack of homogeneity will not be permitted. Compressed air shall not be used in the mixing or transportation of cement-mortar; it will only be allowed to power the equipment being used.
   c. Mechanically control the rate of travel of the machine and the rate of discharge of the mortar against the wall of the pipe to produce a smooth surface with uniform thickness without material segregation.
   d. The machine shall be equipped with attachments for mechanically troweling the mortar, with the machine traveling ahead of the lining and troweling operation. The trowel arrangement shall be such that the pressure applied to the CML is kept uniform, producing a CML of uniform thickness with a smooth, finished surface free of spiral shoulders.
   e. Where accessible and necessary, pack open joints with mortar before lining to provide a smooth surface across the joint. Moisten and clean mortared areas before machine lining.

C. Hand-Application:

1. General:
   a. In areas where machine placing of the CML is impracticable, such as sharp bends, specials, through large diameter crosses, and areas close to valves, place the CML by hand upon approval of the ENGINEER.
   b. Cement-mortar for hand-work shall be of the same materials as the mortar for machine placed CML.
   c. The surface shall be uniform with smooth transitions to adjacent machine placed CMLs and applied to the limits shown on the Drawings for fittings, outlets, and connecting piping. The ENGINEER may order the correction of any defect.

2. Special requirements:
    a. Areas to receive hand-applied CML shall be moistened with water immediately prior to placing the hand-applied mortar.
    b. Steel finishing trowels shall be used for the hand-application of cement-mortar, except at bends.
    c. The outer edges of hand-troweled areas may be brushed to reduce the abutting offset.
    d. Complete hand-finishing work within 1 day after completion of the machine application of CML to that section. If necessary, delay or stop the application of CML by machine to assure compliance with this schedule.

D. Surface Finish:
1. Mechanically troweled except for places where hand-troweling or the placement of unfinished CML has been approved by the ENGINEER.
2. Produce uniform thickness, smooth and free of spiral shoulders on troweled CML.
3. Unfinished CML shall be smooth and regular although slightly dimpled; ridges or uneven buildup caused by an irregular travel rate of the machine will not be accepted; areas to be lined without being mechanically troweled shall be approved in writing by the ENGINEER.

E. Curing:
1. After completion of the CML and hand-finishing of a section of pipe or at the end of a day's run of the machine, the pipe shall be tightly closed by an approved means at both ends and a moist atmosphere maintained to keep the CML damp and prevent the evaporation of water from the CML.
2. Introduce water into the closed section to maintain a moist atmosphere and keep the CML damp as soon as practicable after placing the CML.
3. Cure CML until the section of pipe is filled with water by the OWNER; do not exceed 7 days.

3.3 PROTECTION

A. Do not leave laterals or connections obstructing the pipe from being lined.

B. Flush openings that are 3 inches or less that may be plugged or filled with debris by CML or cleaning operations with air or water:
1. The manner of flushing shall not cause damage to the freshly applied CML.
2. Any damage to the CML during the clearing of openings shall be repaired to the satisfaction of the ENGINEER.
3. If any taps, laterals, or service connections cannot be cleared by backflushing following the CML operation, clear the opening and provide water to the tap, lateral, or service connection in a manner approved by the ENGINEER.

C. The OWNER will flush sidelines and 3 inch and larger services prior to and after the CML operation.

3.4 QUALITY CONTROL

A. General Inspection:
1. The ENGINEER will inspect construction, workmanship, and materials covered. Provide such materials and give such assistance as may be required to provide for safe inspection and testing.
2. The quality of the unlined pipe shall be agreed upon prior to lining.
3. The ENGINEER will inspect mains after lining utilizing CCTV inspection equipment.
4. Repair damage to the CML caused by the ENGINEER during the removal of a portion of the CML to inspect its thickness.

B. Defective CMLs:
1. Defects in CML include, but are not limited to, sand pockets, voids, over-sanded areas, excessively cracked and drummy areas, areas of CML that are thinner than specified, and areas of unsatisfactory surface finish.
2. Temperature and shrinkage cracks in the CML less than 1/16 inch in width do not need to be repaired. Cracks wider than 1/16 inch in width shall be repaired. Cracks smaller than 1/16 inch in width do not need to be repaired if it can be demonstrated to the satisfaction of the ENGINEER that the cracks will heal autogenously under continuous soaking in water. The autogenous healing process may be demonstrated by any procedure that keeps the CML of the pipe continuously wet or moist.
3. CML not applied as specified in this Section is subject to rejection by the OWNER. Remove and replace rejected CML.
4. Replace defective areas encompassing the full diameter of the pipe by machine wherever practicable.
5. Any depressions (craters) greater than 3 inches in the CML material that are a result of the service line blowback process, as determined by CCTV inspection, shall be excavated and replaced at the CONTRACTOR’s expense.

C. The ENGINEER will take samples, at random, of the mortar used in the CML to verify the mix proportions and determine mix strength.

D. Slump tests will be taken on freshly mixed mortar in accordance with ASTM C 143; results shall be within the limits of AWWA C602.

END OF SECTION

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SECTION 33 05 05.17
PIPE INTERNAL JOINT SEALS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for pipe internal joint seals.

1.2 REFERENCES

A. ASTM International (ASTM):
   1. A 240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
   2. D 2000 – Standard Classification System for Rubber Products in Automotive Applications

B. Code of Federal Regulations (CFR):
   1. Title 21 – Food and Drugs Section 177.2600 – Rubber Articles Intended for Repeated Use

C. NSF International/American National Standards Institute (NSF/ANSI):
   1. 61 – Standard for Drinking Water System Components – Health Effects

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Internal Joint Seals:
   1. Miller Pipeline Corporation, Weko-Seal
   2. Victaulic Company, InnerSeal

2.2 COMPONENTS

A. Components of the internal joint seals shall be NSF/ANSI 61 approved.

B. Joint Liner: EPDM rubber derivative membrane, manufactured in accordance with ASTM D 2000:
   1. Material shall be an EPDM polymer where ingredients are listed in CFR Title 21 with the final material not supporting microbiological growth when used in potable, seawater, or in humid aerobic conditions.
   2. Volume change of the rubber shall not exceed 3% after immersion in fresh or seawater at 212°F for 70 hours.
   3. Stress relaxation shall not exceed 12% when tested for 30 minutes to 1 day.

C. Joint Liner Splicing:
   1. Seal splice shall be made using a transfer-molding method with virgin rubber of the same compound from which the seal is manufactured with a 1/4 inch minimum width at the interface.
   2. Vulcanization shall occur at 330°F with 2,000 psi pressure.
   3. No adhesive or glue shall be used.
   4. Test: The seal shall be gripped at a point 6 inches on each side of the splice and shall be bent in both directions as sharply as possible; splice shall be capable of passing this bend test without visible separation.
   5. No voids or cracks are allowed.

D. Bands, Shims, and Set Screws:
   1. Bands, spacers, shims, and set screws for securing rubber membrane across piping joints shall be Type 304 or Type 316 SST manufactured in accordance with ASTM A 240.
   2. Typical mechanical properties:
      a. Yield strength greater than or equal to 30,000 psi.
      b. Tensile strength greater than or equal to 75,000 psi.
      c. Elongation in 2 inches equal to 40%.
      d. Hardness Rockwell B value of 92.
      e. Finish and condition is annealed.

E. SST Bands Manufacturing:
   1. Bands shall be rolled to the radius of the pipe being renewed.
   2. Bands shall have minimum dimensions of 3/16 inch thick by 2 inches wide for pipe sizes 36 inches to 60 inches in diameter.
   3. Each band shall be checked on fixed radius gauge.

F. Cleated End:
   1. Manufactured from the same Manufacturer lot number as the band.
   2. Shop welds and field welds shall be made by certified welders with a minimum of 2 years of experience on this alloy; welds shall be made with stick or wire of material compatible with the bands; shop welds shall be accomplished in an A-1025-Helium/C02 gas atmosphere when using wire.
   3. Field welding shall be made with a coated electrode of material that is compatible with the bands with a tensile strength of 86,000 psi and yield strength of 65,000 psi.
   4. Provide certified materials.

G. Radiused Shims:
   1. ASTM A 240 Type 304 or Type 316 SST, 16 gauge to 22 gauge by 2 inches by 6 inches.
   2. Manufactured by rolling to the radius of the pipe.
   3. Edges to be deburred.

H. Liquid Joint Lubrication:
   1. Liquid joint lubricant used to assist in the installation of the rubber membrane and the bands shall be a non-toxic, NSF/ANSI 61 certified vegetable based lubricating gel.
   2. Required properties:
      a. Does not deteriorate or decompose while in storage for a minimum of 2 years.
      b. Soft, pasty consistency suitable for the use intended from 0°F to 120°F.
      c. Does not have any deteriorating effect on natural or synthetic rubber gaskets.

d. Will not impart taste or odor to the water.
e. No objectionable odor.
f. Non-toxic and does not support the growth of bacteria.
g. pH: 9.6 minimum to 11 maximum.
h. No petroleum based oils or grease.

I. Thread Sealing Compound:
1. Non-toxic paste type with Teflon.
2. Teflon components required properties:
a. Flash point: 410°F, closed cup.
b. Density: 1.4 to 1.42.
c. Viscosity: 200,000 cps to 275,000 cps.
d. Temperature range: -50°F to 500°F.
e. Pressure application: Maximum 10,000 psi.

J. Hydraulic expander for the installation of steel and SST expansion bands shall be capable of hydraulic expansion pressures of 6,000 psi.

PART 3 EXECUTION

3.1 PREPARATION

A. Joint Preparation:
1. The area of pipe on either side of the joint where the actual lip seals make contact with the pipe shall be prepared to a finish that will allow the lip seals to interface consistently and provide a permanent seal.
2. High and low surface imperfections running axially through or part way through the sealing surface shall be removed by scraping or grinding. Deep imperfections that grinding will not remove shall be properly filled with approved non-toxic joint filler. This material shall be rendered smooth and ground, if necessary, to suit the prepared surface of the joint area.
3. Joints shall be filled to the full depth of the gap and rendered flush with the internal surface of the pipe:
a. The filling material shall be a quick-setting or cement mortar that is mixed as required in the pipe.
b. Surplus material spillage shall be removed from the joint work area prior to the surface preparation of the seal area.
4. The extent of the ground area on either side of the joint shall be compatible with the lip seals and at least 1 inch extra grinding is recommended on either side of the ribbed section of the seal.
5. Pipe shall be pre-marked with grease chalk to allow the preparation areas and the seal position to be clearly defined.
6. When the pipe is concrete or reinforced concrete, apply a thin layer of a quick-setting cement mortar to the preparation area where the seal will be placed.

B. Surface Preparation:
1. Immediately prior to fitting the seal, the area shall be cleaned with a dry brush and coated with lubricant.
2. The lubricant shall be hand-applied using a brush over the prepared area.
3. Care shall be taken not to pick up dust deposits from the unprepared surface into the lubricant and thereby onto the prepared surface.

3.2 INSTALLATION

A. Internal joint seals shall be installed in accordance with the Manufacturer’s instructions and the Contract Documents.

B. Prior to fitting, seals shall be given a thorough visual examination by the operator, paying particular attention to the ribbed (lip seals) sections of the seal. If the quality of material construction or condition is in doubt, do not use the seals.

C. Thoroughly clean the areas in which the joints are to be repaired and sealed of grease, dust, debris, roots, and solid or semi-solid matter prior to the start of sealing procedures:
1. Remove and dispose of loose material.
2. Properly dispose of these materials at a sanitary landfill or other approved location.

D. Damage to Pipeline:
1. Protect the pipeline from damage during cleaning and removal operations.
2. Repair damage, which may occur, at no additional cost to the OWNER using methods approved by the ENGINEER.

E. Positioning the Seal:
1. The seal shall be checked to ensure it is not damaged and the test unit is tight before fitting the seal in place. Caulk mark the proper location of the seal.
2. Place the seal in position to bridge the joint gap, guided by the chalk marks indicating the seal position.
3. Position the seal accurately on the prepared areas.
4. Locate the test unit in the seal at the 9 o’clock or 3 o'clock position.
5. Position the seal parallel to the joint gap.

F. Positioning Retaining Bands:
1. Before the SST bands are placed in the grooves provided in the seal, two SST radiused shims, 6 inches long by 18 gauge to 22 gauge, are placed underneath the wedge area in the grooves. This provides a bridge that will transmit the radial load evenly to the seal as the bands are expanded.
2. When two-piece or three-piece bands are used, bands are temporarily locked in position by means of a special mechanical locking device over the wedge area.

G. Expanding the Seal into Position:
   1. Use a hydraulic expander to apply a set pressure to the retaining bands of the seal.
   2. When positioning the expander in line with the retaining band, ensure the band remains in the groove of the seal and does not become moved or dislodged.
   3. The set pressure shall be held for a minimum of 2 minutes.
   4. Fit a radiused locking piece called a wedge between the exposed gaps of the expanded band ends:
      a. Select a size of wedge that has a slight frictional fit between the band ends.
      b. The radius of the wedge shall be equal to the radius of the pipe.
   5. Tap the wedge leading edge first into position, locking in the compression of the seal.
   6. Release the pressure from the expander by peening the board for 360 degrees.
   7. Repeat the procedure on the second retaining band of the seal.
   8. Repeat this entire operation after 30 minutes have elapsed after the first expansion. Install new wedges as necessary.
   9. Once the expanding procedure is complete for bands requiring securing bolts, remove each bolt one at a time, coat with a NSF/ANSI 61 certified threadlocker, and reinstall and torque as recommended by the Manufacturer. The wedge shall be tightened down to a torque of 15 in-lbs.

3.3 QUALITY CONTROL

A. Pressure Testing:
   1. Internally sealed areas shall be individually pressure tested, by Test 1 and Test 2, prior to the Substantial Completion date.
   2. Test 1:
      a. To be applied after each section has been completed and after 30 minutes have elapsed after the final fitting of the seal.
      b. A pressure of 10 psig is applied to the seal through the test valve and is maintained with a regulated air supply while a soap and water solution is applied to the outer edge and entire body of the seal to detect leaks.
      c. A restraining device shall be locked in its expanding position during testing to prevent excessive ballooning to the center membrane of the seal.
   3. Test 2: A pressure of 5 psig is applied to the seal through the test valve and maintained with a regulated air supply while a soap and water solution is applied to the outer edge and entire body of the seal to detect leakage.
   4. Test valve assembly: Following Test 2, the test valve of the seal is sealed with a countersunk hex head completion plug using a non-toxic thread sealing compound on the threads.

END OF SECTION

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SECTION 33 05 07
TRENCHLESS INSTALLATION OF UTILITY PIPING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for trenchless installation of utility piping.

B. Related Sections:

1. SECTION 01 33 00 – SUBMITTAL PROCEDURES
2. SECTION 05 05 23 – WELDING
3. SECTION 31 23 19 – DEWATERING
4. SECTION 31 23 33 – TRENCH BACKFILL
5. SECTION 31 73 00 – TUNNEL GROUTING

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):

1. Boiler and Pressure Vessel Code

B. American Water Works Association (AWWA):

1. C206 – Field Welding of Steel Water Pipe

C. American Welding Society (AWS):

1. D1.1 – Structural Welding Code – Steel

D. ASTM International (ASTM):

1. A 123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
2. A 139 – Standard Specification for Electric-Fusion (Arc)-Welded Steel Pipe (NPS 4 and Over)
3. A 153 – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
4. A 307 – Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength
5. D 638 – Standard Test Method for Tensile Properties of Plastics
6. D 648 – Standard Test Method for Deflection Temperature of Plastics Under Flexural Load in the Edgewise Position
7. D 790 – Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials

1.3 DEFINITIONS:

A. Casing Pipe: An outer sleeve, installed by trenchless or open-cut methods.

B. CP: Pipe, inserted within casing pipe, which acts as a conveyor of liquid.

C. Launching Pit: The pit where tunneling equipment is installed, and where casing pipe and CP are launched.

D. Receiving Pit: The pit located at the end of casing pipe, remote from the launching pit, at the point where CP emerges from casing pipe.

1.4 SUBMITTALS

A. Product Data: The Manufacturer's literature on casing pipe, casing spacers, CP, casing end seals, and related appurtenances.

B. Shop Drawings: Casing pipe, liner plate, skid system casing spacers, CP, casing end seals, and related appurtenances.

C. Quality Control Submittals:

1. Submit a lay schedule showing stationing, elevation, casing pipe lengths, and wall thickness. Submit proposed methods for steel casing pipe, including the CONTRACTOR's proposed method for continuously monitoring the line and grade of casing pipe. The proposed method shall provide the capability to control the line and grade of casing pipe during the operation to ensure the installation remains within the tolerances specified.
2. Five recent references and similar casing installations of casing pipes 18 inches in diameter or greater with a minimum length of 100 feet. Reference Submittals shall include detailed information on the types of soils encountered within the bore pit, the bore itself, and the specific boring equipment utilized; include a list of boring equipment and materials available for the Work.

1.5 QUALITY ASSURANCE

A. System Description: The completed installation shall be suitable for transporting water without affecting the stability and integrity of the overlying roadway, railway, runway, or waterway.

B. Composite Sleeve Casing Spacer Installer Requirements: Installers shall be certified by the Manufacturer. Manufacturer certification shall be current as of the actual date of installation of the casing spacer.

C. Steel casing pipe shall be the product of a single domestic Manufacturer; it shall be tested and inspected at the Manufacturer's site as required by the manufactured material specifications. Submit sworn certificates of tests, results, and satisfactory approvals as specified in SECTION 01 33 00.

D. Pipe may be inspected by an independent laboratory selected by the OWNER; the Manufacturer's cooperation is required. The cost of any inspection of approved pipe requested by the OWNER will be paid for by the OWNER. The cost of inspection of any disapproved pipe shall be paid for by the CONTRACTOR.

E. Welders shall be certified in accordance with AWS. Submit current certifications prior to the start of field work as specified in SECTION 05 05 23.

F. Project Requirements:

1. Discharge from dewatering operations shall be directed into approved receiving basins as specified in SECTION 31 23 19.
2. Provide maintenance of traffic; establish and maintain safety procedures in road, railway, and ditch ROWs during the operation.
3. Inspect locations where operations are to be conducted and casing pipe is to be installed. Verify conditions under which Work is performed. Provide necessary details for the orderly installation of Work whether or not shown or specified in the Contract Documents. Verify number, type, and location of existing utilities prior to beginning Work.

4. Work nights and weekends, if required, to complete Work. Request and obtain written authorization in accordance with the General Conditions prior to working nights and weekends.
5. The method of installation used shall not result in measurable settlement, movement, or cracking of existing structures, buried facilities, irrigation channels, or adjacent roadways and railways. If movement or settlement occurs that causes or may cause damage to these structures over, along, or adjacent to Work, operations shall stop immediately except for activities that assist in making Work secure. Operations may resume only after necessary precautions are taken to prevent further movement, settlement, or damage.
6. Existing structures, buried facilities, irrigation channels, railways, and roadways damaged by operations shall be repaired or replaced as necessary to restore them to a proper condition, at the CONTRACTOR's expense.

G. The use of a Manufacturer's name and model or catalog number is for the purpose of establishing the standard of quality and general configuration desired.

H. The Manufacturer shall submit a written statement that the inspection and the specified tests have been completed and that results comply with the requirements of these Standards.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Care shall be taken in loading, transporting, and unloading to prevent damage to pipe or coatings. Pipe shall not be dropped. Repair any damage to pipe coatings.

B. Pipe and materials shall be carefully handled to protect against damage to lining and coating and interior and exterior surfaces, impact shocks, and free fall. Pipe handling equipment shall be acceptable to the ENGINEER. Pipe shall not be placed directly on rough ground but shall be supported in a manner that protects it from damage. Damaged pipe shall be repaired in a manner acceptable to the ENGINEER or new undamaged pipe shall be furnished and installed.

C. Inspect each pipe to ensure there are no damaged portions. Remove or smooth out burrs, gouges, weld splatter, or other small defects prior to laying.

1.7 SITE CONDITIONS

A. The anticipated geologic conditions are described in the GBR. Methods may include, but are not limited to, tunnel boring machine, microtunneling, auger boring, or open face manual excavation.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Casing Spacers (Skids) and Insulators:
1. Advanced Products & Systems, Inc., Model SI-12
2. BWM Company, Model SS-12
3. CCI Pipeline Systems
4. Pipeline Seal and Insulator, Inc., Model C12G

B. Composite Sleeve Casing Spacer:
1. Clock Spring Company, L.P.

C. Casing Joints:
1. Permalok Corporation, Permalok interlocking pipe system

D. End Seals:
1. Advance Products and Systems, Inc., Model AC or AW
2. Pipeline Seal and Insulator Company, Model C or W

2.2 MATERIALS

A. Steel Casing Pipe:
1. Steel casings shall be leak-proof and in accordance with ASTM A 139, Grade B. Steel casing pipe shall have a minimum yield strength of 35,000 psi and shall be designed to withstand Cooper E-80 live loading with diesel impact and any relevant jacking load.
2. The inside diameter of casing pipe shall be large enough to allow CP to be installed with casing skids and joint restraint without disturbing casing pipe, adjacent subgrade, or adjacent facilities and structures.
3. Casing pipe shall have the minimum nominal diameter and wall thickness shown on the Drawings and listed herein:
   a. Casing pipe installed beneath railroads shall meet the minimum thicknesses required by the railroad which may exceed the values shown herein.

Casing Pipe Inside Diameter (Inches)	Casing Pipe Wall Thickness (Inch)
6 to 12	0.250
16 to 20	0.312
22 to 24	0.375
26 to 28	0.437
30 to 34	0.500
36 to 38	0.562
40 to 50	0.625
52 to 58	0.750
60 to 78	0.813
84 to 90	0.875
96 to 102	0.937
108 to 114	1.000
120	1.125

4. Joints:
   a. Beveled ends for butt-welding.
   b. Permalok.
5. Grout ports: 2 inch standard pipe IP threaded half couplings welded to the casing pipe, and fitted with threaded galvanized iron plugs on 4 foot centers.

B. Casing Spacers (Skids) and Insulators:
1. Type: SST, bolt on with a shell made of at least two halves.
   a. Band: 14 gauge hot-rolled and pickled mild steel coated with a 10 mil to 16 mil fusion-bonded PVC coating.
   b. Non-conductive PVC liner:
      1) Thickness: 0.090 inch minimum.
      2) Hardness: Shore durometer A 85 to A 90.
      3) Dielectric strength: 60 kV minimum.
      4) Surge test, 1/8 inch: 58 kV minimum, step-by-step test.
      5) Water absorption: 1% maximum.
   c. Risers: 10 gauge steel MIG welded to band.
   d. Ultra-high molecular weight polymer glass-reinforced runners with high abrasion resistance and low coefficient of friction meeting the following properties:
      1) Tensile strength in accordance with ASTM D 638: 17,600 psi, minimum.
      2) Flexural strength in accordance with ASTM D 790: 25,300 psi, minimum.
      3) Compression strength in accordance with ASTM D 648, 10% deformation: 18,000 psi, minimum.
      4) Deflection temperature at 264 psi in accordance with ASTM D 648: 405°F.
   e. Studs, nuts, and washers:
      1) Studs: 5/16 inch, 18 inches by 2 1/2 inches 18-8 SST.
      2) Hex nuts: 5/16 inch SST.
      3) Washers: 5/16 inch SAE 2330 SST.
   f. Width: 12 inches.

C. Composite Sleeve Casing Spacers:
1. Type: A composite sleeve consisting of a three-part system consisting of a unidirectional fiberglass sleeve, high-strength filler, and adhesive.
   a. Unidirectional fiberglass sleeve:
      1) Material: Fiberglass and polyester/vinyl ester resin.
      2) Thickness:
         a) Each layer: 0.065 inch.
         b) Complete, eight-layer system: 1/2 inch non-conductive PVC liner.
      3) Width: 11 1/2 inches.
   b. Filler: Compressive strength: Greater than 8,000 psi.
   c. Adhesive: Lap shear strength: Greater than 1,200 psi.

D. End Closure: Pull-on casing seal or wrap-around casing seal.
1. 1/8 inch minimum thick 60 durometer EPDM or neoprene rubber.
2. Wrap around seals shall overlap the casing pipe by 2 inches and shall be held on with AISI 304L SST worm gear clamps held together with mastic strips to seal the edges.
3. Custom pull-on end seals shall be seamless with vulcanized edges.

E. Liner Plate:
1. Plates: Accurately curved to comply with tunnel cross-section and all dimensions of such size and accuracy so that plates of similar curvature will be interchangeable.
2. Connections: Bolts on both the longitudinal and circumferential joints. Bolts and nuts shall not be less than 5/8 inch diameter and in accordance with ASTM A 307, Grade A, and hot-dip galvanized in accordance with ASTM A 153.
3. Zinc coating: Minimum of 2 oz/sf surface area on all sides in accordance with ASTM A 123.
4. Grout ports: Two standard pipe IP threaded half couplings welded into a hole in the center corrugation and fitted with threaded plugs. Locate grout ports at a minimum of every 4 feet along pipeline alternating top of pipe and pipe springline.
5. Loading: Soil and HS-20 traffic loading or Cooper E-80 as applicable.

PART 3 EXECUTION

3.1 GENERAL

A. Furnish labor, materials, equipment, and incidentals required to install casing pipe and CP at the locations shown on the Drawings.

B. Work shall include, but not be limited to, steel casing pipe, liner plate, casing spacers, CP, casing seals, coatings, location markers, and miscellaneous appurtenances as required.

C. Sending and receiving shaft shoring designs and liner plate designs, if liner plate is used, shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

D. Provide special insurance, traffic control, flaggers, and any other requirements imposed by the Owner of the ROW over Work.

3.2 PREPARATION

A. Subgrades shall be kept continuously free from ground and surface waters during casing and CP installation. Additional groundwater controls may be ordered on short notice; implement as directed. Observed water levels prior to the Work shall be below the invert level of the jacking pits and pipe subgrade. Groundwater control along and at the face of the tunneling operation shall include chemical grout stabilization as required.

B. Earthwork operations including, but not limited to, trench excavation, pit excavation, pipe bedding, trench backfill, and compaction required for the installation of casing pipe shall be performed as specified in SECTION 31 23 33. Pipe shall be laid directly on imported bedding material. Blocking is not permitted. The bedding shall form a continuous, solid bearing for the full length of the pipe. Excavations shall be made as needed to facilitate the removal of handling devices after the pipe is laid. Excavation shall be made outside the normal trench section, as needed and at field joints to permit adequate access to the joints for field welding operations.

3.3 INSTALLATION

A. Trenchless Methods:
1. Excavate the launching pit; furnish excavation supports as required. Excavation support shall extend a sufficient depth below the invert of the steel casing pipe to resist any pressure developed by the soil outside the launching pit.
2. Provide a level concrete slab or level stable gravel surface at the bottom of the launching pit. Steel rails or beams may be embedded in the concrete slab to aid in the placement and alignment of casing pipe or CP during installation operations.
3. Furnish, install, and remove thrust blocks or similar features as may be required in driving casing pipe or CP forward.
4. Pothole utility crossings in advance of the installation of casing pipe to determine their exact locations; verify there are no conflicts with the boring and jacking operation. Damages and costs that may be realized by the failure to locate and protect utilities are the responsibility of the CONTRACTOR.
5. Maintain proper alignment and elevation of the casing pipe consistently throughout the tunneling operation. The proposed method shall provide the capability to control the line and grade of the casing pipe during the operation to ensure installation remains within the tolerances provided herein.
6. Tolerances for the installation of casing pipe:
   a. Vertical alignment: ±3 inches; select casing pipe diameter that is sufficiently large to compensate for off grade installation.
   b. Horizontal alignment: ±3 inches.
7. Installation of the casing pipe shall be continuous; take precautions to avoid interruptions that may cause the pipe to freeze in place.
8. Dewatering through the casing pipe during construction is not permitted.
9. Steel casing pipe sections shall have one end square and one end beveled with a single v-groove and full penetration butt-welded on the entire outside circumference of the casing. Prior to butt-welding, the pipe and the pipe joint shall be properly positioned using line up clamps. In the finished joint, the abutting pipe sections shall not be misaligned by more than 1/16 inch. Welding procedures used to install casing pipe shall be prequalified in accordance with AWS D1.1 or ASME Boiler and Pressure Vessel Code, Section IX. ASME certification is required for butt-welded joints. Joints of steel casing shall be butt-welded prior to being subjected to the jacking operation.
10. Jacking shall be performed in a manner that prevents voids from developing outside the jacking sleeve. A jacking shield shall be used to minimize the amount of voids produced during excavation in the forward end of the jacking sleeve. If the jacking operation causes an excessive loss of soil, pressure grout the jacked section to fill external voids outside of the jacked casing.
11. Install in such a manner as to ensure exterior voids are filled after completion. Provide grout holes and fill voids with pressure grout as specified in SECTION 31 73 00.
12. After casing pipe is installed, thoroughly clean its interior; remove excess material leaving a smooth interior throughout.
13. The exit pit shall be excavated to the casing pipe. Provide excavation support as required. Provide sufficient room to continue installation of the CP.

B. Open-Cut:
1. Each pipe section shall be installed to the set line and grade, within approximately ±1/2 inch.
2. After the casing pipe is properly positioned in the trench, backfill it as specified in SECTION 31 23 33.
3. Pipe shall not be installed upon a foundation penetrated by frost or at any time when there is a danger of ice formation or frost penetration at the bottom of the excavation. Pipe shall not be laid unless the trench is scheduled to be backfilled before the formation of ice and frost.
4. Dewatering through the casing pipe during construction is not permitted.
5. After the casing pipe is completely installed, thoroughly clean its interior; remove excess material leaving a smooth interior throughout.
6. Field weld joints in accordance with AWWA C206. Adequate space shall be provided for welding and the inspection of joints.
7. Prior to butt-welding, the pipe and the pipe joint shall be properly positioned in the trench using line up clamps. In the finished joint, the abutting pipe sections shall not be misaligned by more than 1/16 inch. Welding procedures used to install pipe shall be prequalified in accordance with AWS D1.1 or ASME Boiler and Pressure Vessel Code, Section IX. ASME certification shall be required for butt-welded joints.
8. Field butt-welds shall be inspected as soon as practicable after the welding of the field joint is complete. Repair defective welds.

C. CP:
1. Support the CP within the casing pipe so that pipe bells do not rest directly on the casing. Distribute the load of the CP along the casing pipe by using casing spacers.
2. Install within the casing using casing spacers. Install from the jacking pit end of the casing. Each joint within the casing pipe shall be of the restrained push-on type if DI or PVC pipe is utilized, and thoroughly checked prior to being installed into the casing. Steel pipe joints located within a steel casing shall be double welded lap or buttstrap joints as shown on the Drawings.

3. For CP 24 inches and larger, fill the annular space between the tunnel and the CP with sand throughout the casing of tunnel.
4. Install a rubber end closure seal after the CP is installed.

3.4 RESTORATION

A. Remove excavation support systems for jacking pits. If withdrawal could damage or disturb the roadway, railroad, or ditch subgrade, leave supports in place and cut them off 36 inches below finished grade.
B. Following the casing and pipe installation and backfill operations, restore the Work area to its original grade and condition. Replace or construct miscellaneous small structures and fencing, if applicable, to match existing.
C. Remove equipment, supplies, excess excavation materials, and miscellaneous items associated with the casing installation operation. Leave the site in a clean and neat condition.
D. If required by the ROW Owner, coordinate and schedule a final inspection of the Work.

END OF SECTION

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SECTION 33 05 07.13
UTILITY DIRECTIONAL DRILLING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for utility directional drilling.

B. Related Sections:

1. SECTION 33 05 31.13 – POLYVINYL CHLORIDE PIPE FOR WATER TRANSMISSION AND DISTRIBUTION

1.2 REFERENCES

A. ASTM International (ASTM):

1. A 519 – Standard Specification for Seamless Carbon and Alloy Steel Mechanical Tubing

1.3 DEFINITIONS

A. HDD: A trenchless methodology of installing pipe that consists of three main steps: Piloting (drilling of a pilot hole), reaming (pilot hole enlargement), and pullback (installation of the CP).

1.4 SUBMITTALS

A. Product Data: The Manufacturer's literature on drilling and mud system equipment, bentonite slurry, and guidance system.

B. Shop Drawings:

1. Pilot bore plan:
   a. Horizontal scale: 1 inch = 20 feet.
   b. Vertical scale: 1 inch = 2 feet.
   c. Existing utilities and proposed clearances.
   d. Deflection and radius of pilot bore.
   e. Bore entry/exit points and angles.
   f. Confirm the alignment and elevation of critical utilities by potholing, using a vacuum excavator, or using other suitable excavation equipment.

C. Quality Control Submittals:

1. SDS of potentially hazardous substances to be used.
2. Environmental protection and contingency plan for spilled material.

D. As-Built Information:

1. Daily drill log.
2. As-Built profile of pipe bore on scaled drawing.
3. Tabulations of the vertical and horizontal alignments of bore.

1.5 QUALITY ASSURANCE:

A. Qualifications:

1. Drilling crew personnel shall have at least 2 years directional drilling experience with the rig and the guidance system being used.
2. Guidance system operators shall have experience in its setup, calibration, and use.

PART 2 PRODUCTS

2.1 MATERIALS

A. Pipe: As specified in SECTION 33 05 31.13.

B. Tracer Wire:

1. Using 2 inch wide PVC tape, attach #12 AWG solid copper with 0.03 inch blue PE insulation to pipe.
2. Tracer wire shall be run to a test station. The location of the test station shall be approved by the ENGINEER.

C. Drilling Equipment:

1. General requirements:
   a. Of sufficient capacity to perform the bore and pullback the pipe.
   b. In good working order.
   c. The supplies, facilities, equipment, and materials to perform Work.
2. Drill rig:
   a. Hydraulic powered system.
   b. Shall rotate and push hollow drilling pipe into the ground at a variable angle while delivering a pressurized fluid mixture to a guidable drill head.
   c. Anchored to withstand the pulling, pushing, and rotating pressure required to complete installation.
   d. Self-contained with sufficient pressure and volume to power the drilling operations.
   e. Leakage free.
   f. Monitors and records maximum pullback pressure during pullback operations.
   g. Detects electrical current from the drill string with an automatic, audible alarm.
3. Drill head: Steerable; containing cutting surfaces and drilling fluid jets.
4. Mud motors: Adequate power to turn required drilling tools.
5. Drill pipe:
   a. High-quality material grade 4130 seamless tubing, in accordance with ASTM A 519.
   b. Threaded box and pins.
   c. Tools joints hardened from 32 RC to 36 RC (Rockwell C scale).

D. Guidance System:

1. General:
   a. Provides a continuous location of the drill head during the drilling operation.
   b. Tracks at depths up to 50 feet in any soil condition.

c. Enables the driller to guide the drill head by providing information on the tool face, azimuth, and inclination.
d. Accurate to within 2 feet horizontally.

2. Guidance options:
   a. Electronic walkover tracking system.
   b. MGS probe.
   c. Proven gyroscopic probe and interface.

E. Drilling Fluid System:
1. Mixing system:
   a. Self-contained.
   b. Mixes fluid thoroughly to avoid clumping.
   c. Continually agitates fluid during drill operations.
   d. Minimum 1,000 gallon reservoir.
2. Drilling fluid:
   a. Bentonite drilling mud.
   b. Recommended minimum viscosities for soil types as measured by a marsh funnel:

Soil Type	Time (Seconds)
Rocky clay	60
Hard clay	40
Soft clay	45
Sandy clay	90
Stable sand	80
Loose sand	110
Wet sand	110

3. Delivery system:
   a. Minimum capacity of 35 gpm to 500 gpm.
   b. Delivers the drilling fluid at a constant minimum pressure of 1,200 psi.
   c. In-line filters to prevent solids from being pumped into the drill pipe.
4. Recovery system: Pumps or vacuum truck(s) of sufficient size to convey drilling fluid from containment areas to storage and recycling facilities or for disposal.

PART 3 EXECUTION

3.1 GENERAL

A. Superintendent shall be present at the jobsite during the directional bore operation.

3.2 PREPARATION

A. Calibration of Guidance System:
1. Demonstrate to the ENGINEER that the system has been calibrated in accordance with the Manufacturer’s instructions.
2. Obtain an accuracy range within 1 inch of actual position.
3. Consider geo-magnetic anomalies and their influence on the operation of the system.

B. Fluid Containment:
1. Construct a minimum 12 inch high berm around the drilling fluid mixing system, entry and exit pits, and drilling fluid recycling system.
2. Install holding tanks or pits to contain drilling fluids and loose cuttings for recycling or disposal.
3. Prevent drilling fluids from entering unapproved areas and waterways.
4. Properly dispose of drilling fluid.

C. Drill Path Survey:
1. Survey the entire drill path.
2. Place entry and exit stakes in the appropriate locations.
3. If using a MGS, the drill path shall be surveyed for surface geo-magnetic variations or anomalies.

3.3 INSTALLATION

A. Operation:
1. General:
   a. Maintain proper alignment and elevation of the bore hole throughout the directional drilling operation.
   b. Conform to the requirements of applicable permits.
   c. Determine drilling length and equipment pull strength for the type of soil encountered.
   d. Notify the ENGINEER in writing when forward motion is stopped by obstructions.
2. Pilot bore:
   a. Angle the entry hole so that curvature of the pilot bore does not exceed the Manufacturer’s allowable bend radius for PVC pipe.
   b. Monitor the horizontal and vertical drilling head location.
   c. Record the location of the drill head after the advancement of each successive drill pipe at a maximum of 10 foot intervals.
   d. Provide the ENGINEER with a plot of drill head locations on a scaled drawing and tabulations of horizontal and vertical alignments.
   e. Do not allow the deflection radius of the drill pipe to exceed the Manufacturer’s bend limits of PVC pipe.

f. Tolerances for pilot hole:
    1) Vertical alignment: ±0.5 feet.
    2) Horizontal alignment: ±1.0 feet.
g. Submit a copy of As-Built pilot bore records to the ENGINEER.
h. The location of the pilot hole shall be approved by the ENGINEER prior to reaming.

3. Bentonite slurry:
    a. Maintain bentonite slurry to stabilize the open bore hole and reduce drag on the pipeline. Pump through the inside diameter of the drill rod and through openings in the reamer.
    b. Drilling slurry shall be in a homogeneous/flowable state serving as an agent to carry the loose cuttings to the surface through the annulus of the borehole.
    c. Calculate the volume of bentonite mud required for each pullback based on soil conditions, pipe diameter, mud pump capacity, and pullback speed.
    d. Contain bentonite slurry at the entry or exit side of the directional bore in pits or in holding tanks.
    e. Recycle slurry as practicable.
    f. Drill fluid loss:
        1) Cease drilling.
        2) Wait at least 30 minutes.
        3) Inject a quantity of drilling fluid with a viscosity exceeding 120 seconds, as measured by a marsh funnel.
        4) Wait another 30 minutes; determine if loss continues.
        5) If loss continues, discuss additional options with the ENGINEER; proceed accordingly.
4. Pipe:
    a. Provide swivel to the reaming assembly/pull section of the pipe to minimize torsional stress.
    b. Protect the pull section of the pipe during pullback so it moves freely.
    c. Pull the detection wire along with the pipe (PVC pipe only).
    d. Allow the pull section of the pipe to extend past the termination point.
    e. Extend tracer wire into locator stations at each end of the pipe. Tracer wire shall be adequately secured to the pipe prior to the pullback operation (PVC pipe only).
    f. Reaming:
        1) Increase the size of the pilot hole diameter with a reamer.
        2) Select the reamer based on soil conditions.
        3) Ream the final opening no larger than 1 1/2 times the outside diameter of the pipe being installed.
5. Connections:
    a. Allow the pipe to reach the soil temperature.
    b. Make tie-ins 1 day or more after pipe pullback.

3.4 RESTORATION

A. Dispose of drilling mud and cuttings at an approved disposal site.
B. Remove construction-related debris.
C. Restore site to original grade.
D. Backfill bore pits.

END OF SECTION

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SECTION 33 05 19
DUCTILE-IRON PIPE AND FITTINGS
FOR WATER TRANSMISSION AND DISTRIBUTION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for ductile iron pipe and fittings for water transmission and distribution.

B. Related Sections:
1. SECTION 09 90 00 – PAINTING AND COATING
2. SECTION 09 97 13.02 – LIQUID EPOXY LININGS AND COATINGS
3. SECTION 13 47 16 – ISOLATION AND BONDING FOR CATHODIC PROTECTION
4. SECTION 33 14 11 – WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL

1.2 REFERENCES

A. American Water Works Association (AWWA):
1. C104 – Cement Mortar Lining for Ductile Iron Pipe and Fittings
2. C105 – Polyethylene Encasement for Ductile-Iron Pipe Systems
3. C110 – Ductile-Iron and Gray-Iron Fittings
4. C111 – Rubber-Gasket Joints for Ductile Iron Pressure Pipe and Fittings
5. C115 – Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges
6. C116 – Protective Fusion-Bonded Coatings for the Interior and Exterior Surfaces of Ductile-Iron and Gray-Iron Fittings
7. C150 – Thickness Design of Ductile Iron Pipe
8. C151 – Ductile-Iron Pipe, Centrifugally Cast
9. C153 – Ductile-Compact Fittings
10. C223 – Fabricated Steel and Stainless Steel Tapping Sleeves
11. C550 – Protective Interior Coatings for Valves and Hydrants
12. C600 – Installation of Ductile-Iron Water Mains and Their Appurtenances
13. Manual M41 – Ductile Iron and Pipe Fittings

B. American Welding Society (AWS):
1. D11.2 – Guide for Welding Iron Castings

C. Manufacturers Standardization Society (MSS):
1. SP-60 – Connecting Flange Joints between Tapping Sleeves and Tapping Valves

D. NSF International/American National Standards Institute (NSF/ANSI):
1. 61 – Drinking Water System Components – Health Effects

1.3 QUALITY ASSURANCE

A. Pipe Design Criteria: The pipe diameter specified is the nominal pipe diameter for DI pipe.

B. General Requirement:
1. Lay length shall be 18 feet or 20 feet. Random lengths are not acceptable.
2. Pipe shall be designed, manufactured, tested, inspected, and marked in accordance with AWWA C150, AWWA C151, and Manual M41.
3. Allowable pipe deflection is 0.025 by ID. If the calculated deflection exceeds allowable, used improved bedding and pipe zone material to increase E' so that the calculated deflection becomes less than allowable.
4. The Manufacturer shall submit a written statement that the inspection and specified tests have been completed and that results comply with the requirements of these Standards. Components in contact with potable water shall be certified to comply with NSF/ANSI 61, and a copy of the NSF/ANSI 61 certification shall be provided to Denver Water, if requested. DI pipe shall be UL listed, and a copy of the UL certification shall be provided to Denver Water, if requested.

1.4 SUBMITTALS

A. Shop Drawings:
1. The class and wall thickness for pipe and pressure rating and wall thickness of fittings.
2. Standard and restrained joints details indicating pertinent dimensions and manufacturing tolerances.
3. Materials list indicating the anticipated number of straight lengths of pipe to be used and fittings and specials with corresponding stations.
4. Pipe laying schedule showing line layout and marking diagram for all areas. The schedule shall indicate pipe number and length, the station of appurtenances, and the station and invert elevation of bell ends.

1.5 DELIVERY, STORAGE, AND HANDLING

A. DI pipe shall be stacked no higher than the height listed in AWWA C600. Bell ends shall be alternated with spigot ends.

B. The DI Manufacturer shall provide durable coverings to be placed over pipe ends.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. DI Pipe:
1. American Cast Iron Pipe
2. McWane Ductile
3. U.S. Pipe and Foundry Company/Griffin Pipe Products

B. DI Fittings:
   1. Sigma
   2. SIP Industries
   3. Star Pipe Products
   4. Tyler Union
   5. U.S. Pipe and Foundry Company
C. Push-On Joint Design and Fabrication:
   1. American Cast Iron Pipe, Fastite
   2. US Pipe, Tyton
D. Bell-Spigot Restraint:
   1. American Cast Iron Pipe Company, Fast-Grip Gasket, Flex-Ring Joint
   2. US Pipe, Field Lok Gasket, TR Flex
   3. EBBA Iron, Inc., Megalug 1700 Series, Series 1500 TD (4 inch to 12 inch)
   4. The Ford Meter Box Company, UFR Series 1455
   5. Gripper Gasket, LLC, Boltless Restraint
   6. McWane Ductile, Sure Stop 350
   7. Sigma Corporation, One-Lok SLDEH Series
   8. Star Pipe Products, StarGrip 3100P Series
E. Mechanical Joint Restraint:
   1. EBAA Iron, Inc, Megalug 1100 Series
   2. The Ford Meter Box Company, UFR Series 1400
   3. Romac Industries, RomaGrip
   4. SIP Industries, EZ Grip
   5. Sigma Corporation, One-Lok SLDE Series
   6. Smith-Blair, Cam-Lock
   7. Star Pipe Products, StarGrip 3000 Series
   8. Tyler Union, TufGrip
F. Ceramic Epoxy:
   1. Protecto 401
G. Tapping Saddles:
   1. As specified in SECTION 33 14 17

2.2 MATERIALS

A. DI Pipe:
   1. General: Designed, manufactured, tested, inspected, and marked as specified in this Section and in accordance with AWWA C151, Manual M41, and NSF/ANSI 61; manufactured in the U.S.
   2. Fittings:
      a. Fittings shall be DI in accordance with AWWA C110 or AWWA C153.
      b. Fittings shall be coated with an asphaltic coating and lined with cement-mortar in accordance with AWWA C104. Fittings may also be lined and coated with fusion-bonded epoxy in accordance with AWWA C116.
      c. Branch outlets 12 inches and smaller may be in the form of tapping saddles and DI tee fittings. Welded outlets may be used when they are up to 70% of the main pipe diameter. Welded outlet main pipe and outlet pipe shall be Special Thickness Class 53 and shall be fabricated by the Pipe Manufacturer at their facility. Welding shall be in accordance with AWS D11.2. Welded outlets shall be rated for at least the pressure rating required for the main pipe or 250 psi, whichever is greater, with a minimum of 2.0 sf. Outlet joints shall be flanged for exposed applications and flexible, push-on restrained joint bell and spigot for buried applications. Mechanical joint bells with restraining devices are not acceptable for buried applications.
   3. Flanges:
      a. As specified in SECTION 33 14 11.
      b. In accordance with AWWA C115 suitable for the pressure specified.
   4. Pipe class:
      a. Pipe: The minimum thickness class shall be Special Thickness Class 50.
      b. At threaded flanges: The minimum thickness class shall be Special Thickness Class 53.
   5. Linings:
      a. Potable water piping: Cement mortar in accordance with AWWA C104, without seal coat.
      b. Ceramic epoxy: Recycled piping.
   6. Exterior coating:
      a. 1 mil thick asphaltic coating; the finished coating shall be continuous, smooth, neither brittle when cold nor sticky when exposed to the sun and shall be strongly adherent to the pipe.
      b. Piping within vaults: Shop-applied primer compatible with the coating system as specified in SECTION 09 90 00.
   7. Joint design and fabrication:
      a. Standard joint shall be a single rubber gasket joint in accordance with AWWA C111 designed to be assembled by the positioning of a continuous, molded rubber ring gasket in an annular recess in the pipe or fitting socket and the forcing of the plain end of the entering pipe into the socket, thereby compressing the gasket radially to the pipe to form a watertight seal.

b. Mechanical joints, flanges, or other restrained joints shall be located where shown on the Drawings or as approved by the ENGINEER.

8. Joint restraint:
    a. General:
        1) Designed to resist thrusts resulting from internal pressure acting at bulkheads, bends, valves, and extending over the distances shown on the Drawings.
        2) Designed for the working pressure plus water hammer.
        3) Alter the laying schedule in restrained areas to avoid deflected joints. Work out alterations and bear expense for such alterations.
        4) Do not use rods or clamps.
    b. Acceptable products:
        1) Compatible field flex ring allowable for closure joints only as necessary.
        2) Mechanical joint restraint or bell-spigot restraint as specified in SECTION 33 05 19 and SECTION 33 05 31.13.
    c. Mechanical joint restraint:
        1) Manufactured from DI in accordance with ASTM A 536, Grade 65-45-12. Wedges shall be heat treated to a minimum of 370 BHN. Rubber gaskets shall be vulcanized SBR in accordance with AWWA C111. Tee-head bolts shall be manufactured from a high strength alloy steel known in the industry as Cor-Ten, Usalloy, or Durabolt.
        2) Mechanical joint restraints shall be incorporated into the design of the follower gland. Dimensions of the gland shall be such that it can be used with the standardized mechanical joint bell and tee-head bolts in accordance with AWWA C111 and AWWA C153.
        3) The restraint mechanism shall consist of numerous individually activate gripping surfaces to maximize the restraint capability. The gripping surfaces shall be wedges that are designed to spread the bearing surfaces on the pipe. Twist-off nuts, sized the same as the tee-head bolts, shall be used to ensure the proper actuating of the restraining devices. When the nut is sheared off, a standard hex nut shall remain.
        4) The pressure rating shall be as follows with a safety factor of 2:
            a) 3 inches to 16 inches: 350 psi.
            b) 20 inches to 36 inches: 250 psi.
9. Tapping sleeves:
    a. Designed and manufactured in accordance with AWWA C223.
    b. The machined flange face shall be recessed for tapping valves in accordance with MSS SP-60. Hollow-back flanges and segmented flanges are not acceptable.
    c. Gaskets shall be compounded from new materials and the shape of the cross-section of the gasket shall provide an adequate seal for the working pressure. Gaskets shall be shop glued to the groove provided in the body section.
    d. A 3/4 inch NPT threaded outlet shall be attached to the outlet nozzle of each tapping sleeve assembly complete with a 3/4 inch square head, threaded pipe plug.
    e. Ferrous surfaces, except machined or bearing surfaces, shall be prepared in accordance with SSPC SP10. These surfaces shall then be coated with liquid epoxy in two or more uniform coats or with fusion-bonded epoxy to a minimum DFT of 10 mils in accordance with AWWA C550. Machined flange faces shall be shop-coated with a rust-preventive compound; they shall not be painted or coated with the same coating as the body.
10. Tapping saddles:
    a. Double bronze strapped.
    b. Outlet threads shall be AWWA standard taper threads.

B. PE encasement material:

1. Manufactured in accordance with AWWA C105.
    a. Linear, low density film with a minimum of 8 mils DFT.
        1) Flat tube material shall be used for pipe and fitting encasement; flat sheet material shall be used for valve encasement.
    b. V-Bio enhanced PE material shall be manufactured in accordance with AWWA C105 with additional corrosion inhibitor and biocide.
        1) Provide V-Bio enhanced PE encasement for pipe over 20 inches in diameter when nearby soil resistivity values are less than 5,000 ohm-cm.
    c. PE encasement material color:
        1) Potable water: Clear (no color additives).
        2) Recycled water: Pantone 2577U.
    d. Labeling for recycled water pipe:
        1) Labeled: CAUTION: RECYCLED WATER – DO NOT DRINK.
        2) Height: 1 1/2 inches, minimum.
        3) Provide a label every 2 feet along the length of the encasement material.
    e. Adhesive tape:
        1) Secure PE encasement with water resistant PE, vinyl, or PVC adhesive tape.
        2) Thickness: 8 mils DFT, minimum.
2. Recycle piping: Pantone 2577U.

3. Other: Clear (natural color).
4. PE material shall be stored out of direct sunlight.
5. Labeling for recycled piping:
    a. Labeled: CAUTION: RECYCLED WATER – DO NOT DRINK.
    b. Height: 1 1/2 inches minimum.
    c. Every 2 feet along the length of the PE encasement.

PART 3 EXECUTION

3.1 INSTALLATION

A. Application:
1. Linings:
    a. Ceramic epoxy, 40 mils DFT.
        1) Application as specified in SECTION 09 97 13.02.
        2) CML is not allowed for recycled or reuse water.

B. Field Pipe Wrapping:
1. A pre-cut length of tubing approximately 20 feet long shall be used per 18 foot length of pipe. Before lowering into the trench, tubing shall be slid over the bell end of the pipe and bunched behind the bell.
2. Excess PE material shall be drawn up around the pipe barrel, folded neatly into an overlap on top of the pipe, and held in place by pressure-sensitive tape at 3 foot to 5 foot intervals.
3. In the trench, the bell end of the pipe shall be raised clear of the trench bottom and the tubing stretched out along the length of pipe. 1 foot surplus shall be provided at each end of a length of pipe. This surplus shall be bunched behind each end of the length of pipe.
4. After each joint is made, tubing shall be pulled over the bell end of the pipe, folded around the adjacent spigot end, and wrapped circumferentially with pressure-sensitive tape.
5. At flanges, cut the PE material to be within 1/4 inch of the back face of the flange. Secure with slightly overlapping circumferential wraps of pressure-sensitive tape for a distance of 4 inches from the back of the flange.
6. Use the following flat width tubing:

Nominal Pipe Diameter (Inches)	**Flat Tubing Width (Inches)**
6	20
8	24
12	30
16	37
20	45
24	54
30	67
36	81
42	81
48	95
54	108
60	108
64	121

7. Clean material prior to wrapping operations.
8. During installation, soil or embedment material shall not be trapped between the PE material and the item to be protected.
9. PE encasement shall be secured at ends, seams, overlaps, and folds by adhesive tape or plastic tie straps approved for such purpose.
10. Sufficient slack shall be provided in contouring the encasement around buried items to prevent stretching the material where it bridges irregularities and to prevent damage by backfilling operations.
11. Installation of the PE tubing shall ensure the recycled water warning is at or above springline on each side of the pipe.
12. Cuts, tears, punctures, and other damage to the PE material shall be repaired with adhesive tape and a short length of additional PE material. The ENGINEER will inspect repairs prior to backfilling activities.
13. Flat tube material shall be used for pipe and fitting encasement; flat sheet material shall be used for valve encasement.

C. Buried Flanged Joints: As specified in SECTION 33 14 11.

D. Jointing:
1. Push-on joint:
    a. For the push-on joint, the inside of the bell and the outside of the spigot end shall be thoroughly cleaned to remove oil, grit, excess coating, and other foreign matter.
    b. The rubber gasket shall be flexed inward and inserted in the gasket recess of the bell socket. In cold weather it may be necessary to warm the gasket to facilitate insertion.
    c. A thin film of non-toxic, water soluble, NSF/ANSI 61 approved gasket lubricant shall be applied to the inside surface of the gasket and the spigot end of the pipe.

d. The spigot end of the pipe shall be pushed into the socket with care keeping the joint from contacting the ground. The joint shall then be completed by forcing the plain end to the bottom of the socket in a manner approved by the ENGINEER.
e. Each joint shall be checked with a feeler gauge to ensure the proper installation of the gasket.
f. Pipe that is not furnished with a depth mark shall be marked before assembly to assure the spigot end is inserted to the full depth of the joint.
g. Field cut pipe joint ends shall be filed or ground to resemble a spigot end as recommended by the Manufacturer.
h. Field cut end repairs shall be done in accordance with the Pipe Manufacturer's instructions.
i. Deflection of the joint shall not exceed the Manufacturer's recommended maximum deflection.

2. Mechanical joint:
    a. For the mechanical joint, the last 8 inches outside of the spigot and the inside of the bell shall be thoroughly cleaned to remove oil, grit, excess coating, and other foreign matter from the joint and then painted with a thin film of non-toxic, water soluble NSF/ANSI 61 approved gasket lubricant.
    b. The gland shall then be slipped on the spigot end of the pipe with the lip extension of the gland toward the plain end.
    c. The rubber gasket shall be painted with the gasket lubricant and placed on the spigot end with the thick edge toward the gland.
    d. The entire section of the pipe shall be pushed forward to seat the spigot end in the bell. The gasket shall then be pressed into place within the bell. Care shall be taken to locate the gasket evenly around the entire joint.
    e. The gland shall be moved toward the bell and centered with the gland lip against the gasket. The bolts shall be inserted and the nuts screwed tightly with fingers. Nuts shall be tightened with a torque limiting wrench, the range of torque in accordance with AWWA C600. Bolts spaced 180 degrees apart shall be tightened alternately to produce an equal pressure on all parts of the gland.
    f. Deflection of the joint shall occur after joint assembly but before tightening the bolts. The deflection for mechanical joints shall not exceed the Manufacturer's recommended maximum deflection.
3. Joint restraint:
    a. Complete the joint restraint as recommended by the Manufacturer.
    b. No joint deflection is allowed.
4. Mechanical joint restraints:
    a. Complete the mechanical joint as described herein.
    b. Complete the mechanical joint restraint as recommended by the Manufacturer.
    c. No joint deflection is allowed.
5. Bond DI joints as specified in SECTION 13 47 16. Joint bonds are required for pipe greater than 20 inches in diameter, and for pipe where soil resistivity is less than 5,000 ohm-cm.

E. Cutting and Fitting: Make pipe cuts required to conform to location, line, and grade. Cuts on pipe shall be made by the use of pipe cutters or pipe saws recommended by the Manufacturer and approved by the ENGINEER. Cuts shall be straight and true. Cut ends and rough edges shall be ground smooth. For push-on joint connections, the cut end shall be beveled.

3.2 PROTECTION

A. Protection of Fittings: Buried DI pipe fittings shall be PE wrapped in accordance with AWWA C600.

END OF SECTION

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SECTION 33 05 24.23
STEEL PIPE FOR WATER TRANSMISSION

PART 1 GENERAL

1.1 GENERAL

A. Section includes general information, products, and execution for steel pipe for water transmission.

B. Related Sections:

1. SECTION 05 05 23 – WELDING
2. SECTION 09 90 00 – PAINTING AND COATING
3. SECTION 09 97 13.01 – POLYURETHANE COATINGS
4. SECTION 09 97 13.02 – LIQUID-EPOXY LININGS AND COATINGS
5. SECTION 09 97 13.03 – CEMENT MORTAR LININGS AND COATINGS
6. SECTION 09 97 13.05 – HEAT-SHRINK COATINGS
7. SECTION 09 97 13.06 – TAPE AND VISCOELASTIC COATINGS
8. SECTION 13 47 16 – ISOLATION AND BONDING FOR CATHODIC PROTECTION
9. SECTION 33 14 11 – WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):

1. B 16.11 – Forged Fittings, Socket-Welding and Threaded

B. American Water Works Association (AWWA):

1. C200 – Steel Water Pipe – 6 Inch (150 mm) and Larger
2. C206 – Field Welding of Steel Water Pipe
3. C207 – Steel Pipe Flanges for Waterworks Service – Sizes 4 Inch Through 144 Inch (100 mm Through 3600 mm)
4. C208 – Dimensions for Fabricated Steel Water Pipe Fittings
5. Manual M11 – Steel Water Pipe: A Guide for Design and Installation

C. NACE International (NACE):

1. SP0274 – High-Voltage Electrical Inspection of Pipeline Coatings

D. NSF International/American National Standards Institute (NSF/ANSI):

1. 61 – Drinking Water System Components – Health Effects

1.3 SUBMITTALS

A. Shop Drawings:

1. Joint and pipe wall construction details indicating the type and thickness of cylinder, manufacturing tolerances, and other pertinent information required for the manufacture of the product. Joint details shall be submitted where deep bell or buttstrap joints are required for control of temperature stresses.
2. Shop Drawings of fittings and specials such as elbows, wyes, tees, outlets, and nozzles or other specials where shown on the Drawings indicating the amount and position of reinforcement. Fabricate fittings and specials as stipulated herein and in accordance with the Manufacturer's specifications and drawings as approved by the ENGINEER.
3. Design calculations that comprise the complete stress analysis of each critical section of pipe wall, girth joints, harness system, specials, and openings sufficient to ascertain conformance of pipe and fittings with the Contract Documents.
4. Material lists including all materials to be utilized. Use of materials other than those permitted within the scope of the Contract Documents is prohibited.
5. Line layout and marking diagrams indicating the specific number of each pipe and fitting and the location of each pipe and the direction of each fitting in the completed line. In addition, the line layouts shall include:
   a. The station and top of pipe elevation at changes in grade or horizontal alignment.
   b. The station and top of pipe elevation to which the bell end of each pipe will be laid.
   c. Elements of curves and bends in horizontal and vertical alignment.
   d. The limits of each reach of restrained or welded joints.

1.4 QUALITY ASSURANCE

A. Pipe Design Criteria: The pipe diameter specified is the minimum finished inside diameter in inches after lining.

B. General Requirements:

1. Maximum laying length shall be 50 feet.
2. Pipe shall be designed, manufactured, tested, inspected, and marked in accordance with AWWA C200 and as specified in this Section.
3. Steel used for the fabrication of pipe shall have a maximum carbon content of 0.25% and shall have a minimum elongation of 22% in a 2 inch gauge length.
4. After the joint configuration is completed and prior to lining, each length of pipe of each diameter and pressure class shall be shop-tested and certified to a pressure of at least 75% of the specified yield strength of the pipe steel.

C. Steel Cylinder Thickness:

1. Cylinder thickness for internal pressure:
   a. For resistance to internal pressure, the thickness of the steel cylinder shall be determined using the following formula: $t = \frac{(PD/2)}{(Y/S)}$

   Where:

   t = Steel Cylinder thickness in inches
   D = Outside diameter of steel cylinder in inches

P = Working pressure in psi
Y = Specified minimum yield point of steel in psi
S = Safety factor of 2.0

b. In no case shall the design stress (Y/S) exceed 21,000 psi. The steel shell thickness shall not be less than the minimum thickness shown below nor shall the calculated stress exceed 28,000 psi when the internal pressure is equal to working pressure plus water hammer pressure.

Nominal Pipe Diameter (Inches)	Minimum Steel Cylinder Thickness (Inch)
<24	0.135
24	0.165
30	0.165
36	0.188
42	0.207
48	0.250
54	0.271
60	0.280
66	0.312
72	0.375
84	0.406
90	0.438
96	0.468
108	0.500

2. Cylinder thickness for external load:
   a. Upon determination of cylinder thickness for internal pressure, deflection of the pipe shall be checked by the following formula: $D_x = \dfrac{DKWr^3}{EI + 0.0614E'r^3}$

   Where:
   D_x = Vertical deflection of pipe in inches, not to exceed the allowable deflection as specified in this Section
   D = Deflection lag factor = 1.15
   K = Bedding constant = 0.1
   W(1) = Vertical load on pipe in lb/in
   r = Mean radius of pipe shell in inches
   EI = Flexural rigidity of pipe wall in lb-in
   E' = Modulus of soil reaction for use of bedding sand in lb/in^2 = 1200
   Modulus of soil reaction for use of CLSM in lb/in^2 = 3000

   b. If the calculated deflection D_x exceeds allowable, use improved bedding and pipe zone material to increase E' so that the calculated deflection becomes less than allowable.
3. Welding of joint rings to resist thrust: Where steel pipe with field welded Carnegie joint rings are used for thrust restraint, the joint rings shall be welded to the cylinder with double fillet welds.

D. Joint Design and Fabrication:
1. O-ring joints:
   a. Bell and spigot O-ring type joints shall consist of a bell and spigot end formed integrally on the pipe by swaging, expanding, or by welding on an approved Carnegie Section. The gasket shall be retained on the spigot end by a groove formed by rolling with dies. At no point on the spigot end shall the clear inside diameter of the pipe be less that the nominal inside diameter of the pipe barrel. The inside of the bell end and the outside of the spigot end shall be smoothed by grinding as necessary and shall be free of raised bumps and scratches.
   b. The gasket for the joint shall be a continuous O-ring made of a special rubber composition of such size and cross-section as to provide a watertight joint for a pressure of at least 250 psi. The material requirements of the gasket shall be in accordance with AWWA C200. Each gasket shall be checked for diameter, cut length, soundness, curing, and splices; certification of such tests shall be furnished to the OWNER as specified in this Section.
   c. The joint shall provide for a 3/4 inch pull-out from normal joint closure. The Manufacturer shall furnish joint materials including rubber gaskets and lubricant. Joint lubricant shall be in accordance with NSF/ANSI 61.
2. Welded joints:
   a. Pipe and fittings for field welded joints shall be buttstrap joints, lap joints, or rubber gasket joints prepared for field welding and shall be in accordance with AWWA C200. Attachment of joint rings to the pipe cylinder shall be accomplished with full thickness fillet welds on both the inside and the outside of the cylinder.
   b. The method used to form, shape, and size bell ends shall be such that the physical properties of the steel are not substantially altered. Bell ends shall be formed by expanding with segmental dies. If approved by the ENGINEER, bell ends formed by a rolling process shall be accomplished in no more than six passes

1 For design earth cover of more than 10 feet, the vertical load on the pipe shall be the weight of the earth directly over the pipe. For pipe design when the design earth cover is 10 feet or less, the vertical load on the pipe shall also include the AASHTO HS-20 design live load. For design earth cover less than 3 feet, impact shall also be included.

(revolutions) over the bell surface and any resulting radius shall not be less than 15 times the thickness of the material being formed.

c. Shop-applied linings and coatings shall be held back a minimum of 2 1/2 inches from the point at which the weld is to be made.

d. Bell and spigot ends shall be sized to provide a difference in circumferential measurement between the outside circumference of the spigot and the inside circumference of the bell of no less than 0.09 inch and no more than 0.49 inch for pipe diameters 24 inches through 54 inches, and no less than 0.09 inch and no more than 0.39 inch for pipe diameters larger than 54 inches.

E. Offset Tolerances: For pipe wall thicknesses of 3/8 inch or less, the maximum radial offset (misalignment) for submerged arc and gas metal arc welded steel pipe shall be 0.1875 times the pipe wall thickness or 1/16 inch, whichever is larger. For pipe wall thicknesses greater than 3/8 inch, the maximum radial offset shall be 0.1875 times the pipe wall thickness or 5/32 inch, whichever is smaller.

F. Welding: As specified in SECTION 05 05 23.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Pipe:
1. American SpiraWeld Pipe
2. Mid America Pipe
3. Northwest Pipe
4. Thompson Pipe Group

B. Rust-Preventive Compound:
1. Houghton International, Rust Veto 344

C. Pipe Specials and Fittings:
1. American SpiralWeld Pipe
2. Mid America Pipe
3. Mountain Man Welding and Fabrication, Inc.
4. Northwest Pipe
5. Thompson Pipe Group
6. Trinity Steel and Pipe, Inc.
7. Utility Coatings and Fabrication

D. Coatings and Linings:
1. As specified in the Contract Documents

2.2 ACCESSORIES

A. Flanges:
1. As specified in SECTION 33 14 11.
2. Flanges shall be ring type, flat faced, and serrated in accordance with AWWA C207.
3. Blind flanges shall be in accordance with AWWA C207. Above 24 inch nominal diameter consider ring flanged and dished heads.
4. Shop coat machined faces of flanges with a rust-preventive compound.
5. Shop coat edges and back faces of attached flanges with polyurethane as specified in SECTION 09 97 13.01 or epoxy as specified in SECTION 09 97 13.02.
6. Shop coat edges, back faces, non-threaded surfaces, and the inside of blind flanges with polyurethane as specified in SECTION 09 97 13.01 or epoxy as specified in SECTION 09 97 13.02.

B. Specials and Fittings:
1. Design:
   a. Steel specials and fittings shall be in accordance with AWWA C208. Pipe material used in fittings shall be of the same material and minimum thickness as the pipe.
   b. The minimum radius of steel elbows shall be 2 1/2 times the pipe diameter and the maximum miter cut angle on each section of the elbow shall not exceed 11.25 degrees.
   c. Fittings shall be equal in design strength of the pipe and shall have the same lining and coating as the abutting pipe.
   d. With approval of the ENGINEER, outlets may be spaced differently than shown on the Drawings to meet the Pipe Manufacturer’s fabrication limitations. The effect of this change, such as increased concrete manhole size, shall be at the CONTRACTOR’s expense.
   e. Steel specials and fittings shall be made of segmentally welded sections from hydrostatically tested pipe with ends to mate with the type of joint or coupling specified for the pipe.
2. Linings and coatings: Specials and fittings that cannot be mechanically lined and coated shall be lined and coated by hand-application using the same materials used for the pipe. Lining and coating applied in this manner shall provide protection equal to that specified for the pipe.
3. Threaded outlets: Forged steel Class 3000 in accordance with ASME B 16.11.
4. Deflections and long radius curves:
   a. Moderate deflections and long radius curves may be made by means of beveled joint rings, by pulling standard joints, by using short lengths of pipe, or a combination of these methods.
   b. The maximum total allowable angle for beveled joints shall be 5 degrees per pipe joint.
   c. The maximum allowable angle for pulled joints shall be in accordance with the Manufacturer's instructions or the angle that results from a 3/4 inch pull-out from normal joint closure, whichever is less.

d. Deflections or fabricated angles shall fall on the alignment. The chord produced by deflecting the pipe shall be no further than 6 inches from the alignment shown on the Drawings.

5. Angle points:
   a. Laying schedule angle points shall meet the horizontal angle points as shown on the Drawings.
   b. Laying schedule vertical angle points shall meet the vertical angle points as shown on the Drawings where interference is critical.

C. Closures and Correction Pieces: Closures and correction pieces shall be provided as required so that closures may be made due to different headings in the pipe laying operation and so that correction may be made to adjust the pipe laying to conform to pipe stationing shown on the Drawings. Correction pieces shall be placed at approximate intervals of 2,000 feet, prior to bends greater than 25 degrees, and prior to outlets and valves that have critical stationing. The location and number of closure or correction pieces shall be presented on the laying schedule for approval by the ENGINEER.

D. Markings:
1. Mark pipes and specials in accordance with the laying schedule and marking diagram.
2. Number in sequence; this number shall appear on the laying schedule and marking diagram in its proper location for installation.
3. Special pipe sections and fittings shall be marked at each end with top field centerline.
4. The word TOP shall be painted or marked on the outside top spigot end of the sections.
5. Minimum size of lettering: 4 inches.
6. Non-toxic.
7. Recycled water pipe:
   a. Include a stamp warning:
      1) Labeled: CAUTION: RECYCLED WATER – DO NOT DRINK.
      2) Installed along springline on both sides of pipe.
      3) In contrast with coating color.
      4) Compatible with the exterior coating.
      5) The warning shall be continuous and shall be spaced a distance no greater than 1 foot between the end of one warning message and the beginning of the next.

E. Strutting:
1. Adequate strutting shall be provided on specials, fittings, and straight pipe, to avoid handling, storage, hauling, and installation damage to the pipe coating and lining.
2. The strutting shall be placed as soon as practicable after the lining has been applied and shall remain in place while each pipe is loaded, transported, unloaded, installed, and backfilled at the jobsite.

F. Allowable Deflection: In accordance with AWWA Manual M11.

G. Specials and Fittings:
1. Reinforcement for wyes, tees, outlets, and nozzles shall be designed in accordance with AWWA Manual M11.
2. Reinforcement shall be designed for the working pressure as specified in this Section.
3. Design calculations shall be submitted to the ENGINEER.

PART 3 EXECUTION

3.1 GENERAL

A. Check the deflection of the pipe and relocate the struts or provide additional struts to keep the deflections as specified in this Section and to maintain the pipe in a round condition.

B. Handle the pipe by use of wide slings and padded cradles or of other suitable material designed and constructed to prevent damage to the pipe coating. Use of chains, hooks, or other equipment that may injure the pipe coating will not be permitted. Other pipe handling equipment and methods shall be approved by the ENGINEER.

C. Stockpiled pipe shall be supported on sand or earth berms free of rock exceeding 3 inches in diameter; it shall not be placed directly on the ground. The pipe shall not be rolled and shall be secured to prevent accidental rolling.

D. Pipe shall not be rolled or skidded at any point when in contact with the ground.

E. Workers will be permitted to walk on tape coatings only when necessary and shall wear shoes with rubber soles.

F. For dielectric coated steel pipe perform holiday inspection in accordance with NACE SP0274 just prior to the pipe being lowered into the trench. Make necessary repairs to the coating.

3.2 INSTALLATION

A. Jointing:
1. General: Field openings shall not be permitted on the pipe without the written consent of the ENGINEER.
2. Rubber gasket joints:
   a. Pipe shall be laid with bell ends facing in the direction of laying. Clearance shall be provided at the sides and bottom of pipe to facilitate the checking of the joint for proper gasket placement and for placement of the joint coating material.
   b. Prior to placing the rubber gasket in the groove on the spigot end of the pipe, both bell and spigot ends shall be thoroughly cleaned, and the inside of the bell and the rubber gasket lubricated.
   c. The spigot end shall be aligned with the bell end and carefully centered so that the pipe is supported in a manner to ensure the gasket will not drag as it enters the bell.
   d. Pipes shall be pulled together by an approved method such as bands or come-alongs or band and hydraulic jacking heads, as recommended by the Pipe Manufacturer. In all cases, the joint shall be assembled with the axis of the adjoining pipes in a straight line. Any required deflection shall be accomplished by swinging the pipe end after the joint has been assembled. Care shall be taken to assure that the gasket is not twisted or pulled when the pipe is jointed.

e. The pull-out in the rubber gasket joints shall not exceed the maximum pull-out recommended by the Pipe Manufacturer.

f. After the joint has been pulled completely together as indicated by the stab marks, the gasket shall be checked using a feeler gauge. Check around the complete circumference of the joint to assure that the gasket has not rolled out. If a gasket has rolled out, the joint shall be pulled apart, the gasket inspected, and if damaged, as determined by the ENGINEER, shall be discarded and a new gasket installed.

g. Bond rubber gasketed joints as specified in SECTION 13 47 16.

3. Welded joints:

a. General:

1) Field welded joints shall be in accordance with AWWA C206.

2) Where exterior welds are called for, adequate space shall be provided for the welding and inspection of the joint.

3) In laying welded steel pipe with buttstrap or lap joints, pipe deflection shall be limited to that which will produce a minimum lap of 1 1/2 inches and which will not cause a weld to be closer than 3/4 inch to the nearest tangent of a bell radius.

4) Buttstraps, where required, shall be a minimum of 6 inches wide, the same thickness and material type as the pipe wall, and shall provide for a minimum lap at each pipe joint as described in AWWA C206.

5) Prior to the beginning of the welding procedure, any tack welds used to position the pipe during laying shall be removed or may be left in place if the conditions stated in AWWA C206 are met. Any annular space between the faying surfaces of the bell and spigot shall be equally distributed around the circumference of the joint by shimming, jacking, or other suitable means.

6) Immediately following pipe laying, the joints shall be finish-welded, tested if required, and the exterior joint spaces coated in accordance with the Contract Documents. The pipe shall then be backfilled to at least 1 foot above the top of the previously laid pipe except for the last 100 feet, the joints of which shall be left open for subsequent field welding and coating.

7) After completion of the welding of the joint, the joint will be visually inspected. Double welded joints shall be air tested in accordance with AWWA C206. Defects shall be removed, rewelded, and retested.

8) Where more than one pass is required, each pass except the first one and the final one, shall be peened to relieve shrinkage stresses; dirt, slag, and flux shall be removed before the succeeding bead is applied.

9) In laying welded lap joints, spigots shall be laid ahead.

b. Jointing:

1) Pipe ends shall be cut straight on joints where buttstraps are used for realignment, adjustment, or deflection and fillet welds shall be made as shown on the Drawings.

2) Field welded single lap joints may be made on the inside or the outside of the pipe at the CONTRACTOR's option.

4. Flanges:

a. General: As specified in SECTION 33 14 11.

5. Field joint lining:

a. General:

1) Field joint lining material shall be the same material as the main pipeline lining.

2) Epoxy shall be as specified in SECTION 09 97 13.02.

3) Cement mortar shall be as specified in SECTION 09 97 13.03.

6. Field joint coating:

a. General:

1) Field joint coating for cement-mortar coated pipe shall be as specified in SECTION 09 97 13.03.

2) Field joint coating for tape, polyurethane, and epoxy-coated steel pipe shall be polyurethane as specified in SECTION 09 97 13.01, epoxy as specified in SECTION 09 97 13.02, or a heat-shrinkable sleeve as specified in SECTION 09 97 13.05.

B. Backfill and Strut Removal:

1. Remove pipe struts after backfill has been placed.

2. Following the removal of struts, the ENGINEER will check the pipe for deflection. Where excessive deflection occurs, remove the earth cover and side fill material, re-round the pipe by strutting, and replace the pipe zone and backfill material to limit deflection to that specified herein.

3.3 PROTECTION

A. Damage to Steel Pipe:

1. Notify the ENGINEER of damage.
2. The ENGINEER will determine whether the pipe can be field repaired.
3. Where feasible, damaged pipe shall be placed so that the damaged portions will be on top.
4. Buried pipe shall be excavated to expose the entire damaged section.
5. No attempt shall be made to re-round the pipe.
6. Repair the damaged area as directed by the ENGINEER.
7. Weld patches shall have rounded edges and shall extend a minimum of 1 inch past the damage.

B. Protection of Appurtenances: Buried steel pipe appurtenances such as nozzles shall be coated with the same system as the pipe.

C. Coating of Exposed Metal: Exposed metal surfaces except flanges shall be coated with the same system as the pipe.

D. Linings:
  1. General:
     a. Apply linings in accordance with the Manufacturer’s instructions, including surface cleaning and preparation.
     b. Hold back lining 2 1/2 inches from the point at which the field weld is to be made.
     c. Leave ends of lining square and uniform.
     d. Allow lining to cure completely prior to shipping.
  2. Acceptable steel pipe linings:
     a. Epoxy shall be as specified in SECTION 09 97 13.02.
     b. Cement mortar shall be as specified in SECTION 09 97 13.03.

E. Coatings:
  1. General:
     a. Apply in accordance with the Manufacturer’s instructions, including surface cleaning and preparation.
     b. Hold back coating 2 1/2 inches from the point at which the field weld is to be made.
     c. Leave ends of coating square and uniform.
     d. Allow lining to cure completely prior to shipping.
  2. Acceptable steel pipe coatings:
     a. Polyurethane as specified in SECTION 09 97 13.01.
     b. Epoxy shall be as specified in SECTION 09 97 13.02.
     c. Cement mortar shall be as specified in SECTION 09 97 13.03.
     d. Paint on piping within vaults shall be as specified in SECTION 09 90 00.
     e. Tape shall be as specified in SECTION 09 97 13.06.

END OF SECTION

SECTION 33 05 31.13
POLYVINYL CHLORIDE PIPE FOR WATER TRANSMISSION AND DISTRIBUTION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for polyvinyl chloride pipe for water transmission and distribution.

B. Related Sections:
1. SECTION 13 47 16 – ISOLATION AND BONDING FOR CATHODIC PROTECTION
2. SECTION 31 23 33 – TRENCH BACKFILL
3. SECTION 33 05 19 – DUCTILE-IRON PIPE AND FITTINGS FOR WATER TRANSMISSION AND DISTRIBUTION
4. SECTION 33 14 11 – WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL
5. SECTION 33 14 17 – WATER SERVICE LINES

1.2 REFERENCES

A. American Society for the Testing of Materials (ASTM):
1. A 536 – Standard Specification for Ductile-Iron Castings
2. D 1784 – Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
3. D 3139 – Standard Specification for Joints for Plastic Pressure Pipes Using Flexible Elastomeric Seals
4. F 477 – Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe

B. American Water Works Association (AWWA):
1. C111 – Rubber-Gasket Joints for Ductile Iron Pressure Pipe and Fittings
2. C115 – Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges
3. C116 – Protective Fusion-Bonded Epoxy Coatings for the Interior and Exterior Surfaces of Ductile-Iron and Gray-Iron Fittings
4. C153 – Ductile-Iron Compact Fittings
5. C223 – Fabricated Steel and Stainless Steel Tapping Sleeves
6. C600 – Installation of Ductile-Iron Water Mains and Their Appurtenances
7. C605 – Underground Installation of Polyvinyl Chloride (PVC) Molecularly Oriented Polyvinyl Chloride (PVCO) Pressure Pipe and Fittings
8. C900 – Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 In. Through 60 In. (100 mm Through 1,500 mm)
9. Manual M23 – PVC Pipe - Design and Installation

C. Manufacturers Standardization Society (MSS):
1. SP-60 – Connecting Flange Joints between Tapping Sleeves and Tapping Valves

D. NSF International/American National Standards Institute (NSF/ANSI):
1. 14 – Plastics Piping System Components and Related Materials
2. 61 – Drinking Water System Components – Health Effects

E. Plastic Pipe Institute (PPI):
1. TR-3 – Policies and Procedures for Developing Hydrostatic Design Basis (HDB), Pressure Design Basis (PDB), Strength Design Basis (SDB), and Minimum Required Strength (MRS) Ratings for Thermoplastic Piping Materials or Pipe

F. Underwriters Laboratory (UL):
1. 1285 – Pipe and Couplings, Polyvinyl Chloride (PVC), and Oriented Polyvinyl Chloride (PVCO) for Underground Fire Service

G. Uni-Bell PVC Pipe Association:
1. PVC Pressure Pipe Tapping Guide

1.3 DEFINITIONS

A. DR: A ratio equivalent to the average outside pipe diameter divided by the pipe wall thickness. For the same DR, the pressure capacity and the pipe stiffness remain the same.

1.4 SUBMITTALS

A. Shop Drawings:
1. Joint and pipe wall construction details including the type and thickness of the cylinder, joint details, and manufacturing tolerances.
2. Line layout (only for pipe 24 inches or larger in diameter):
   a. Indicate the starting station and top elevation to which each piece of pipe and each fitting will be placed.
   b. Indicate the orientation of each fitting.
   c. Indicate the limits of restrained pipe joints.
   d. Show elements of curves and bends in the horizontal and the vertical directions.
   e. Note cut-to-fit locations.
3. Mark diagrams and detail Drawings (for pipe 24 inches or larger in diameter):
   a. Assign a mark number to each pipe section and fitting.
   b. Label cut-to-fit, with separate mark numbers.
   c. Show locations of appurtenances on the pipe.

B. Design Information (only for pipe 24 inches or larger in diameter): Submit design calculations in accordance with AWWA Manual M23.

C. Manufacturer's Installation Information:
   1. Provide maximum joint deflection information for unrestrained pipe.
   2. Provide maximum joint deflection for restrained joints.
   3. Provide maximum stacking height of pipe.
   4. Fusible installations:
      a. Provide maximum allowable sag during unloading and moving.
      b. Provide maximum allowable bend radius.
      c. Provide safe pulling force.
      d. Provide temperature impacts to the maximum bend radius and the safe pulling force.

D. Appurtenant Materials:
   1. Tapping materials:
      a. Tapping sleeves and valves:
         1) Provide the Manufacturer data sheet.
         2) Provide the Tapping Sleeve Manufacturer's recommendations for installation.
      b. Tapping machine and cutting tool: Manufacturer data.
      c. Qualifications of Tapping Subcontractor.
   2. Fusible PVC:
      a. Provide the following data:
         1) Fusion machine information.
         2) Pulling head information.
      b. Provide CONTRACTOR diagrams:
         1) Layout of fusing operation on-site.
         2) Pipe support methods during fusing and installation.
      c. Provide qualifications of the PVC welder.
   3. Other materials:
      a. Fittings, lubricants, and restraint devices: Manufacturer data.
      b. Tracer wire, test site, and PVC tape: Manufacturer data.

E. Certifications: Certify that submitted piping, accessories, and equipment either meet the Specifications as stated or meet the Specification through an alternate means; specify the methodology used.
   1. In accordance with AWWA C900.
   2. In accordance with UL 1285.
   3. In accordance with NSF/ANSI 14.
   4. In accordance with NSF/ANSI 61, potable lines only.

F. Quality Control:
   1. Provide information on the PVC Manufacturer's QA program.
   2. Hydrostatic testing: If requested by the OWNER, provide hydrostatic proof testing records in accordance with AWWA C900.
   3. Joint fusion reports (fusible PVC only): Provide a report of critical fusion parameters and pipe data for each fused joint.
   4. The Manufacturer shall submit a written statement that the inspection and specified tests have been completed and that results comply with the requirements of these Standards. Components in contact with potable water shall be certified to comply with NSF/ANSI 61, and a copy of the NSF/ANSI 61 certification shall be provided to Denver Water, if requested.

1.5 QUALITY ASSURANCE

A. Pipe Design Criteria:
   1. PVC fittings are not allowed.
   2. PVC pipe shall not be used in manholes or vaults without the written approval of the ENGINEER.
   3. Pipe to be manufactured to the CI outside diameter.
   4. The pipe laying schedule may need to be altered to meet the requirements and installation recommendations of the product used. Changes in the laying schedule are to be approved by the ENGINEER and be as shown on the Drawings.

B. Tapping Subcontractor Qualifications: A minimum of 5 years of documented experience in the Work of this Section.

C. PVC Fusion Welder:
   1. A minimum of 3 years of documented experience in fusing pipe of the diameter equal to or greater than required by the Work in this Section.
   2. Approved by the Fusible Pipe Manufacturer.
   3. Refresher trained within the past 12 months.

D. Environmental Concerns:
   1. PVC pipe is not to be installed in areas having suspected petroleum contamination.
   2. PVC pipe material properties will change when subjecting the pipe to temperatures significantly different from the standard ambient temperature of 73°F.

1.6 DELIVERY, STORAGE, AND HANDLING

A. Delivered pipe shall be clean:
   1. Pipe shall not contain any chemical residues from the pipe manufacturing operation.
   2. Reject any pipe containing greasy residues.
   3. Reject any pipe containing diesel soot.

B. Inspection:
  1. Examine the pipe identification marks to verify pipe meets the Contract Documents.
  2. Reject pipe with scratches penetrating more than 10% of the pipe wall thickness.
  3. Reject cracked pipe.
  4. Remove rejected pipe from the site.
C. Store and handle pipe as recommended by the Manufacturer and in accordance with AWWA C605.
  1. Fusible PVC shall not exceed the Manufacturer's maximum allowable sag when lifted.
D. Seal the ends of pipe to protect the inside from contamination during storage.
E. Additional care is needed in handling PVC pipe at lower temperatures due to a decrease in impact strength in PVC material and an increase in stiffness of pipe gaskets.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. C900 PVC Pressure Pipe (unrestrained joint):
  1. Diamond Plastics
  2. IPEX
  3. JM Eagle
  4. North American Pipe Corporation
  5. Vinyltech Corporation/Northern Pipe Products
B. C900 Integrally Restrained Pipe:
  1. North American Specialty Products: Certa-Lok RJ
  2. North American Specialty Products: Certa-Lok RJIB
  3. Diamond Plastics: Diamond Lok-21 (Bulldog Restraint System)
  4. JM Eagle: Eagle Loc 900 (Bulldog Restraint System)
C. C900 Fusible Pipe:
  1. Underground Solutions, Fusible PVC
D. Mechanical Joint Restraint Devices:
  1. EBAA Iron, Inc., Megalug 2000PV series
  2. Star Pipe Products, StarGrip 4000 series and Series 4000G2 (4 inch to 12 inch only)
  3. Sigma Corporation, One-Lok SLCE series
  4. Romac, RomaGrip
  5. Smith Blair, Cam-Lock
  6. Tyler Union, TufGrip
  7. The Ford Meter Box Company, UFR 1500 and UFR 1500R (4 inch to 6 inch only)
  8. SIP Industries, EZ Grip
E. Bell and Spigot Restraint Devices:
  1. EBAA Iron, Inc.:
    a. Series 1500 (4 inches to 12 inches)
    b. Series 1500 TD (4 inches to 12 inches)
    c. Series 2800 (14 inches to 54 inches)
  2. Star Pipe Products, PVC pipe restrainers series 1100
  3. Ford Meter Box, Series1390
  4. Diamond Plastics Corporation, Bulldog Restraint System Diamond Lok-21
  5. JM Eagle, Bulldog Restraint System Eagle Loc 900
  6. North American Pipe, C900/RJ and C900/RJIB Certa-Lok
  7. RieberLok (4 inches to 12 inches)
  8. SIP Industries, EZ Grip PTP
  9. Sigma Pipe Products, Series 1100
F. Bell Protection Device:
  1. EBAA Iron, Inc., 5000 series Mega-Stop
G. Restrained Flange Adaptor:
  1. EBAA Iron, Inc., Series 2100 Megaflange
H. Marker Balls:
  1. 3M Extended Range Ball Markers, Potable 1423-XR/iD, Blue Water
  2. 3M Extended Range Ball Markers, Recycled 1408-XR, Purple General Purpose

2.2 MATERIALS

A. PVC Pressure Pipe:
  1. Material requirements:
    a. Manufactured from an un-plasticized PVC compound having a minimum cell classification 12454 in accordance with ASTM D 1784.
    b. Compounds shall qualify for a rating of 4,000 psi (27.58 MPa) for water at 73.4°F in accordance with PPI TR-3.
  2. Pipe Specifications:
    a. Manufactured in accordance with AWWA C900.
    b. Wall thickness:
      1) 4 inch: DR-14.
      2) 6 inch and larger: DR-18.
    c. Standard laying lengths of 20 feet.

3. Bell and spigot joints, non-restrained:
    1) Pipe joints shall be made using an integral bell.
    2) Pipe shall be furnished with metal-reinforced Reiber-type gaskets that are pre-installed in the pipe bell during the belling process. Removable gaskets shall not be permitted.
    3) The Manufacturer shall furnish gasket lubricant for each quantity of pipe furnished.
    4) Joints shall be in accordance with ASTM D 3139.
    5) Gaskets shall be in accordance with ASTM F 477 and shall be designed to meet the zero-leakage test requirements.
    6) Pipe shall be furnished with marks to designate proper insertion depths and prevent over-insertion during assembly.
4. PVC carrier pipe (for use in casings):
    a. Allowable joints:
        1) Fusible PVC.
        2) Certa-Lok RJ or RJIB (where clearance allows).
5. Color:
    a. Potable water: Blue or white.
    b. Recycled water: Purple, Pantone 2577U.
6. Markings:
    a. Manufacturer and trademark.
    b. Nominal size and DR ratio/pressure class.
    c. Hydrostatic proof test pressure.
    d. Manufacturing date code.
    e. Certifications.
    f. Recycled water piping:
        1) Repeating warning label located on the exterior of the pipe, on both sides that reads CAUTION: RECYCLED WATER – DO NOT DRINK.
        2) Label height: 3 inches.

B. PVC Pipe Joint Restraint Devices:
1. General:
    a. Designed to resist thrusts resulting from internal pressure acting at bulkheads, bends, valves, and extending over the distances shown on the Drawings.
    b. Designed for the working pressure plus water hammer as specified in SECTION 33 14 11.
2. Integrally-restrained joints shall incorporate an internal or external bell protection device to prevent over-insertion.
3. Mechanical joint restraint:
    a. Manufactured from DI in accordance with ASTM A 536, Grade 65-45-12. Wedges shall be heat treated to a minimum of 370 BHN. Rubber gaskets shall be vulcanized SBR in accordance with AWWA C111. Tee-head bolts shall be manufactured from a high strength alloy steel known in the industry as Cor-Ten, Usalloy, or Durabolt.
    b. Mechanical joint restraints shall be incorporated into the design of the follower gland. Dimensions of the gland shall be such that it can be used with the standardized mechanical joint bell and tee-head bolts in accordance with AWWA C111 and AWWA C153.
    c. The restraint mechanism shall consist of numerous individually activated gripping surfaces to maximize the restraint capability. The gripping surfaces shall be wedges that are designed to spread the bearing surfaces on the pipe. Twist-off nuts, sized the same as the tee-head bolts, shall be used to ensure the proper actuating of the restraining devices. When the nut is sheared off, a standard hex nut shall remain.
    d. The pressure rating shall be equal to that of the pipe being used with a safety factor of 2.

C. Fittings:
1. General:
    a. DI fittings as specified in SECTION 33 05 19. PE encased DI fittings.
    b. Lined and coated with fusion-bonded epoxy in accordance with AWWA C116.
    c. Outlets 12 inches in diameter and smaller may be in the form of tees or tapping saddles.
    d. Manufacturer-welded DI outlets are acceptable.
2. In-line flanges:
    a. Pressure rating: Equal to that of pipe.
    b. Flange bolt circles: In accordance with AWWA C115.
    c. Encase DI flanges in wax tape as specified in SECTION 13 47 16.
    d. Acceptable methods of attaching flange to pipe:
        1) Restrained transition to a DI pipe spool piece with a flanged end.
        2) Restrained flange adaptor.

D. Tracer Wire:
1. Wire: Minimum #12 AWG solid copper wire with 0.03 inch blue (potable) or purple (recycled) colored PE insulation.
2. PVC tape, 2 inch wide.
3. Locator wire test sites:
    a. Style-B test site: Valve box lid or 3-inch test box lid marked tracer.

E. Marker Balls:
1. Passive antenna encased in water-resistant PE shell.

F. Tapping Sleeves:
   1. Designed and manufactured in accordance with AWWA C223.
   2. The machined flange face shall be recessed for tapping valves in accordance with MSS SP-60. Hollow-back flanges and segmented flanges are not acceptable.
   3. Gaskets shall be compounded from new materials and the shape of the cross-section of the gasket shall provide an adequate seal for the working pressure. Gaskets shall be shop glued to the groove provided in the body section.
   4. A 3/4 inch NPT threaded outlet shall be attached to the outlet nozzle of each tapping sleeve assembly complete with a 3/4 inch square head, threaded pipe plug.
   5. Ferrous surfaces, except machined or bearing surfaces, shall be prepared in accordance with SSPC SP10. These surfaces shall then be coated with liquid epoxy in two or more uniform coats or with fusion-bonded epoxy to a minimum DFT of 10 mils in accordance with AWWA C550. Machined flange faces shall be shop-coated with a rust-preventive compound; they shall not be painted or coated with the same coating as the body.

PART 3 EXECUTION

3.1 GENERAL

A. As specified in SECTION 33 14 11, SECTION 31 23 33, and herein.

3.2 INSTALLATION

A. General: Install pipe in accordance with the Manufacturer's instructions and the Specifications.

B. Push-On Joint:
   1. A thin film of non-toxic, water soluble gasket lubricant shall be applied to either the inside surface of the gasket or the spigot end of the pipe, or both.
   2. Push the spigot end in, until the first depth mark on the spigot end is flush with the end of the bell. Do not insert the spigot end beyond the distance recommended by the Manufacturer:
      a. Brace the bell while the spigot end is pushed through the gasket to help prevent previously completed joints in the pipeline from being stacked or inserted past the depth mark, taking care not to damage the pipe. Use of a bell protection system to prevent over-insertion is also acceptable. Damaged pipe shall be replaced and removed from the site.
      b. Use the second reference mark on the pipe or the Manufacturer instructions to determine whether the spigot has been installed to the proper depth. If the spigot is determined to be over-inserted, both the pipe that was over-inserted and the pipe it was inserted into shall both be rejected, marked as such, and removed from the site.
      c. After removing over-inserted pipes at the joint, examine the adjacent joint which was previously completed and remove the pipe if the joint is now over-inserted. This process shall continue until a joint is found which was not over-inserted.
   3. Field cut pipe joints shall be filed or ground to resemble a spigot end as recommended by the Manufacturer. Reference lines for spigot insertion shall be added as recommended by the Manufacturer or a bell protection system shall be used.
   4. Field-cut end repairs shall be made in accordance with the Pipe Manufacturer's recommendations.
   5. Deflection of the joint shall not exceed the Manufacturer's recommended maximum deflection.
   6. Joint restraints shall be installed as required by the laying schedule.

C. Certa-Lok Installation:
   1. Follow the Manufacturer's instructions for installation of joint.
      a. Clean pipe and coupling (RJ) to remove debris and contaminants.
      b. Inspect the seal inside the pipe for placement and alignment.
      c. Apply Manufacturer recommended lubricant to the gasket seal and to the spigot end. Remove any lubricant that may have gotten into the spline groove.
      d. Ensure pipe ends are concentrically and angularly aligned. Verify the spline hole is accessible.
      e. Push the pipe together using mechanical means, either into the coupling (RJ joint) or bell and spigot (RJIB) and insert the nylon spline using a spline insertion tool until it bottoms out.
      f. Excess spline beyond 1 inch, may be cut off.
   2. Follow the Manufacturer's recommendations to connect a Certa-Lok product to standard PVC pipe.

D. Bulldog Restraint System Pipe:
   1. The Manufacturer's Representative shall be on-site during the first day of installation of the joint.
   2. Install a bell protection device at each joint to prevent over-insertion of the spigot in the bell.
   3. Follow the Manufacturer's instructions for the installation of joints.
      a. Clean the pipe joint of debris.
      b. Inspect the joint to verify the grip ring is in the proper location and there is no debris that may interfere with the gripping mechanism.
      c. Apply lubricant as required by the Manufacturer. Do not lubricate the grip ring.
      d. Align the joint prior to installation.
      e. Push the spigot end until it reaches the Manufacturer's insertion line. Do not insert the spigot end beyond the distance recommended by the Manufacturer.
   4. Connecting the bulldog joint to a standard bell and spigot pipe:
      a. Due to the length of the bell in a bulldog joint, Manufacturer-supplied spigot insertion marks cannot be used when joining a bulldog joint to a standard bell and spigot joint.
      b. Use the Manufacturer's recommendations to mark new insertion lines on a bulldog spigot to be installed in a standard bell or a standard spigot to be inserted in a bulldog bell.

E. RieberLok Gasket:
1. Follow the Manufacturer's instructions for the installation of joints.
   a. Remove the original gasket. Working from the bell end of the pipe, use a medium sized flat blade screwdriver to remove the original gasket.
   b. Clean the bell socket and pipe groove of debris.
   c. Making sure the gasket groove is clean; install the RieberLok gasket in the pipe's gasket groove by forming a loop in the gasket and inserting it in the groove. Install the gasket with the painted face marked "INSTALL THIS FACE OUT" pointing out of the bell and facing the installer.
   d. Apply a light coating of assembly lubricant to the first few inches of the spigot end of the pipe including the beveled area. Apply a light coating of assembly lubricant to the inside surface of the gasket.
   e. Align the two pipes to be mated, bell to spigot, and insert the spigot into the bell of the mating pipe until resistance is felt. Using a suitable device, push the spigot into the bell until the assembly stripe is reached.

F. Fusible Joints:
1. General:
   a. Use temporary shelter over fusion operations during inclement weather; protect operations from precipitation and cold winds.
   b. Support pipe in a manner not to exceed the allowable bend radius, corrected for actual temperature, during welding or installation into the ground.
   c. When installing fusible joints, use a pulling head designed for fusible PVC and for the specific pipe outside diameter to be used.
2. Butt-welding:
   a. Ensure the electronic data logger is recording critical pipe fusion information for each pipe joint.
   b. Securely align the pipe ends in the fusion machine.
   c. Use the fusion machine's dual cutting heads to face and square the ends of the PVC pipe.
   d. Heat the pipe ends to the proper bead formation, remove the heating element and bring the ends together.
   e. Hold the joined pipe segments under pressure until the joint cools to the proper temperature.
   f. Do not remove internal or external beads.
   g. Recorded data to be reviewed by the Pipe Manufacturer's QA/QC Manager; final data report to be provided to the ENGINEER.

G. Carrier Pipe Installation:
1. Use Certa-Lok or fusible PVC pipe inside the casing.
2. Assemble pipe joint in accordance with these specifications.
3. Install casing spacers to the spacing recommended.
4. Attach PVC tracer wire to the pipe in a manner so it will not get snagged during installation.
5. After casing pipe is installed, push or pull carrier pipe through the casing.
6. After carrier pipe has been installed through the casing, install a casing end seal between the casing and the carrier pipe at both ends.

H. Mechanical Joint:
1. Remove PVC spigot bevel, as necessary.
2. The last 8 inches outside of the spigot and the inside of the bell shall be thoroughly cleaned to remove oil, grit, excess coating, and other foreign matter from the joint and then painted with a thin film of non-toxic, water soluble gasket lubricant.
3. The gland shall then be slipped on the spigot end of the pipe with the lip extension of the gland toward the plain end.
4. The rubber gasket shall be painted with the gasket lubricant and placed on the spigot end with the thick edge toward the gland.
5. The entire section of the pipe shall be pushed forward to seat the spigot end in the bell. The gasket shall then be pressed into place within the bell. Care shall be taken to locate the gasket evenly around the entire joint.
6. The gland shall be moved toward the bell and centered with the gland lip against the gasket. Bolts shall be inserted, and the nut screwed up tightly with the fingers. Nuts shall be tightened with a torque-limiting wrench following the range of torque in accordance with AWWA C600. Bolts spaced 180 degrees apart shall be tightened alternately in order to produce an equal pressure on all parts of the gland.
7. Deflection of the joint shall occur after joint assembly but before tightening the bolts. The deflection for mechanical joints shall not exceed the Manufacturer's maximum recommended deflection.
8. Mechanical joint restraints shall be added as required by the laying schedule.

I. Cutting and Fitting Pipe:
1. Make pipe cuts required to conform to location, line, and grade.
2. Use pipe cutters or pipe saws recommended by the Manufacturer and approved by the ENGINEER.
3. Cuts to be straight and true. For push-on pipe connections, bevel cut ends.
4. Grind cut ends and rough edges smooth.

J. Tapping of PVC:
1. General:
   a. Tapping of service lines 2 inches and less will be made by DW's Meter Shop.
   b. Other taps, including taps for pipeline appurtenances and larger service taps, will be made by the pre-qualified CONTRACTOR.
   c. No direct tapping of PVC pipe is permitted.
   d. Tapping under pressure is not permitted.

e. PVC pipe shall be 32°F or warmer.

2. Equipment:
   a. Tapping saddles and corporation stops shall be used for taps 2 inches and smaller.
   b. Tapping sleeves and valves shall be used for taps larger than 2 inches.
   c. Tapping equipment shall be approved by the Pipe Manufacturer and shall be in accordance with Uni-Bell's PVC Pressure Pipe Tapping Guide.
   d. Hand saws and hand drills are not allowed.
3. Procedures:
   a. Verify the tapping bit is long enough for pipe wall thickness.
   b. Verify bolts on tapping sleeves are installed in accordance with the Manufacturer's torque requirements. Do not over-tighten.
   c. Locate taps a minimum of 24 inches for 12 inch diameter or less, or 36 inches for large diameter, from both the back of the bell and the spigot insertion line.
   d. Keep taps at least 18 inches apart on the pipe.
   e. Tapping procedures shall be in accordance with Uni Bell's PVC Pressure Pipe Tapping Guide.
   f. Tapping shall be at a speed recommended by the Pipe Manufacturer.
   g. In weather below 40°F, verify the temperature of PVC pipe is at least 32°F before the tap is made. Adjust the tapping speed as recommended by the Manufacturer. Slower speeds may be required.
4. Quality control:
   a. The ENGINEER shall examine the tap coupon. The coupon shall have smooth, straight side walls, no fracturing of the pipe wall shall be apparent.
   b. If the coupon is not acceptable, determine the cause and adjust the tapping procedure.

K. Tracer Wire Installation:
1. General:
   a. Attach tracer wire to pipe with 2 inch wide PVC tape around the circumference of the pipe diameter, modify when inside casing pipe.
   b. Splice wire in accordance with the Manufacturer's recommendations.
   c. Leave 3 feet of slack wire in test site.
   d. In the presence of the ENGINEER, verify continuity of the tracer wire.
2. Locator wire test sites:
   a. Locate test sites a minimum of 1,000 feet from each other.
   b. Locate test site on either side of casing pipe.
   c. Locate test sites adjacent to line valves.

L. Marker Ball Installation:
1. Install marker balls after the pipe or the appurtenance is fully bedded.
2. If pipe is deeper than 5 feet, measured from ground line, backfill up to 3 feet 6 inches and install the marking ball by hand.
3. Install marker balls a maximum of 3 feet 6 inches deep, measured from ground line, and a minimum of 4 inches above the top of pipe.
4. Install the first marker ball at the property line valve, every 40 feet along the pipe alignment, at every horizontal bend, and at each valve.
5. Cover the marking ball by hand with 6 inches of bedding to keep it from moving (one method is to twist the marking ball into the bedding and then cover it up).
6. Backfill the trench after the marking ball is covered and secured.

M. Pressure Testing: As specified in SECTION 33 14 11.

END OF SECTION

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SECTION 33 05 31.26
POLYVINYL CHLORIDE PIPE SLEEVE

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for polyvinyl chloride pipe sleeves.
- B. Related Sections:
  1. SECTION 03 15 05 – ANCHORING TO CONCRETE

1.2 REFERENCES
- A. ASTM International (ASTM):
  1. D 1784 – Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
  2. D 1785 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
  3. D 2467 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
- B. NSF International/American National Standards Institute (NSF/ANSI):
  1. 61 – Drinking Water System Components – Health Effects

1.3 SUBMITTALS
- A. Product Data: The Manufacturer's literature on PVC pipe and fittings, plastic pipe cement, primers, applicators, and pipe supports.
- B. Locations as shown on the Drawings or supply Shop Drawings.
- C. Joining Procedures.

1.4 QUALITY ASSURANCE
- A. System piping components shall be the products of one Manufacturer.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS
- A. Solvent Cements:
  1. IPS Corporation
- B. Primers:
  1. IPS Corporation, P68, P70, or P75
- C. Vertical Pipe Supports for Exposed Pipe Conditions:
  1. Grinnell Power-Strut, PS 200 EH SST
  2. Pipe clamps: Grinnell Power-Strut, PS 1100SS Universal Pipe Clamp (SST)
  3. SST expansion anchors: As specified in SECTION 03 15 05
- D. Horizontal Pipe Supports:
  1. Grinnell Power-Strut PS 200 EH (SST)
  2. Pipe clamps: Grinnell Power-Strut, PS 1100SS Universal Pipe Clamp (SST)
  3. SST expansion anchors: As specified in SECTION 03 15 05

2.2 MATERIALS
- A. PVC Pipe and Fittings:
  1. PVC pipe and fittings shall be made from virgin compounds in accordance with ASTM D 1784.
  2. Pipe shall be manufactured from PVC Schedule 80, Type 1 (normal impact), Grade 1 (high chemical resistance), in accordance with ASTM D 1785.
  3. Pipe and fittings shall be listed by the PPI as having a hydrostatic design stress rating of 2,000 psi at 73°F. Materials from which pipe is fabricated shall be certified in accordance with NSF/ANSI 61.
  4. Permissible variations in length, diameter, weight, wall thickness, and straightness of pipe shall be in accordance with ASTM D 1785.
  5. Nominal pipe lengths shall be 20 feet, with shorter lengths as required.
  6. Fittings shall be Schedule 80 socket type in accordance with ASTM D 2467.
  7. Spigot ends of pipe shall have a factory-made 3/32 inch, 10 degree to 15 degree bevel.
- B. Solvent Cements: See Table 1.
- C. Pipe Supports for Exposed Pipe Conditions:
  1. Vertical pipe supports: Two SST wedge anchors shall be furnished for each section of channel framing.
  2. Horizontal pipe supports: In accordance with the dimensions shown on the Drawings.

Table 1 – PVC Solvent Cement

	Regular Body			Medium Body			Heavy Body	Extra Heavy Body
Pipe Size (Inches)	**700 2700**	**702**	**710**	**704 2704**	**705 2705**	**721 2721**	**711 2711**	**719 2719**
2	x	x	x	x	x	x	x	x
2 1/2	x	x	--	x	x	x	x	x
3	x	x	--	x	x	x	x	x
4	x	x	--	x	x	x	x	x
6	--	--	--	--	--	--	x	x

PART 3 EXECUTION

3.1 GENERAL

A. Furnish and install labor, materials, tools, and equipment.

B. Perform Work and services necessary for the installation of Schedule 80 PVC pipe in accordance with the Contract Documents.

C. Coordinate with the Work of other trades.

D. Although such Work is not specifically shown on the Drawings or specified, furnish and install supplementary or miscellaneous items, appurtenances, and devices incidental to or necessary for a sound, secure, and complete installation, such as fittings.

3.2 INSTALLATION

A. PVC Pipe and Fitting Joints:

1. For PVC pipe and fitting joints, assemble materials for the job including primer, cement, cleaner, and applicator for the size of pipe and fittings to be assembled.
2. Pipe shall be cut square using a mitre box saw or power saw. If pipe is not square, it shall be re-cut until square. Cuts on a diagonal are not acceptable.
3. Remove burrs or raised beads on the inside of pipe with an internal deburring tool. On the outside of pipe, remove with a file or external deburring tool.
4. With a clean, dry rag, remove dirt, grease, shavings, and moisture from the inside and the outside of the joints to be joined.
5. Check the joint for dry fit prior to cementing. For a proper joint, the fitting or the pipe joint shall go over the end of the joining pipe easily but become tight about 1/3 to 2/3 of the way. An acceptable joint shall fully bottom the pipe in the socket during assembly.
6. Use the properly sized applicator for the size of pipe or fittings being jointed. An acceptable applicator size shall be approximately 1/2 the pipe diameter.
7. Prime pipe to penetrate and soften joint surfaces:
   a. Apply the primer into the fitting socket, keeping the surface and applicator wet until the surface has softened. More applications may be needed for hard surfaces and cold weather conditions. Re-dip the applicator as required. When the surface is primed, remove puddles of primer from the socket.
   b. Thoroughly apply primer to the end of pipe to a point 1/2 inch beyond the depth of the socket.
   c. Apply a second application of primer to the fitting socket. Do not permit the primer to run down the inside of the fitting or pipe.
8. Using the proper size and type of applicator, apply the appropriate solvent cement while surfaces are wet.
9. Cementing:
   a. Stir or shake cement prior to using.
   b. Apply a full, even layer of cement to the pipe end equal to the depth of the fitting socket.
   c. Apply a medium layer of cement into the fitting socket; avoid puddling cement in the socket. On the bell end, do not coat beyond the socket depth or permit cement to run into the pipe beyond the bell.
   d. Apply a second full, even layer of cement on the pipe.

B. Joint Assembly:

1. Assemble the pipe and the fitting while cement is wet. If it is not completely wet, recoat the parts before assembly. If the cement coatings have hardened, cut pipe, dispose of the fitting, and start over. While inserting, twist 1/8 to 1/4 until reaching the pipe stop. Do not rotate after the pipe has reached the socket bottom.
2. Maintain pressure on the joint for a minimum of 30 seconds to eliminate movement or push-out.
3. After assembly, a joint shall have a ring or bead of cement completely around the juncture of the pipe and the fitting. If voids are present, the cement was not sufficiently applied; redo the joint.
4. Using a rag, remove excess cement from the pipe and the fitting including the ring or bead around the socket entrance.
5. Avoid disturbing or moving the joint.
6. Handle newly assembled joints carefully until the initial set has taken place, see Table 2. Follow estimated set and cure times before handling pipe or pressure testing the system, see Table 3.

Table 2 – Average Initial Set Schedule of IPS Solvent Cements (Minutes) (Hours)

Temperature °F Range	Pipe Sizes (Inches)				
	1/2 to 1 1/4	1 1/2 to 2	2 1/2 to 8	10 to 15	15+
60 to 100	2	5	30	2 hours	4 hours
40 to 60	5	10	2 hours	8 hours	16 hours
0 to 40	10	15	12 hours	1 day	2 days

Table 3 – Average Joint Cure Schedule for IPS Solvent Cements (Minutes) (Hours)

	Pipe Sizes (Inches)				
RH ≤ 60%	1/2 to 1 1/4	1 1/2 to 2	2 1/2 to 8	10 to 15	15+
°F range during cure	Up to 160 psi			Up to 100 psi	
60 to 100	15	30	1 1/2 hours	2 days	3 days
40 to 60	20	45	4 hours	4 days	5 days
0 to 40	30	60	3 days	8 days	14 days

END OF SECTION

SECTION 33 05 39.41
REINFORCED CONCRETE PIPE FOR SEWERS AND CULVERTS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for reinforced concrete pipe for sewers and culverts.

B. Related Sections:

1. SECTION 03 62 00 – NON-SHRINK GROUTING
2. SECTION 31 23 33 – TRENCH BACKFILL

1.2 REFERENCES

A. ASTM International (ASTM):

1. C 76 – Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe
2. C 361 – Standard Specification for Reinforced Concrete Low-Head Pressure Pipe
3. C 443 – Standard Specification for Joints for Concrete Pipe and Manholes, Using Rubber Gaskets
4. C 497 – Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile
5. C 1479 – Standard Practice for Installation of Precast Concrete Sewer, Storm Drain and Culvert Pipe Using Standard Installation

1.3 SUBMITTALS

A. Product Data: The Manufacturer's literature for gaskets and ancillary items.

B. Shop Drawings:

1. Dimensional drawings of pipe, joints, and fittings.
2. A pipe laying diagram corresponding to dimensional drawings.

C. Quality Control Submittals:

1. Provide the Manufacturer's design and calculations prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.
2. Provide a materials list for concrete and reinforcing steel.

D. Test reports, load and failure test reports, cylinder compression test results, and joint tests. Report full results showing compliance with ASTM C 497.

1.4 DELIVERY, STORAGE, AND HANDLING

A. Prevent damage to materials during loading, transportation, and unloading.

B. Handling:

1. Handle pipe in a manner to avoid chipping or spalling by contact with other objects.
2. Move pipe in a balanced manner, do not drag.
3. Do not roll pipe over rough ground.
4. Lift pipe horizontally and use padding on lifting devices that could damage the pipe.

C. Storage:

1. Provide support under the barrel.
2. Do not support pipe on bell.
3. Stockpile in a manner that the bell and spigot ends alternate between adjacent pipe sections.
4. Store rubber gaskets out of direct sunlight and away from oil, grease, and excessive heat.

PART 2 PRODUCTS

2.1 MATERIALS

A. Concrete Pipe: In accordance with ASTM C 76.

1. Design criteria:
   a. Pipe shall be designed in accordance with ASTM C 76, ASTM C 1479, and ASTM C 361 for the following conditions with the most critical condition controlling design:
      1) Hydrostatic head: Less than 13 psi.
      2) Dead load and live load: 10 feet of cover and HL-93.

B. Joint and Gasket:

1. Bell and spigot, or tongue and groove joint with rubber gasket in accordance with ASTM C 443. Only for internal pressures equal to or less than 13 psi.
2. O-ring gasket shall be in accordance with ASTM C 361 suitable for internal pressure specified.

2.2 APPROVED MANUFACTURERS

A. Forterra Pipe and Precast

B. Rinker Materials

PART 3 EXECUTION

3.1 INSTALLATION

A. General:

1. Install pipe to the elevation, grade, and locations shown on the Drawings.
2. Inspect pipe before installation; correct defects. Mark defective materials with black paint and promptly remove from the site.
3. Lay pipe beginning at the low point of the system, true to the grades and alignment shown on the Drawings, with unbroken continuity of invert.
   a. Place bells facing upstream.
   b. Lay pipe to the slope gradients shown on the Drawings with maximum variation from true slope of 1/8 inch in 10 feet.
   c. Install pipe and fittings in accordance with the Manufacturer's instructions, seal joints watertight.

4. Observe recommendations in accordance with ASTM C 1479 for installation, delivery, and storage of pipe material.

B. Cleaning Pipe:
1. Clear the pipe interior of dirt and other debris as Work progresses.
2. Place plugs in the ends of uncompleted pipe at the end of the day or whenever work stops for more than 1 hour.
3. Provide access to pipe joints for inspection to ensure gaskets are in place.

C. Installation:
1. Excavate pipe trench to the dimensions shown on the Drawings.
2. Place bedding and embedment material as shown on the Drawings and as specified in SECTION 31 23 33. Bedding conditions shall be in accordance with ASTM C 1479 with no less than Type 2 installation.
3. Excavate bell holes in the bedding so the pipe is resting on the barrel and not the bell.
4. Install reinforced concrete pipe into manholes and structures where needed, as shown on the Drawings. Grout penetrations where needed, as shown on the Drawings, and as specified in SECTION 03 62 00.
5. Clean and prepare the bell and spigot to receive the gasket.
6. Install the gasket on the spigot as recommended by the Manufacturer. Equalize the stretch if required.
7. Align the bell and spigot prior to joining the pipe.
8. Use a controlled pulling force to bring the pipe sections together. Do not use excavation equipment to push pipe sections together.
9. After pipe is joined, install remaining embedment and backfill as shown on the Drawings.
10. Joints shall be grouted around the full circumference from the inside after the joint has been pushed home.
11. Lifting lugs on pipe and manholes shall be grouted after installation.
12. Provide support under the barrel.
13. Curves:
    a. Observe Drawings for details regarding changes in direction. Where changes of direction by curvature is acceptable, perform curve by deflecting pipe at each joint with the permissible deflection allowance recommended by the Manufacturer.
    b. R=L/2(Tan 1/2 D/N), where R = radius of curvature, feet; L = average laid length of pipe sections measured along the centerline, feet; D = total deflection angle of curve, degrees, Check D/N from the Manufacturer.
    c. Employ the use of special radius (beveled or mitered) pipe where deflected straight pipe will not provide a short enough change in radius.
14. Fittings:
    a. In addition to straight pipe or radius pipe, furnish bends, tees, adapters, closure pieces, and other fittings shown on the Drawings or as required to complete the work. Design fittings to provide the same strength as the adjacent piping.
    b. Fittings shall be smooth or mitered providing mitered angles do not exceed 22 1/2 degrees, and fitting has a R/2 value greater than or equal to 1, where R = radius of bend, inches; d = diameter of pipe, inches.

3.2 QUALITY CONTROL

A. Interior Inspection:
1. Inspect piping to determine if line displacement or other damage has occurred.
2. Make inspections after the lines between manholes or manhole locations are installed and approximately 2 feet of backfill is in place. Re-inspect 5 days prior to the Substantial Completion date.
3. If the inspection indicates poor alignment, debris, displaced pipe, infiltration, or other defects, correct such defects and re-inspect.

B. Testing:
1. Manufacturer testing: In accordance with ASTM C 76 and ASTM C 361, if applicable.
2. Hydrostatic and gasket testing: In accordance with ASTM C 443 or ASTM C 361, depending on the joint requirement.

END OF SECTION

SECTION 33 05 61
PRECAST MANHOLES AND BELOW GRADE STRUCTURES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for precast manholes and below grade structures.

1.2 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):
   1. Standard Specifications for Highway Bridges

B. American Concrete Institute (ACI):
   1. 301 – Specifications for Structural Concrete
   2. 318 – Building Code Requirements for Structural Concrete
   3. 350 – Code Requirements for Environmental Engineering Concrete Structures

C. ASTM International (ASTM):
   1. A 48 – Standard Specification for Gray Iron Castings
   2. A 536 – Standard Specification for Ductile Iron Castings
   3. C 33 – Standard Specification for Concrete Aggregates
   4. C 88 – Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate or Magnesium Sulfate
   5. C 150 – Standard Specification for Portland Cement
   6. C 260 – Standard Specification for Air-Entraining Admixtures for Concrete
   7. C 478 – Standard Specification for Precast Reinforced Concrete Manhole Sections
   8. C 497 – Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile
   9. C 618 – Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete
   10. C 990 – Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants
   11. C 1260 – Standard Test Method for Potential Alkali Reactivity of Aggregates (Mortar-Bar Method)

1.3 SUBMITTALS

A. Concrete mix design, base sections, riser sections, eccentric and concentric conical top sections, flat slab tops, subdecks, manhole platforms, grade rings, manhole frame and cover, sectional plans and elevations showing dimensions and reinforcing steel placement, lifting inserts, and joint; include the Manufacturer's certification of compliance with this Section.

B. Structural design calculations and drawings that are prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

C. Pipe connections to the manholes.

D. Manhole steps including the method of installation and the Manufacturer's certification of compliance with the pull-out resistance test as specified in this Section.

E. The repair method for minor damage to precast concrete sections.

F. Concrete test cylinder reports from an independent testing laboratory certifying conformance with this Section.

G. Joint sealant data sheets.

1.4 QUALITY ASSURANCE

A. Materials shall be new and unused.

B. The quality of materials, manufacturing process, and finished sections are subject to inspection and approval by the OWNER and the ENGINEER. Inspections may be made at the place of manufacture or at the Work site following delivery.

C. The materials will be examined for compliance with ASTM specifications, the Contract Documents, and the approved Manufacturer's drawings. Additional inspection criteria may include appearance, dimensions, blisters, cracks, and soundness.

D. The OWNER or the ENGINEER will reject materials for failure to meet any specification requirement. Rejection may occur at the place of manufacture, at the Work site, or following installation. Mark and identify rejected materials and immediately remove them from the Work site; replace rejected materials at the CONTRACTOR's sole expense.

E. Repair minor damage to precast concrete sections by Manufacturer-approved methods if the repair is approved by the OWNER or the ENGINEER.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Precast Concrete Manholes and Structures:
   1. Copeland Precast, Inc.
   2. Forterra Precast
   3. Lindsay Precast
   4. Oldcastle Precast, Inc.
   5. Vaughn Concrete Products
   6. Rinker Materials
   7. Eagle Precast (manholes only)

B. Manhole Frame and Cover, CI and DI:
   1. D&L Foundry
   2. Deeter Foundry Inc.
   3. EJ
   4. Neenah Foundry Company

5. Sigma Corporation
6. Star Pipe Products

C. Manhole Steps or Rungs: M.A. Industries, No. PS2-PFS

D. Preformed Flexible Joint Sealant:
1. Hamilton-Kent, Kent Seal No. 2
2. Henry Company, Ram-Nek

E. Pipe Penetrations:
1. Waterplug
2. Embeco
3. Flexible sleeve: Press-Seal, PSX Gasket
4. Compression seal assembly: Link-Seal
5. Compression gasket: A-LOK

2.2 MATERIALS

A. General:
1. Reference to a Manufacturer's name and model or catalog number is for the purpose of establishing the standard of quality and the general configuration desired.
2. Like items of materials or equipment shall be the end products of one Manufacturer to provide a standardization of appearance, operation, maintenance, spare parts, and the Manufacturer's service.
3. Provide lifting lugs or holes in each precast section for proper handling.
4. Openings through the manhole riser shall be cored or cast-in with blockouts. Breakouts and doghouse openings are not allowed.
5. Finish: Standard grade finish in accordance with ACI 301.

B. Precast Concrete Manhole Sections:
1. Precast concrete riser sections, transition top sections, flat slab tops, and grade rings shall be in accordance with ASTM C 478 and the following requirements:
   a. Flat top covers shall be used where shown on the Drawings or where the manhole rim to the top of the pipe is 8 feet or less.
   b. Tongue and groove joints for riser sections, transition top sections, and flat slab tops.
   c. Adjustable grading rings; concrete; 3 inches, 4 inches, or 6 inches.
   d. Sections shall be cured by an approved method.
   e. Design criteria shall be as follows:
      1) Minimum AASHTO H-20 and HL-93 loading plus the earth load.
      2) Calculate the earth load with a unit weight of 130 pcf.
      3) Lateral soil pressure based on saturated soil producing 100 pcf/ft acting on an empty manhole.
      4) Internal fluid pressure based on a unit weight of 63 pcf with the manhole filled from invert to cover with no balancing external soil pressure.
      5) Dead load of manhole sections fully supported by the base and transition.
      6) Provide additional reinforcing steel in walls and slabs to transfer stresses and openings.
      7) The minimum clear distance between the edges of any two wall penetrations shall be 12 inches or 1/2 the diameter of the smaller penetration, whichever is greater.
   f. Mark the date of manufacture, the Manufacturer's name, and the Manufacture's trademark on the inside and outside of each precast section.
   g. Ship precast concrete sections after concrete has attained 3,000 psi compressive strength.

C. Precast Concrete Structures:
1. Precast reinforced concrete structures include vault structures with integral base and top slabs.
2. Notify the OWNER and the ENGINEER in writing at least 5 days prior to placing concrete during the manufacturing process. The OWNER or the ENGINEER may inspect the reinforcing steel placement prior to placing concrete.
3. Design criteria:
   a. Precast concrete:
      1) Minimum compressive strength: 5,000 psi.
      2) Concrete mix:
         a) Cement:
            (1) Type II portland cement in accordance with ASTM C 150.
            (2) Site specific soil may require cement that meets high sulfate resistance limits for Type V cement in accordance with Table 4 in ASTM C 150.
            (3) Type III cement in accordance with ASTM C 150 meeting sulfate resistance is allowed for high-early strength mixes.
         b) Fly ash: Class C or Class F fly ash in accordance with ASTM C 618.
         c) Aggregates:
            (1) Natural aggregates, free from deleterious coatings and substances in accordance with ASTM C 33.
            (2) Alkali reactivity of aggregates:
               (a) In accordance with ASTM C 33.
               (b) Tested for reactivity in accordance with ASTM C 1260.
               (c) A maximum of 0.10% expansion for any aggregate product used in portland cement concrete.

(d) Aggregate soundness testing in accordance with ASTM C 33 and ASTM C 88, using sodium sulfate solution.
(e) Aggregate grading and quality shall be in accordance with ASTM C 33.
(3) Admixtures:
(a) Furnish from one Manufacturer.
(b) Free of chlorides, calcium chloride, or other corrosive chemicals.

b. Manufactured products:
1) In accordance with ACI 301, ACI 318, and ACI 350, as applicable.
2) Analyze walls and slabs using accepted engineering principals.
3) When f_y exceeds 40,000 psi f_s shall not exceed 50% of f_y.
4) Design products to support their own weight, weight of soil at 130 pcf, and a live load equal to AASHTO HS-20 and AASHTO HL-93 applied to top slab.
5) Cast base slab and walls together to form a monolithic base section.
6) Design structure walls for a water pressure assuming groundwater level at ground surface; originate the pressure diagram at finished ground surface; include lateral pressure from vehicles in accordance with AASHTO Standard Specifications for Highway Bridges.
7) Consider discontinuities in the structure produced by openings and joints; provide additional reinforcing around openings; frame openings to carry full design loads to support walls.
8) Locate horizontal wall joints through the centerline of any wall openings or at a 12 inch minimum clear distance from the closest outside edge of wall openings.
9) Design the structure with a minimum number of joints; the maximum number of structure sections including the top slab shall be four.
10) Provide lifting hooks for the top slab.

2.3 ACCESSORIES

A. Manhole Frame and Cover:
1. Good quality, strong, tough, even grained CI, smooth, free from scale, lumps, blisters, sand holes, and defects of any kind that render the product unsuitable for the service for which it is intended; machined to a true surface; thoroughly cleaned castings and subject to hammer inspection.
2. The Manufacturer shall submit a written statement that the inspection and specified tests have been completed and the results comply with the requirements of these standards. A copy of the certification shall be provided to DW, if requested. The report shall include the material data that is traceable to the originating foundry, traceable test bars that match, the name of the Manufacturer, and the date of the pour.
3. Ring: CI in accordance with ASTM A 48, Class 35B or better.
4. Cover: DI, in accordance with ASTM A 536, Grade 60-40-18 or better.
5. Designed for AASHTO H-20 and AASHTO HL-93 loading.
6. Nominal size: 24 inches diameter; cover shall weigh approximately 165 lbs; frame (ring) shall weigh approximately 240 lbs.
7. The cover shall contain the OWNER's name, Denver Water, in 1 1/2 inch high lettering that is centered and recessed on the exposed face.
8. Stamped with the Manufacturer's name and model identification.
9. Recycled piping manhole lids:
a. Coated with fusion-bonded epoxy, 20 mils minimum, Pantone 2577U in color.
b. Lids shall be labeled Recycled Water.

B. Manhole Steps or Rungs:
1. Comprised of 1/2 inch grade 60 steel reinforcement rod encased in PP co-polymer plastic with a tread width of 14 inches.
2. Furnish horizontal and vertical load test results in accordance with ASTM C 478 and ASTM C 497.

PART 3 EXECUTION

3.1 ERECTION

A. Jointing Precast Manhole Sections and Structures:
1. Seal tongue and groove joints with preformed flexible joint sealant.
2. Completed joint shall withstand 15 psi internal water pressure without leakage or the displacement of sealant.
3. In accordance with ASTM C 990.
4. Joint sealant:
a. Packaged in extruded preformed rope shapes of proper size to completely fill the joint when completely compressed.
b. Protected by a suitable, renewable two-piece wrapper that may be removed as the material is applied to the joint without disturbing the other wrapper.

3.2 INSTALLATION

A. Pipe penetrations shown on the Drawings shall be made through the manhole or the vault sections in the following manner:
1. Modular mechanical seal: Integrally cast the sleeve in the precast manhole or the vault section or install the sleeve in a form or cored opening. Install pipe through the sleeve. Wrap the assembly around the pipe and connect the first and the last links. Slide the assembly into the space between the pipe and the sleeve. Tighten bolts to expand the links of the assembly to create a gas and water tight seal. The seal shall be rated at 20 psig hydrostatic pressure.

2. Grout in place: The precast manhole or the vault section shall have a formed, tapered circular opening larger than the outside diameter of the pipe. Plastic pipe shall have a waterstop gasket secured to the pipe with a SST clamp. Grout shall be non-shrink and waterproof.
3. Flexible sleeve: Integrally cast the sleeve in the precast manhole or the vault section or install the sleeve in a form or cored opening. Fasten pipe in the sleeve with SST clamps. Coat SST clamps with bituminous material to protect from corrosion. The flexible sleeve shall be tested and approved by the PVC Pipe Manufacturer.
4. Compression gasket: Integrally cast the compression gasket in the precast manhole or the vault section. Insert pipe into the compression gasket. Compression gaskets shall be tested and approved by the PVC Pipe Manufacturer.

B. Manhole and Structure:
1. Transport and handle precast concrete sections in accordance with the Manufacturer’s instructions. Use lifting devices where provided in the precast sections. Follow the Manufacturer’s instructions for lifting procedures when lifting devices are not provided.
2. Assemble and place buried precast concrete structures in properly excavated and compacted soil foundations. Set precast concrete structures to grade and oriented to provide the required dimensions and clearances from pipes and other structures.
3. Prevent flotation, with ground water level at finished ground surface, by dead weight of the structure and soil load above the structure; do not consider the skin friction, the soil friction, or the weight of equipment in the structure. Protect Work from flooding.
4. Place the manhole base on a bed of 12 inches of No. 57/67 aggregate. Set the manhole base grade so that a maximum grade adjustment of 12 inches is required to bring the manhole frame and cover to the final grade.
5. Use precast concrete grade rings and non-shrink mortar to adjust the manhole frame and the cover to the final grade.
6. Set precast concrete barrel sections and structures plumb within 1/4 inches. Seal the joints of precast barrel sections with preformed flexible joint sealant in a sufficient quantity to fill 75% of the joint cavity. Fill the inside joint with non-shrink grout and finish flush with adjoining surfaces. Caulk the inside of any leaking barrel section joint with non-shrink grout to the satisfaction of the ENGINEER.
7. Where required, core holes in precast sections to accommodate pipes prior to setting manhole sections in place and prevent loosening of the joints.
8. Plug holes in the concrete barrel sections that are required for handling with a non-shrink grout or non-shrink grout in combination with concrete plugs; finish flush on the inside.
9. Allow joints to set for 12 hours before backfilling unless a shorter period is approved by the ENGINEER.

C. Manhole Step:
1. Preform holes for manhole steps during casting of the riser and cone sections using tapered form pins specifically made for preforming manhole rungs.
2. Drive manhole steps into preformed holes after concrete has developed a compressive strength of 3,000 psi.
3. Alternatively, cast manhole steps into riser and cone sections when concrete is placed.
4. Drilling holes for manhole steps may be used to accommodate field conditions when approved by the ENGINEER. Drill holes shall be of the diameter, spacing, and depth required by the Manhole Step Manufacturer.
5. Install steps at 12 inches o.c. vertically, not more than 1/2 inch out of plumb. The top step shall be 18 inches to 24 inches below the manhole cover.

D. Manhole Frame and Cover:
1. Utilize precast concrete extension collars to ensure the frame and the cover are set to the finished grade. Concrete extension collars shall make up the riser section providing the riser section does not exceed 12 inches vertically. Set the manhole frame and the cover to final grade prior to placement of permanent paving or final backfill.
2. Extension collars shall be securely attached to the manhole riser section with a non-shrink grout bed and plastic joint sealing compound in the pavement or with a concrete collar in unpaved areas.

E. Manhole Pipe Connections: Connect pipe to manholes and structures with the connectors shown on the Drawings. Close or seal pipes for future connections with a gasketed watertight plug.

3.3 QUALITY CONTROL

A. Manhole and Structure Testing: The ENGINEER will visually inspect manholes and structures for potential leaks before backfilling is allowed. Seal joints to the satisfaction of the ENGINEER.

3.4 CLEANING

A. Clean new manholes of silt, debris, and foreign matter of any kind prior to final inspections.

END OF SECTION

SECTION 33 12 33
PRESSURE REGULATING AND PRESSURE RELIEF VALVES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for pressure regulating and pressure relief valves.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):

1. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250

B. American Water Works Association (AWWA):

1. C 207 – Steel Pipe Flanges for Waterworks Service, Sizes 4 In. Through 144 In. (100 mm through 3,600 mm)
2. C 530 – Pilot Operated Control Valves
3. C 550 – Protective Interior Coatings for Valves and Hydrants

C. ASTM International (ASTM):

1. A 536 – Standard Specification for Ductile Iron Castings
2. B 62 – Specification for Composition Bronze or Ounce Metal Castings

D. NSF International/American Nation Standards Institute (NSF/ANSI):

1. 61 – Drinking Water System Components – Health Effects
2. 372 – Drinking Water System Components – Lead Content

E. The Society for Protective Coatings/NACE International (SSPC/NACE):

1. SSPC SP 10/NACE No. 2 – Near-White Blast Cleaning

1.3 SUBMITTALS

A. Shop Drawings:

1. Make, model, and weight of valve.
2. Complete catalog information, descriptive literature, specifications, dimensions, and Bill of Material with identification of materials of construction for valves and actuator assemblies.
3. Detailed mechanical drawings for the hydraulic control circuit showing the equipment dimensions, size, and locations of connections for equipment.
4. Performance data curves showing valve position versus head loss over entire design flow range for valve.
5. Factory finish system.

B. Quality Assurance Submittals:

1. Certification or compliance letter showing materials and coatings used in manufacturing the valve are in accordance with NSF/ANSI 61 and NSF/ANSI 372.
2. Factory functional and performance test reports: Include verification the valve is rated for the operation points defined herein for continuous service.
3. Special shipping, storage and protection, and handling instructions.
4. Manufacturer's installation instructions.
5. Manufacturer's certificate of proper installation (after installation).
6. Suggested spare parts list to maintain the equipment in service for a period of 5 years. Include a list of special tools required for checking, testing, parts replacement, and maintenance with current price information.
7. List of special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.

C. Installation O&M Requirements:

1. The Manufacturer shall submit installation O&M instructions in a manual presenting full details for installation and maintenance of equipment furnished in accordance with the Contract Documents:
   a. Provide printed, tabbed, and bound instructions covering details pertaining to installation and maintenance of equipment and data. Identify parts with a number and description.
   b. Provide a complete copy of the manual in Adobe PDF.
   c. These manuals shall include but are not limited to:
      1) Standard valve operational manuals normally furnished by the Manufacturer.
      2) Valve shop and repair manuals equivalent to the manuals used by factory-authorized shop repair personnel.
      3) Details of parts and subassemblies available as repair parts.
2. As specified in SECTION 01 78 23.

1.4 WARRANTY

A. Provide a full, unconditional 2 year warranty covering the valve and related components, and performance guarantees for each component. The warranty period shall commence after the equipment is fully tested, placed into service, tested in service, and accepted by the Manufacturer and the OWNER. Provide labor, equipment, and materials associated with performing the warranty work including any disassembly/reassembly work, loading/unloading of equipment, and transportation to and from the repair facility to repair or replace the valves.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURES

A. Pressure Regulating Valves (Type V531):

1. Bermad, Model 720-PD
2. Cla-Val, Model 90-01 KO
3. Singer, Model 106-PR-AC

B. Pressure Relief Valves (Type V532):
   1. Bermad, Model 73Q
   2. Cla Val, 50 01 KO
   3. Singer, Model 106 RPS AC
C. Dual Pilot System Two-Way, Two-Position Electric Solenoid Valve:
   1. ASCO Next Generation, 120 VAC, model number 8210P087
D. Valve Position Indication:
   1. Fraba Posital Model MCD-AC005-0012-S10G-PAM325.
E. Epoxy Coating:
   1. AkzoNobel, Amercoat Resicoat R4-ES

2.2 MATERIALS

A. The Valve Manufacturer shall be fully responsible for the components of the valve assembly.
B. The Valve Manufacturer be actively in production and successful installations not less than 5 years.
C. General Design Criteria:
   1. Pressure regulating valves (Type V531) or pressure relief valves (Type V532) shall be hydraulically operated, pilot controlled, diaphragm activated globe valves. Valves shall include a SST seat ring, stem, spring, and internal and external fasteners and washers. A SST dry position indicator rod shall be furnished as an integral part of the valve to show the valve position extending from the valve cover. Bushings and the stem nut shall be bronze to prevent galling. Externally mounted SST plumbing, strainers, and drain cocks shall be provided to maintain or relieve pressure. The valve shall be designed to provide an access opening in the valve body for removing the internal parts without removing the main valve body from the line:
      a. Pressure regulating valves (Type V531) shall have the regulating port on the pilot system sensing downstream pressure and control flow from the top chamber on the main valve.
      b. Pressure relief valves (Type V532) shall have the sensing port on the pilot valve relief upstream pressure and control flow from the top chamber on the main valve.
   2. Except as modified or supplemented herein, valves shall be designed and manufactured in accordance with AWWA C530.
D. Certification: Components in contact with treated water shall be in accordance with NSF/ANSI 61 and NSF/ANSI 372.
E. Valve Construction:
   1. Valve:
      a. The pressure relief valve reduces an upstream high pressure to a factory-adjusted lower downstream pressure for varying rates of flow without causing shock, water hammer, or cavitation on the system.
      b. Location: Exposed, below grade.
      c. Media: Chlorine treated potable water.
   2. Valve body:
      a. DI in accordance with ASTM A 536, grade 65-45-12. Bronze castings, fittings, and bushings shall be in accordance with ASTM B 62.
      b. The valve body shall have flanged ends with bolt hole patterns in accordance with ASME B16.1, Class 125. Flanges shall be machined to a flat surface with a serrated finish in accordance with AWWA C207. The alignment of the flange bolt holes shall conform to a two-hole centered alignment, straddling the vertical centerline. Actual lay length of the valve shall be within ±1/16 inch of the Manufacturer's stated length.
   3. Main valve diaphragm: Nylon reinforced EPDM material and rolling type.
   4. Anti-cavitation trim: Valves may be utilized in conditions where cavitation will likely occur. Pressure relief valves shall be equipped with anti-cavitation trim to operate properly under the flows and pressure conditions shown herein. Each anti-cavitation valve shall be optimized to the actual parameters of the application and will be warrantied to perform correctly under the conditions listed herein. AISI 316 SST seat, anti-cavitation trim, and valve stem.

2.3 OPERATION

A. Design Criteria: As shown on the Drawings.

2.4 ACCESSORIES

A. Pilot Systems:
   1. Single or dual type as shown on the Drawings.
   2. Single pilot valve:
      a. External sensing port for controlling operation of the main valve shall be a single-seated, diaphragm operated, spring-loaded, and SST body material.
      b. Pilot spring adjustable range: 20 to 200 psi.
      c. Attached to the main valve with 3/8 inch or larger SST piping and isolation valves arranged for easy access in making adjustments and for removal from the main valve while the main valve is under pressure.
      d. The sensing port senses downstream pressure and controls flow from the top chamber on the main valve.
      e. Threaded nipple extending inside the valve body covering the port threads at the port connections.
   3. Dual type pilot valves (two):
      a. External sensing port for controlling operation of the main valve shall be single-seated, diaphragm operated, spring-loaded, and SST body material.
      b. Pilot spring adjustable range: 20 to 200 psi.
      c. Attached to the main valve with 3/8 inch or larger SST piping and isolation valves arranged for easy access in making adjustments and for removal from the main valve while the main valve is under pressure.

d. High and low pilot valves are in parallel with an electric solenoid valve upstream of the high SP pilot valve to allow cycling of the main valve between the low and high pilot SPs.
e. Two-way, two-position electric solenoid valve:
1) SST construction, normally closed, spring offset, manual overrides which mechanically lock into desired spool position, and suitable for water service and sized as required.
2) Mounted upstream of HI pilot valve.
3) Operation: When de-energized the low pilot is active. When energized the high pilot is active and the low pilot is inactive.

B. Valve Position Indication:
1. For pressure relief valves, provide stem extension kits for transmission of the valve position to the encoder through the encoder mounting bracket:
a. Furnish a fabricated mounting bracket for absolute rotary encoder to be mounted to the pressure relief valve head cover as defined and as shown on the Drawings.
b. The absolute rotary encoder with analog output shall be heavy-duty type, SST housing related NEMA Type 6, IP68 or better.
1) Operating temperatures from -40 to 100°C.
2) 4 mA to 20 mA output with short-circuit protection.
3) 12-bit output resolution.
4) Programmable measurement range.
5) Calibrated accuracy of +/-0.35 degrees.

C. Needle Valve:
1. SST and included with the main valve to control the speed of the disc travel in the closing direction of valve operation.
2. Mounted upstream of pilot valves and downstream of strainer.

D. High Efficiency Strainer:
1. Located on external piping to provide protection against fouling or damaging the control system from foreign particles upstream of valves.
2. Increased capacity to hold debris.
3. 40 mesh, SST screen.

E. Isolation Valves:
1. Full port, SST gate or ball valves required for isolation and manual operation of the main valve.
2. Provide a sufficient number of valves to perform isolation and manual operation function with the mainline valve under operating conditions.

F. Pressure Gauge:
1. Provide SST analog pressure gauge with 0 to 200 psi range, 1/4-inch MNPT, and bourbon tube.
2. Provide a SST bleed valve on SST tee and SST isolation gauge cock or ball valve.
3. Pressure gauge assembly and bleed shall be installed and used to locally set pilot SPs without having to move the main valve.
4. Assemblies shall be provided for pressure relief valves.

G. Valve Nameplates for Main and Pilot Valves:
1. Embossed 16 gauge Type 316 SST securely mounted on the upper valve cover of the main valve.
2. Nameplates on pilot valves shall be securely strapped to the inlet pipe of the pilot valve with metal wire.
3. Plate shall bear 1/4 inch high embossed block type lettering and include the following:
a. Manufacturer’s name and date manufactured.
b. Model number.
c. Serial number.
d. Size.
e. Maximum/minimum flow capacity, gpm.
f. Working pressure, psi.
g. Pilots valves only: Pressure setting, psi, and spring range.

2.5 FINISHES

A. Factory Finishing:
1. Interior and exterior ferrous surfaces of the valve body, except seating surfaces, bearing surfaces, and machined surfaces, shall be prepared for coating by sandblasting to a near white metal finish in accordance with SSPC SP 10/NACE No. 2. These surfaces shall then be coated with a fusion-bonded epoxy in two or more uniform coats to a minimum DFT of 12 mils. Epoxy coating shall be in accordance with AWWA C550.
2. Flange faces shall be shop-coated with a rust-preventive compound.

PART 3 EXECUTION

3.1 INSTALLATION

A. The Manufacturer of the line equipment shall provide the following:
1. Factory testing and certification of test results.
2. Certification or letter of compliance as specified in NSF/ANSI 61 and NSF/ANSI 372 that is sent to DW.
3. O&M manuals, including installation and storage instructions.
4. Certification of proper installation.
5. List of special tools, materials, and supplies furnished with equipment for use prior to and during startup and for future maintenance.
6. Functional testing.

7. Performance testing.

3.2 QUALITY CONTROL

A. Factory Functional Testing:
   1. Performance test shall be conducted on the fully assembled valve.
   2. Tests shall be performed with water.

B. Performance Testing:
   1. Perform as installed at OWNER's facilities.
   2. Perform tests as required and agreed to by the ENGINEER to prove conformance to these Specifications. Correct any deficiencies and retest as required.
   3. The ENGINEER may decide to send a representative to the factory to inspect the valves prior to and during testing.

C. Manufacturer's Services:
   1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
      a. Installation assistance and field alignment work: 1.
      b. Startup of the equipment: 1.

END OF SECTION

SECTION 33 14 11
WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for water utility transmission and distribution piping – general.

B. Related Sections:
   1. SECTION 09 90 00 – PAINTING AND COATING
   2. SECTION 09 97 13.02 – LIQUID EPOXY LININGS AND COATINGS
   3. SECTION 09 97 13.04 – WAX TAPE COATINGS
   4. SECTION 13 47 13 – COMMON WORK RESULTS FOR CATHODIC PROTECTION
   5. SECTION 13 47 15 – GALVANIC CATHODIC PROTECTION
   6. SECTION 13 47 16 – ISOLATION AND BONDING FOR CATHODIC PROTECTION

1.2 REFERENCES

A. American Water Works Association (AWWA):
   1. C111 – Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
   2. C200 – Steel Water Pipe, 6 In. (150 mm) and Larger
   3. C210 – Liquid Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines
   4. C213 – Fusion-Bonded Epoxy Coatings and Linings for Steel Water Pipe and Fittings
   5. C219 – Bolted, Sleeve-Type Couplings for Plain-End Pipe
   6. C227 – Bolted, Split-Sleeve Restrained and Nonrestrained Couplings for Plain-End Pipe
   7. C550 – Protective Interior Coatings for Valves and Hydrants
   8. C651 – Disinfecting Water Mains

B. ASTM International (ASTM):
   1. A 193 – Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
   2. A 194 – Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
   3. D 2000 – Standard Classification System for Rubber Products in Automotive Applications
   4. F 436 – Standard Specification for Hardened Steel Washers Inch and Metric Dimensions

C. City and County of Denver Wastewater Management Division:
   1. Standard Detail S350

D. Denver Water (DW):
   1. Engineering Standards, Chapter 11 – Recycled System

E. NSF International/American National Standards Institute (NSF/ANSI):
   1. 60 – Water Treatment Chemicals – Health Effects

1.3 SUBMITTALS

A. Shop Drawings:
   1. General:
      a. Pipe design information, including calculations and Drawings.
      b. Check, correct, and sign Shop Drawings and data prior to submission. Unchecked Submittals will be rejected.
      c. Indicate the Project name and the Contract number.
      d. Pipe segment mark numbers.
      e. Laying schedule corresponding to mark number.
   2. Certified drawings of valves and appurtenances: Provide certified dimensional drawings of valves, fittings, and appurtenances.

1.4 QUALITY ASSURANCE

A. Pipe Design Criteria:
   1. The pipe, fittings, and specials shall be designed and manufactured to meet the strength requirements given and shall conform when laid with line and grades including outlets, connections, test bulkheads, and appurtenances as shown on the Drawings.
   2. Working pressure: 150 psi.
   3. Waterhammer pressure: 70 psi.
   4. Design cover: 10 feet or as shown on the Drawings, if greater.
   5. Design live load: AASHTO HS-20 when cover is less than 10 feet, plus impact factor of 1.5 when less than 3 feet.
   6. Weight of the earth: 120 pcf.

B. Do not manufacture pipe until required Shop Drawings and design calculations have been approved by the ENGINEER. No changes are permitted from the initial approved design unless unforeseen field conditions arise that make such changes necessary as determined by the ENGINEER.

C. Certifications:
   1. Provide certified test reports covering each material utilized in the Work sufficient to determine conformance with standard specifications for the particular pipe alternative including:
      a. Mill certification of analyses and tests of steel.
      b. Certified hydrostatic test reports.
      c. Certification of compliance of materials with applicable AWWA standards, ASTM Specifications, and DW’s Engineering Standards.

d. Certification of application of linings and coatings.
e. Certification of rubber gaskets.
2. Expenses incurred in making samples for certification of tests shall be borne by the Manufacturer.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Handling:
1. Pipes, fittings, and appurtenances shall be carefully handled and protected against damage to the lining and coating, impact shocks, and free fall as specified in this Section. Pipe handling equipment shall be approved by the ENGINEER.
2. Inspect each pipe and fitting for damage. Pipe damaged while in the custody of the CONTRACTOR shall be repaired or replaced, as determined by the ENGINEER, by the CONTRACTOR at no additional expense to the OWNER. No pipe shall be installed where the coating or lining shows cracks that may be harmful as determined by the ENGINEER.
3. Joint gaskets shall be stored in a cool location out of direct sunlight.
4. Support stockpiled pipe on sand bags placed under the pipe. Provide sand bags of sufficient size to prevent the pipe from contacting the ground or any obstruction and allow for the proper use of slings. Securely cover pipe ends to prevent the entry of animals, water, dirt, mud, or any undesirable substance and prevent the drying out of the interior of the pipe.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. BSTC:
1. Baker
2. Dresser
3. Smith-Blair
4. Romac
5. The Ford Meter Box Company
6. JCM Industries

B. BSSTC:
1. Victaulic

C. Coatings:
1. Protecto Wrap Company, JS160H
2. Rust preventive compound:
   a. Houghton International, Rust Veto 344

D. Dismantling Joints:
1. JCM Industries, Model 309 with tie-rods
2. Romac Industries, Style DJ 400
3. Smith Blair, Model 975

E. Gaskets:
1. Durlon, Model 8600
2. Garlock 3200
3. Klingersil, Model C-4324 and C-6400
4. Leader, Model 940

F. CI Valve Boxes:
1. Bingham & Taylor, CCO5 Series, CUL5 Series, and GRE5 Series
2. EJ, 8560 Series and 6800 Series Drop Lid
3. Sigma Corporation, VB630 Series
4. Star Pipe Products, VB-0006 Series

2.2 ACCESSORIES

A. Standard Pipe Joints:
1. Standard pipe joints shall be suitable for at least 250 psi water service and, regardless of type, designed to be self-centering.
2. Bells and spigots shall have a smooth, close sliding fit at the self-centering surface. The joint shall be capable of symmetrical or asymmetrical joint closure and shall remain watertight under all conditions of water service.
3. Joint assemblies shall be formed and accurately manufactured so that when the pipes are drawn together in the trench, they form a continuous watertight conduit with a smooth and uniform interior surface and provide for a slight movement of any pipe in the pipeline due to contraction, settlement, or lateral displacement.
4. Maximum tolerances permitted in the construction of the joint shall be that stated in the Pipe Manufacturer's design as approved; however, in no case shall the tolerances exceed those required in AWWA C111 and AWWA C200.
5. If the CONTRACTOR proposes to use a joint which has not been approved by the ENGINEER on a previous project, provide a detail drawing of joints to be used, for approval, 1 week prior to the submittal of the Bid or Proposal. The detail drawing shall show pertinent details, dimensions, and tolerances. Joints may be furnished only by a Manufacturer who has furnished pipe with joints of similar design for comparable working pressure that have been in successful service for a period of at least 5 years. Provide a list of installations on which a similar joint has been successfully used showing pipe diameter, wall thickness, and working pressure or field test pressure.
6. Furnish joint materials, gaskets, and lubricants.

B. Flanges:
   1. Flange details shall be submitted with the Shop Drawings.
   2. Bolt holes in flanges shall straddle field vertical centerline.
   3. Insulated flanges shall have bolt holes 1/4 inch diameter greater than the bolt diameter.
   4. Shop coat machined faces of flanges with a rust-preventive compound.
C. Gaskets for Flanges:
   1. 1/8-inch ring type, compressed non-asbestos sheet packing, one-piece.
   2. Insulated gasket information: As specified in SECTION 13 47 16.
D. Flange Bolts and Washers:
   1. All-threaded studs shall be in accordance with ASTM A 193, Grade B7 with heavy hex nuts in accordance with ASTM A 194, Grade 2H.
   2. Studs and bolts shall extend through the nut a minimum of 1/4 inch.
   3. Hardened steel washers shall be in accordance with ASTM F 436.
E. BSTCs:
   1. Plain ends for use with couplings shall be prepared in accordance with AWWA C219 for a distance of 12 inches from the ends of the pipe, with outside diameter not more than 1/64 inch smaller than the nominal outside diameter of the pipe.
   2. The center sleeve shall be made of steel and fabricated and tested by cold expansion in accordance with AWWA C219 to meet minimum design pressure of 150 psi. The weld of the center ring shall be air tested for porosity. End rings and the center sleeve shall be coated in accordance with AWWA C210 or AWWA C213 with a minimum DFT of 12 mils.
   3. End rings shall be contoured milled steel and fabricated and tested by cold expansion in accordance with AWWA C219.
   4. Gaskets shall be rubber compound material that will not deteriorate from age or exposure to air under normal storage or use conditions and shall be immune to attack by impurities normally found in water. Gaskets shall be in accordance with AWWA C219 and ASTM D 2000, except the durometer hardness shall be 74±5, the minimum elongation shall be 175%, and the tensile strength shall be 1,000 psi.
   5. Bolts and heavy hex nuts:
      a. In accordance with AWWA C219.
      b. Fabricated from high strength low allow steel known in the industry as Cor-Ten, Usalloy, or Durabolt.
      c. The Manufacturer shall supply information as to the torque to which the bolts shall be tightened.
   6. Where insulating couplings are required, both ends of the coupling shall have a wedge-shaped gasket which assembles over an insulating compound rubber sleeve to obtain insulation of coupling metal parts from the pipe.
F. BSSTC (Non-Restrained):
   1. Ends of pipe, including a distance from the end of the pipe to no less than the overall width of the coupling, shall be prepared in accordance with AWWA C227.
   2. The body shall be fabricated from steel in accordance with AWWA C227 to meet a minimum design pressure of 150 psi. The interior and exterior of the body shall be coated in accordance with AWWA C210 or AWWA C213 with a minimum DFT of 12 mils.
   3. Closure and sealing mechanisms shall be fabricated in accordance with AWWA C227.
   4. Gasket composition and physical requirements shall be in accordance with AWWA C227 and ASTM D 2000.
   5. Studs, nuts, and washers shall be in accordance with AWWA C227.
   6. BSSTC shall not be used when electrical isolation is required.
G. Specials and Fittings for Access Manholes:
   1. Access manholes with covers shall be 20 inches in diameter for pipelines 42 inches in diameter and smaller and 24 inches in diameter for pipelines greater than 42 inches in diameter.
   2. Access manholes, in addition to those shown on the Drawings that are needed by the CONTRACTOR to complete the installation of the pipe including the lining of joints, shall be provided at the CONTRACTOR's expense.
   3. Additional manholes needed by the CONTRACTOR shall be provided with precast manholes for future access to the pipe.
H. Protection of Pipe Lining: The Manufacturer shall provide PE material or other suitable bulkheads on the ends of the pipe and on special openings to keep the pipe clean and prevent the drying out of the lining. Bulkheads shall be substantial enough to remain intact during shipping and until the pipe is installed.
I. Joint Restraint:
   1. Restrained joints shall be provided for the lengths shown on the Drawings for horizontal bends, line valves, and bulkheads.
   2. Joints that fall within 10 feet of vertical angle points that have a deflection greater than 6 degrees shall be restrained.
J. Underground Utility Warning Tape for Recycled Pipe: In accordance with DW Engineering Standards Chapter 11.
K. Dismantling Joint:
   1. Size and location as shown on the Drawings.
   2. Restrained flange to flange using tie-rods that are all-thread studs in accordance with ASTM A 193, Grade B7. Restraining gland systems are not acceptable.
   3. Pressure requirements equivalent or greater than pipe with a minimum design working pressure of 150 psi.
   4. Carbon steel for the outer body and inner body shall be in accordance with AWWA C200.
   5. Carbon steel for the flanges shall be in accordance with AWWA C207

6. Carbon steel for the end ring shall be in accordance with AWWA C219.
7. DI for the outer body, inner body, flanges, and end ring shall be in accordance with ASTM A 563, Grade 65-45-12.
8. Rubber gasket shall be in accordance with AWWA C219.
9. Flanges:
   a. Class shall match the mating pipe.
   b. Hollow-back or segmented flanges are not acceptable.
   c. Machined to a flat face with a serrated finish in accordance with AWWA C207.
10. Minimum assembly tolerance: 2 inches.
11. Ferrous surfaces, except machined or bearing surfaces, shall be prepared in accordance with SSPC SP10. These surfaces shall then be coated with liquid epoxy in two or more uniform coats or with fusion-bonded epoxy to a minimum DFT of 10 mils in accordance with AWWA C550. Machined flange faces shall be shop-coated with a rust-preventive compound; they shall not be painted or coated with the same coating as the body.

L. CI Valve Boxes:
1. Three-piece adjustable screw type with a 16-inch top section, 18-inch extension, 24-inch stem, and 30-inch bottom and base.
2. Manufactured of gray CI in accordance with ATM A 48, Class 35B. The use of an aluminum alloy as a casting material is not acceptable.
3. Components shall be deburred and machined so that final dimensions are within ±0.0625 inch of the specified dimensions.
4. Components shall be provided with the Manufacturer’s standard rust-preventive coating.

PART 3 EXECUTION

3.1 PREPARATION

A. Remove or smooth out any burrs, gouges, weld splatter, or other small defects prior to laying pipe and fittings.

B. Before the placement of pipe in the trench, each pipe or fitting shall be thoroughly cleaned, with special attention to the joint area. The openings of pipes and fittings in the trench shall be closed during any interruption to the Work.

3.2 INSTALLATION

A. Existing Pipe:
1. Anticipate the need to provide materials and Work effort to fit new pipe to existing pipe.
2. Information provided on existing pipe, including inside and outside diameters, are design dimensions based on available data and may not represent exact diameters once pipe is exposed.
3. Existing pipe may be found to be out of round once excavated.

B. Pipe Laying:
1. General:
   a. Pipe shall be laid directly on specified imported bedding material. Blocking of the pipe is not permitted.
   b. Each section of pipe shall be laid in the order and position shown on the laying schedule.
   c. Bell holes shall be formed at the ends of the pipe to prevent point loading at the bells or couplings. Excavations shall be made as needed to facilitate the removal of slings after the pipe is laid.
2. Pipe cleaning: Keep the pipe interior free of debris.
3. Frozen foundation: No pipe shall be installed upon frozen material or when the ENGINEER determines there is a danger of the material freezing. Do not lay pipe unless the trench will be backfilled before freezing occurs.
4. Tolerance: Pipe shall be laid to the set line and grade within approximately ±1 inch. On grades of zero slope, the intent is to lay to grade.
5. Raising or lowering pipe: Where necessary to raise or lower pipe, the ENGINEER may change the alignment or the grades by the deflection of joints, by the use of bevel adapters, or by the use of additional fittings. The deflection of the joint shall not exceed the maximum deflection recommended by the Pipe Manufacturer. No joint shall be deflected any amount which, in the opinion of the ENGINEER, will be detrimental to its strength and water tightness.
6. Laying on grades: Pipes shall generally be laid uphill on grades exceeding 10%. Pipe which is laid on a downhill grade shall be blocked and held in place until sufficient support is furnished by the following pipe to prevent movement.
7. Pipe protection:
   a. When pipe installation is not in progress, protect the ends of the installed pipeline and special openings with temporary, watertight fittings or appropriately sized pneumatic plugs designed for the type of joint and installed with Manufacturer guidelines.
   b. Clean temporary fittings and pneumatic plugs prior to installation.
   c. Protect installed capped and plugged pipe against buoyant forces by pipe bedding, backfill, or other temporary means.

C. Pipeline Contaminant Prevention:
1. Whenever the pipe is left unattended, install temporary plugs (bulkheads or pneumatic) at openings. Temporary plugs shall be watertight, cleaned and disinfected, installed properly, and designed in a way that prevents human tampering or children, animals, and environmental contamination from entering the pipe.
2. Properly install approved bulkheads or pneumatic plugs on pipe openings before storm events and before leaving the work site unattended.
   a. Proper installation includes tightening MJ bolts or inflating pneumatic plugs in accordance with the Manufacturer’s specifications.
3. Debris shall be removed and the pipe interior cleaned prior to installing the bulkheads or pneumatic plugs.

4. Bulkheads or pneumatic plugs shall be thoroughly cleaned with a detergent and disinfected with 100 mg/l NSF/ANSI 60 certified sodium hypochlorite solution (chlorine) using a swab or spray application method before installation.
    a. Plugs shall be kept free from contamination during storage and cannot be used in recycled applications (e.g., sanitary sewer, storm water systems).
    b. Do not clean plugs with solvents or other aggressive agents; these may damage plugs or contaminate the potable water main.
    c. Follow the Manufacturer's installation and safety instructions.
5. Report any known human tampering, flooding, or other contamination events to the OWNER immediately.

D. Valves:
1. Operate each valve subsequent to installation to ensure proper operation.
2. Valve stems shall be installed plumb and in the location shown on the Drawings.
3. Buried valves shall be coated with wax tape in accordance with the Contract Documents.
4. Adjustable supports shall be placed under buried valve flanges.

E. Buried Flanged Joints:
1. Flange faces shall be thoroughly cleaned of foreign material, including rust-preventive compound, with a power wire brush.
2. Gaskets shall be centered and the connecting flanges drawn up watertight without unnecessarily stressing the flanges.
3. Nuts and all-thread shall be tightened in a progressive diametrically opposite sequence and torqued with a suitable, approved, and calibrated torque wrench.
4. Clamping torque shall be applied to the nuts only.
5. Flanges shall be wrapped in wax tape as specified in SECTION 09 97 13.04.

F. Insulated Joints:
1. Insulated joints and appurtenant features shall be provided by the CONTRACTOR where shown on the Drawings.
2. Prevent electrical conductivity across the joint with insulators.
3. After assembly, an electrical resistance test will be performed by the ENGINEER. If the resistance test indicates a short-circuit, remove the insulating units to inspect for damage. Replace damaged portions and reassemble the insulating joint at no extra cost to the OWNER. Retest the insulated joint to ensure proper insulation.

G. Flexible Coupled Joints:
1. General (BSTC and BSSTC):
    a. Connecting pipe ends, couplings, and gaskets shall be clean and free of dirt and foreign matter with special attention being given to the contact surfaces of the pipe, gaskets, and couplings. The couplings shall be assembled and installed in conformance with the Manufacturer's instructions.
    b. Wrenches used in bolting couplings shall be of a type and size recommended by the Manufacturer. Coupling bolts shall be tightened to secure a uniform annular space between the follower rings and the body of the pipe with bolts tightened approximately the same amount. Clamping torque shall be applied to the nut only.
    c. Upon completion of the coupled joint on metallic pipe, the coupling and bare metal of the pipe shall be cleaned, primed, and protected as specified in this Section.
2. BSTC:
    a. Diametrically opposite bolts shall be tightened progressively and evenly. Final tightening shall be done with a suitable, approved, and calibrated torque wrench set for the torque recommended by the Coupling Manufacturer.
    b. For non-insulated mechanical couplings on metallic pipe, the middle ring and one follower ring shall be bonded for electrical conductivity to both ends of the connecting pipes.
    c. For insulated mechanical couplings, the middle ring and one follower ring shall be bonded to the connecting pipe end opposite the insulating rubber sleeve.

H. Joint Bonding:
1. Except where otherwise shown on the Drawings, joints shall be bonded for electrical conductivity in accordance with the Contract Documents. The pipe shall be cleaned to bare bright metal at the point where the bond is installed.
2. Damage to the pipe or pipe lining caused by the joint bonding shall be repaired at the CONTRACTOR's expense.

I. CP: As specified in SECTION 13 47 13, SECTION 13 47 16, and SECTION 13 47 15.

J. Underground Utility Warning Tape for Recycled Pipe: Install 12 inches above recycled water pipelines and appurtenances.

K. Painting and Coatings:
1. General: Metal except aluminum, brass, bronze, or copper shall be painted or coated.
2. Metal exposed to atmospheric service environment shall be painted and coated as specified in SECTION 09 90 00.
3. Buried and submerged metal shall be coated as specified in SECTION 09 97 13.02.
    a. Rods, nuts, bolts, and other metallic assembly hardware shall be wax taped as specified in SECTION 09 97 13.04.
4. Miscellaneous appurtenances:
    a. Black steel vent pipe that is to be buried shall be given two coats of cold-applied 1200 mastic except for metal with shop-applied coating approved by the ENGINEER.

L. Sanitary Sewer Crossings:
   1. In accordance with CPCS Detail 33215.
   2. Sanitary sewer crossings in the City and County of Denver shall be encased in accordance with Standard Detail S350.
   3. Sanitary sewer crossings outside of the City and County of Denver shall be encased in accordance with the applicable detail for the jurisdiction.

M. Raising or Lowering Distribution Mains:
   1. As specified in this Section and DW's Engineering Standards.
   2. Reuse of existing material is not allowed.
   3. Pipeline replacement material shall be of the same type as existing pipeline with the following exceptions:
      a. Use PVC or DI pipe and fittings for raising or lowering CI pipe.
      b. Use PVC pipe and DI fittings for raising or lowering asbestos-cement pipe.

N. Water Service Lines: Replace and repair in accordance with DW's Engineering Standards.

O. Dismantling Joint:
   1. Wax tape coat the flanges and rods as specified in SECTION 09 97 13.04.
   2. Do not modify the joint in any manner that would invalidate the Manufacturer's warranty.

3.3 QUALITY CONTROL

A. Hydrostatic Test of Water Pipes:
   1. Preparation:
      a. Pipe shall be cleaned of debris and foreign materials to the satisfaction of the ENGINEER.
      b. No hydrostatic test shall be made on any portion of the pipeline until field-placed concrete has cured for 7 days.
      c. Testing shall not begin until field-placed linings have cured as recommended by the Manufacturer.
   2. Testing responsibilities:
      a. The OWNER will furnish the water, pump, and calibrated meter for testing, operate the testing equipment, run the test, maintain the required test pressures, and blow off the pipeline after testing.
      b. Assist the OWNER with testing and investigate all possible leaks.
      c. Furnish labor, necessary bulkheads, and miscellaneous materials to facilitate the filling and testing of the pipelines.
   3. Test procedures:
      a. Pipe shall be tested at 150 psi as measured at the lowest point in the test section.
      b. The test will be made from appropriate taps alongside the pipeline and the gauge pressure read at this point.
      c. The pipeline will be filled by the OWNER at a rate which will not cause any surges or exceed the rate at which the air can be released through the air valves at a reasonable velocity. The air within the pipe shall be properly purged.
      d. The test duration will be designated by the ENGINEER.
      e. The rate at which the pipeline is blown off shall be under the control of the OWNER.
   4. Allowable leakage rates: The amount of leakage in all sections of the pipeline, including appurtenant parts, shall not exceed 10 gallons per inch of diameter per mile of pipe per day.
   5. Repair of leaks: Locate and repair leaks or other defects which may develop under test. Any section of the pipe which indicates defective material furnished by the OWNER shall be repaired by the CONTRACTOR at the expense of the OWNER. Joints made in the field are the responsibility of the CONTRACTOR.

B. Disinfection of Waterlines:
   1. General:
      a. The OWNER shall identify the disinfection and testing procedures to be used for the pipeline and appurtenances. The water source for flushing (typically a nearby hydrant) will be identified.
      b. The OWNER will take the water sample and perform the testing.
      c. Provide access for the OWNER to perform the disinfection and testing.
      d. Disinfection will occur after the pipe has been successfully pressure tested, unless otherwise noted.
      e. Recycled waterlines are typically not disinfected; however, if contamination of the pipe occurs during shipment, storage, or installation, the OWNER will determine if disinfection is needed.
   2. Disinfection process:
      a. The OWNER will furnish the chemicals and hose equipment necessary for injection into a pipeline. Where required, the CONTRACTOR will provide a National Hose Thread adapter for connection to the OWNER's hoses.
      b. Where areas of the Work are identified as spray-disinfected, this Work shall be done by the CONTRACTOR. Disinfect potable pipelines and fittings in accordance with AWWA C651 with an NSF/ANSI 60 certified sodium hypochlorite solution.
   3. Bacteriological testing process:
      a. The OWNER will take the water sample for bacteriological testing.
      b. When tested Monday through Thursday, the ENGINEER will notify the CONTRACTOR within 24 hours of the test results. When tested on a Friday, results will be available on Monday.
      c. In the event of a failed test result, re-clean the pipe and the OWNER will repeat the disinfection and testing process.
      d. Final acceptance of the pipeline is contingent upon passing disinfection.

C. Inspection of the Fabrication:
   1. No less than 14 days prior to the start of any phase of the pipe manufacture, notify the ENGINEER in writing of the manufacturing start date.
   2. During the manufacturing of the pipe, the ENGINEER shall be given access to areas where it is in process and shall be permitted to make inspections necessary to confirm compliance with the Contract Documents.
   3. The manufacturing of the pipe will be inspected by the OWNER at the OWNER's expense.

D. Materials Testing:
   1. Ensure the required material tests are performed. Coordinate the testing such that the ENGINEER may witness the tests, providing the ENGINEER does not cause delays to the CONTRACTOR’s schedule.
   2. The ENGINEER may request samples of any material, including lining and coating samples, for testing by the OWNER. Samples shall be furnished at no additional cost to the OWNER.

E. CCTV Inspection:
   1. Employ the use of CCTV to record the quality of the interior of the pipe and ensure the pipe is clear of debris.
   2. If the video shows debris or damage, the CONTRACTOR is responsible for removing the debris and making repairs to the pipe.
   3. Potable pipelines: Equipment that will be in contact with the pipe shall be steam cleaned, rinsed with a 220 ppm hypochlorite solution, and rinsed with tap water prior to insertion.
   4. The video shall become part of the OWNER’s records of the Work upon the Substantial Completion date.

END OF SECTION

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SECTION 33 14 17
WATER SERVICE LINES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for the installation and replacement of water service lines and appurtenances.

1.2 REFERENCES

A. American Association of State Highway Transportation Officials (AASHTO):
   1. Standard Specification for Highway Bridges
   2. M306 – Standard Specification for Drainage, Sewer, Utility, and Related Castings

B. American Society of Mechanical Engineers (ASME):

C. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250

D. American Water Works Association (AWWA):
   1. C207 – Steel Pipe Flanges for Waterworks Service – 4 In. Through 144 In. (100 mm through 3,600 mm)
   2. C223 – Fabricated Steel and Stainless Steel Tapping Sleeves
   3. C228 – Stainless-Steel Pipe Flanges for Water Service – Sizes 2 In. Through 72 In. (50 mm through 1,800 mm)
   4. C509 – Resilient Seated Gate Valves for Water Supply Service
   5. C515 – Reduced-Wall, Resilient Seated Gate Valves for Water Supply Service
   6. C550 – Protective Interior Coatings for Valves and Hydrants
   7. C800 – Underground Service Line Valves and Fittings
   8. C810 – Replacement and Flushing of Lead Service Lines

E. ASTM International (ASTM):
   1. A 48 – Standard Specification for Gray Iron Castings
   2. A 276 – Standard Specification for Stainless Steel Bars and Shapes
   3. B 62 – Standard Specification for Composition Bronze or Ounce Metal Castings
   4. B 88 – Standard Specification for Seamless Copper Water Tube
   5. B 98 – Standard Specification for Copper-Silicon Alloy Rod, Bar and Shapes
   6. B 584 – Standard Specification for Copper Alloy Sand Castings for General Applications
   7. B 763 – Standard Specification for Copper Alloy Sand Castings for Valve Applications
   8. C 478 – Standard Specification for Precast Reinforced Concrete Manhole Sections
   9. F 593 – Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs

F. NSF International/American National Standards Institute (NSF/ANSI):
   1. 61 – Drinking Water System Components – Health Effects

G. The Society for Protective Coatings/NACE International (SSPC/NACE):
   1. SP 10/NACE No. 2 – Near-White Blast Cleaning

1.3 SUBMITTALS

A. Product Data:
   1. Service line material and fittings.

B. Quality Control Submittals:
   1. Statement of method of installation and sequence of construction.
   2. Disposal manifest for removed service lines (if applicable).

1.4 QUALITY ASSURANCE

A. Service line work shall be performed by a bonded and licensed plumber.

B. The customer shall not install devices on the meter or inside the meter pit without prior written approval from Denver Water.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Tapping Saddles:
   1. Double bronze (DI and AC), 4 inch to 20 inch:
      a. A.Y. McDonald, Model 3825
      b. The Ford Meter Box Company, Model 202B Tap
      c. Mueller Company, Model BR2B
   2. Bronze (PVC):
      a. A.Y. McDonald, Model 3805, 4 inch to 12 inch
      b. A.Y. McDonald, Model 3895, 4 inch to 8 inch
      c. The Ford Meter Box Company, Model S70, Style B, 4 inch to 12 inch
      d. The Ford Meter Box Company, Model S90, Style B, 4 inch to 12 inch
      e. Mueller Company, Model H-13000 Series (C900), 4 inch to 12 inch
      f. Mueller Company, Model H-13400 Series (C900), 4 inch to 12 inch
      g. Mueller Company, Model S-13000 Series (C900), 4 inch to 8 inch
   3. Bronze and SST (PVC), 4 inch to 20 inch:
      a. A.Y. McDonald, Model 3845
      b. The Ford Meter Box Company, Model 202BS Tap
      c. Mueller Company, Model BR1S, 4 inch to 12 inch

B. Carbon Steel and SST Tapping Sleeves:
   1. Carbon steel sleeve (DI pipe):
      a. The Ford Meter Box Company, Model FTSC, 4 inch to 20 inch

b. JCM Industries, Model 412, 6 inch to 20 inch
c. Romac Industries, Model FTS 420, 6 inch to 20 inch
d. Smith-Blair, Model 622, 4 inch to 20 inch
2. SST tapping sleeves (CI, DI, AC, and PVC pipe):
a. Cascade, Model Style CST, 4 inch to 20 inch
b. The Ford Meter Box Company, Model FTSS, 4 inch to 20 inch
c. JCM Industries, Model JCM 432, 4 inch to 16 inch
d. JCM Industries, Model JCM 462, 4 inch to 20 inch
e. PowerSeal, Model 3490, 4 inch to 20 inch
f. Romac Industries, Model Style SST, 4 inch to 20 inch
g. Romac Industries, Model STS 420, 6 inch to 20 inch

C. Tapping Valves – Mechanical Joint Type:
1. American AVK
2. American Flow Control/American Cast Iron Pipe Company, Series 2500 RW
3. Clow
4. Kennedy
5. Mueller Company
6. U.S. Pipe and Foundry Company

D. Meter Yolks (Copper Setters):
1. A.Y. McDonald, Model 737-3xxWXCC xx, 3/4 inch
2. A.Y. McDonald, Model 737-4xxWXCC xx, 1 inch
3. A.Y. McDonald, Model 720-B612WWxx 666, 1 1/2 inch, Bypass
4. A.Y. McDonald, Model 721-612WNxx 660, 1 1/2 inch, No Bypass – IRR Meters
5. A.Y. McDonald, Model 720-B712WWxx 777, 2 inch, Bypass
6. A.Y. McDonald, Model 721-712WNxx 770, 2 inch, No Bypass – IRR Meters
7. The Ford Meter Box Company, Model V83-xxW-22-xx-NL, 3/4 inch
8. The Ford Meter Box Company, Model V84-xxW-22-xx-NL, 1 inch
9. The Ford Meter Box Company, Model VBB76-12B-xx-xx-NL, 1 1/2 inch, Bypass
10. The Ford Meter Box Company, Model VBB76-12-xx-xx-NL, 1 1/2 inch, No Bypass – IRR Meters
11. The Ford Meter Box Company, Model VBB77-12B-xx-xx-NL, 2 inch, Bypass
12. The Ford Meter Box Company, Model VBB77-12-xx-xx-NL, 2 inch, No Bypass – IRR Meters
13. Mueller Company, Model B-2489N, 3/4 inch
14. Mueller Company, Model B-2489N, 1 inch
15. Mueller Company, Model B-2423N, 1 1/2 inch, 2 inch, Bypass
16. Mueller Company, Model B-2422-00N, 1 1/2 inch, 2 inch, No Bypass – IRR Meters

E. Corporation Stops:
1. A.Y. McDonald, Model 74701B, 3/4 inch to 2 inch
2. Cambridge Brass, Model 302NL Series, 3/4 inch to 1 inch
3. The Ford Meter Box Company, FB600-x-NL, 3/4 inch to 2 inch
4. Mueller Company, Model B25000N, 3/4 inch to 2 inch

F. Curb Stops:
1. A.Y. McDonald, 76100, 3/4 inch to 2 inch
2. Cambridge Brass, Model 202NL-CxCx Series, 3/4 inch to 2 inch
3. The Ford Meter Box Company, Model B22-xxx-NL, 3/4 inch to 2 inch
4. Mueller Company, Model B25204N, 3/4 inch to 2 inch

G. Couplings:
1. A.Y. McDonald, CTS Coupling, Model 74758-22, 3/4 inch to 2 inch
2. The Ford Meter Box Company, Iron to Copper Pack Joint, Model C84-66-NL, 1 1/2 inch by 1 1/2 inch
3. The Ford Meter Box Company, Iron to Copper Pack Joint, Model C84-77-NL, 2 inch by 2 inch
4. The Ford Meter Box Company, Copper Flare to Copper Flare, Model C22-33-NL, 3/4 inch by 3/4 inch
5. The Ford Meter Box Company, Copper Flare to Copper Flare, Model C22-44-NL, 1 inch by 1 inch
6. The Ford Meter Box Company, Copper Flare to Copper Flare, Model C22-66-NL, 1 1/2 inch by 1 1/2 inch
7. The Ford Meter Box Company, Copper Flare to Copper Flare, Model C22-77-NL, 2 inch by 2 inch
8. The Ford Meter Box Company, Copper to Copper Pack Joint, Model C44-66-NL, 1 1/2 inch by 1 1/2 inch
9. The Ford Meter Box Company, Copper to Copper Pack Joint, Model C44-77-NL, 2 inch by 2 inch
10. The Ford Meter Box Company, Iron to Iron Pack Joint, Model C85-66-NL, 1 1/2 inch by 1 1/2 inch
11. The Ford Meter Box Company, Iron to Iron Pack Joint, Model C85-77-NL, 2 inch by 2 inch
12. The Ford Meter Box Company, Flared Adapter Coupling, Model C28-66-NL, 1 1/2 inch by 1 1/2 inch
13. The Ford Meter Box Company, Flared Adapter Coupling, Model C28-77-NL, 2 inch by 2 inch
14. The Ford Meter Box Company, Flared Coupling Adapter Loc-Pak, Model CF35-66-NL, 1 1/2 inch by 1 1/2 inch
15. The Ford Meter Box Company, Flared Coupling Adapter Loc-Pak, Model CF35-77-NL, 2 inch by 2 inch
16. Mueller Company, Copper Flare to Copper Flare, Model H-15400N, 3/4 inch to 2 inch

H. Compression Fittings:
1. A.Y. McDonald, Mac Pak Compression Fittings, Model 74753-22, 3/4 inch to 2 inch
2. A.Y. McDonald, T Compression Fittings, Model 74753T, 3/4 inch to 2 inch
3. Mueller Company, Compression Connection, Model H-15403N, 3/4 inch to 2 inch

I. Press Fittings:

1. Viega, ProPress Coupling with Stop, Model 2915, 1/2 inch to 2 inch

J. Stop and Waste Valves:
   1. The Ford Meter Box Company, Model Z22-333SW-NL, 3/4 inch
   2. The Ford Meter Box Company, Model Z22-444SW-NL, 2 inch
   3. Mueller Company, Model H-15214N, 3/4 inch to 2 inch

K. Gate Valves:
   1. Apollo, Model 102TLF, 1/4 inch to 3 inch
   2. Crane, Model LF 438, 1/4 inch to 3 inch
   3. Milwaukee, Model Gate UP105, 1/4 inch to 2 inch
   4. Nibco, Model 113-LF, 1/4 inch to 2 inch
   5. Stockham, Model LFB-103, 1/4 inch to 3 inch

L. Swing Check Valves:
   1. Apollo, Model 161T-LF, 1/4 inch to 2 inch
   2. Apollo, Model 161 S-LF, 1/4 inch to 2 inch
   3. Nibco, Model S-43-Y-LF, 1/2 inch to 2 inch
   4. Nibco, Model T-413-Y-LF, 1/2 inch to 2 inch
   5. Stockham, Model LFB-319Y, 1/4 inch to 2 inch

M. Service Line 2 inch and Smaller:
   1. Cambridge Lee Industries
   2. Cerro Flow Products
   3. CMC Howell Metal
   4. Mueller Industries
   5. Wieland Copper

N. Meter Pits:
   1. Concrete:
      a. Copeland Precast, Inc.
      b. Forterra Precast

O. Meter Pit Dome Assembly:
   1. Bingham & Taylor, Model IFLW20DWM
   2. EJ, Model 00842004
   3. Sigma Corporation, Model MBSW3DTH-35
   4. Star Pipe Products, Model MB1014W

P. Composite Meter Pit Lid:
   1. EJ, Composite Lid Denver Model (1200 Series)
   2. Nicor, Inc., Composite Lid Model 125SDENI
   3. Nicor, Inc., Composite Lid Model 13.25 PWBLKWAT

Q. Composite Meter Pit Extensions (Off-Grade):
   1. Bingham & Taylor, Model MPE2002
   2. Bingham & Taylor, Model MPE2004
   3. Bingham & Taylor, Model MPE2022
   4. Sigma Corporation, Model RMP20-EXT12-DW

R. Curb Stop Service Boxes:
   1. 3/4 inch and 1 inch:
      a. Bingham & Taylor, Model I2B04EWOS
      b. Sigma Corporation, Model 794E-35
      c. Sigma Corporation, Model 795E-35
      d. Star Pipe Products, Model SB94ES
      e. Star Pipe Products, Model SB95ES
   2. 1 1/2 inch and 2 inch (roadway box):
      a. Bingham & Taylor, Model I4B144RW
      b. Star Pipe Products, Model RWB 145RHD

2.2 MATERIALS

A. Brass and Bronze Goods:
   1. Potable:
      a. ASTM B 584 using copper alloy UNS No. C89833.
      b. AWWA C800 using lead free copper alloy UNS No. C89520.
      c. NSF/ANSI 61.
   2. Recycled:
      a. AWWA C800 using copper alloy UNS No. C83600, commercially known as 85-5-5, in accordance with ASTM B 62 with the following additional requirement: Each Manufacturer shall submit samples to DW for testing. If the Manufacturer is approved, the sample shall be kept by DW and used as the standard by which future purchases will be compared.

B. Outlet Threads:
   1. AWWA standard taper threads.

C. Tapping Saddles:
   1. Double bronze strapped for use with DI and AC pipe.

2. Two-piece non-hinged design for PVC pipe shall provide full support around the circumference of the pipe, having a bearing area of sufficient width along the axis of the pipe so the pipe will not be distorted when the saddle is tightened.
3. Bronze and SST saddles for PVC pipe shall provide full support around the circumference of the pipe, having a bearing area of sufficient width along the axis of the pipe so the pipe will not be distorted when the saddle is tightened.

D. Corporation Stops:
   1. AWWA standard taper thread by copper flare.

E. Curb Stops:
   1. Copper flare by copper flare.

F. Curb Stop Service Boxes:
   1. Curb stop service boxes, or stop boxes, shall be CI, Buffalo type. The bottom part, shaped like an inverted U, shall straddle the service line and have a flanged bottom to support itself.
   2. Gray CI in accordance with ASTM A 48, Class 35B.
   3. Aluminum alloy cast material is not acceptable.

G. Press Fittings:
   1. Buna N sealing elements.

H. Gate Valves:
   1. 2 inch and smaller shall be all-bronze, screwed bonnet and ends, single solid wedge gate, with non-rising stems rated at 125 psi SWP and 200 psi CWP.

I. Swing Check Valves:
   1. 2 inch and smaller shall be all-bronze body and cap, threaded ends and cap, Y-pattern, swing type disc, rated 125 psi SWP and 200 psi WOG.

J. Tapping Valves:
   1. Designed and manufactured in accordance with AWWA C509 or AWWA C515, with the following additional requirements or exceptions.
   2. Suitable for frequent operation and for long periods of inactivity, operate with flow in either direction, with operating pressure of 200 psi compatible with chlorinated water.
   3. 4 inch through 12 inch nominal diameter, 150 lb class tapping valves with mechanical joint type.
   4. Valves shall be iron body, resilient seated gate valves with non-rising stems. If resilient seats are bonded to gates, the gates shall be completely encapsulated with the material except for guide tabs or slots.
   5. Install valves with the stem positioned vertically in buried horizontal water lines without gearing, bypasses, rollers, or tracks.
   6. Install valve bonnet below the frost line.
   7. Valve stem materials:
      a. Bronze in accordance with ASTM B 763.
      b. Copper alloy No. C99500.
      c. Copper alloy in accordance with ASTM B 98, No. C66100/H02.
      d. SST in accordance with ASTM A 276, Type 304, Type 316, or AISI 420.
   8. Valves shall have 2-inch square wrench nuts.
   9. Stem seal shall consist of two O-rings.
   10. Valves shall open clockwise.
   11. Bonnet, gland bolts, and nuts shall be in accordance with ASTM F 593, Type 304 SST, or electroplated with zinc or cadmium. Hot-dipped galvanized process is not acceptable.
   12. End connections:
      a. Size and drill flanges in accordance with ASME B16.1, Class 125.
      b. Machine flanges to flat surface with a serrated finish in accordance with AWWA C207.
      c. Mechanical joint components shall be in accordance with tee-head bolts and hexagon nuts fabricated from high-strength, low alloy steel known in the industry as Cor-Ten, Usalloy, or Durabolt.
      d. Accessories for mechanical joint shall consist of gasket, gland, and fasteners packaged separately from valves.
      e. Label each package for proper identification, and the number of units per package.
   13. Seat ring:
      a. The valve body and seat opening shall be sized large enough to accommodate the following:
         1) 4 inch nominal diameter for shell cutter diameter of 3 7/8 inches.
         2) 6 inch nominal diameter for shell cutter diameter of 5 13/16 inches.
         3) 8 inch nominal diameter for shell cutter diameter of 7 7/8 inches.
         4) 10 inch nominal diameter for shell cutter diameter of 9 3/4 inches.
         5) 12 inch nominal diameter for shell cutter diameter of 11 7/8 inches.
         6) Shell cutter diameter shall have a tolerance of 1/32 inch.
   14. After shop assembly, operate and hydrostatically test the valve in accordance with AWWA C509 and AWWA C515.
   15. Ferrous surfaces, except machined or bearing surfaces, shall have the surface prepared for coating in accordance with SSPC SP10/NACE No. 2.
   16. Coat prepared surfaces with liquid epoxy with a minimum of two coats, or with fusion-bonded epoxy to a minimum DFT of 10 mils in accordance with AWWA C550.
   17. Shop coat machined flange faces with rust-preventive compound.
   18. Submit the Manufacturer’s written statement certifying that inspection and testing have been completed and results comply with this Section.
   19. Certify that components in contact with potable water comply with NSF/ANSI 61 with a copy of the certification.

K. Fabricated carbon steel and SST tapping sleeves, 4 inch to 20 inch, shall be designed and manufactured in accordance with AWWA C223, with the following additional requirements or exceptions:
   1. Components shall be suitable for exposure to chlorinated water with a working pressure of 150 psi.
   2. End connections:
      a. Carbon steel flanges shall be fabricated from steel plate with dimensions in accordance with AWWA C207, Class D.
      b. SST flanges shall be fabricated from steel plate with dimensions in accordance with AWWA C228, Class SD.
      c. Machine flange faces to a flat surface with a serrated finish in accordance with AWWA C207 or AWWA C228 as applicable.
      d. Recess the machined flange face for the tapping valve in accordance with MSS SP-60.
      e. Hollow-back flanges and segmented flanges are not acceptable.
   3. Gaskets shall be compounded from new materials and the shape of the cross-section shall provide adequate seal for working pressure.
   4. Shop glue gasket to the groove provided in body section.
   5. 3/4 inch NPT threaded outlet shall be attached to outlet nozzle of tapping sleeve assembly complete with 3/4-inch square head, threaded pipe plug.
   6. Ferrous surfaces, except machined or bearing surfaces, shall have surface prepared for coating in accordance with SSPC SP10/NACE No. 2.
   7. Coat prepared surfaces with liquid epoxy with minimum of two coats, or with fusion-bonded epoxy to minimum DFT of 10 mils in accordance with AWWA C550.
   8. Shop coat machined flange faces with rust-preventive compound.
   9. Submit the Manufacturer’s written statement certifying that inspection and testing have been completed and results comply with this Section.
   10. Certify that components in contact with potable water comply with NSF/ANSI 61 with a copy of the certification.

L. Service Line 2 Inches and Smaller:
   1. Seamless copper water tube in accordance with ASTM B 88, furnished in coils, annealed, Type K Copper UNS No. 12200.
   2. The Manufacturer shall submit a written statement that the inspection and the specified tests have been completed and that results comply with the requirements of this Section.
   3. Components in contact with potable water shall be certified to comply with NSF/ANSI 61, and a copy of the NSF/ANSI 61 certification shall be provided to DW, if requested.
   4. Pipe installed in the City and County of Denver and Total Service Contract Areas shall be manufactured domestically.

M. Meter Pits:
   1. Constructed as cylindrical concrete or plastic pits 24 inches in diameter and 52 inches to 78 inches deep with metal dome or bell housing, double lid of frost proof construction that fits a 20-inch ID concrete or plastic meter pit top ring.
   2. Consist of a 24 inch nominal diameter by 42 inch or 48 inch high cylinder of concrete or plastic.
   3. Base shall have two doghouse cutouts 3 inches wide by 4 inches high and located 180 degrees apart to accommodate service line tubing.
   4. Top shall have a shelf or tapered design to support a standard dome or bell housing with a 20 inch nominal diameter.
   5. Concrete meter pits shall consist of a combination of two to four precast concrete rings that total 48 inches in height where:
      a. Top ring shall not exceed 12 inches in height.
      b. Rings shall have a 2 inch minimum wall thickness and reinforced to minimize breakage during installation and use.
      c. Rings shall be constructed of concrete in accordance with this Section and ASTM C 478.
   6. Plastic meter pits shall be one-piece design with nominal 24 inch diameter by 42 inch high unit that tapers in 12 inches to accept a 20 inch diameter dome unit; or two-piece design with a nominal 24 inch diameter by 30 inch high base unit and 12 inch or 18-inch top unit that tapers from 24 inch diameter to accept a standard 20 inch diameter dome unit.
   7. Units shall be constructed of LMDP or HDPE with wall thickness of no less than 1/2 inch.
   8. Withstand 200 lb lateral load applied with 4-inch square plate positioned 1 inch below the top of the pit with maximum deflection of 1 inch.
   9. Base unit shall have a flange at the bottom of it, and a molded flange near the top of it to resist settling and provide additional resistance to deformation from lateral loads during backfilling.
   10. Meter pit shall be bright white on its interior.
   11. The Manufacturer’s name and model number shall be molded or printed on each piece.
   12. Grade adjustment rings from the same Manufacturer shall be used to raise the top of the pit to grade or accommodate the plumb pit to angled grades.

N. Meter Pit Dome Assembly:
   1. Gray CI in accordance with ASTM A 48, Class 35B.
   2. Nominal 20 inch bottom diameter that tapers to nominal 12 inch diameter opening at the top with height of 10 inches to 12 inches.
   3. The dome or bell housing shall have inside lip to support inner frost lid, and upper lip to accommodate locking mechanism of meter pit lid.
   4. When installed on the meter pit top ring, dome shall be rated for AASHTO H 20 highway loading plus impact not to exceed 20,000 lbs, tested in accordance with AASHTO M306 without any damage or permanent deformation.

O. Meter Pit Lid:

1. Cap type top lid shall be gray CI in accordance with ASTM A 48, Class 35B or high impact, no break Hydrozone HD composite or other approved fiber reinforced polymer material.
2. The CI lid shall have center hole that is 2 inches in diameter to accept the AMR/AMI device.
3. Composite lids shall withstand temperature range from 40°F to 90°F and shall be resistant to UV light degradation.
4. Top lids shall be furnished with a worm gear locking bolt with a five-sided brass nut.
5. The lid shall be rated for AASHTO H 20 highway loading plus impact shall not to exceed 20,000 lbs and shall be tested in accordance with AASHTO M306 without any damage or permanent deformation.
6. Cast or imprinted with the words Denver Water Meter.
7. Inner frost lid:
   a. Molded of HDPE.
   b. 12 inch diameter and at least 1/8 inch thick.
   c. Dish-shaped with a recess that is 2 inches to 3 inches deep with three to five 1/4 inch diameter drainage holes located around the edge of the recessed area.
   d. There shall be a 1/4 inch wide notch the full width of the top lip and lifting tab that projects 2 inches inward with 9/16 inch or larger hole.

PART 3 EXECUTION

3.1 GENERAL

A. Provide the materials, equipment, and labor necessary for a complete installation.

3.2 PREPARATION

A. Notification:
1. Coordinate with the ENGINEER to notify customers of impending service line replacement. Provide at least 14 days' notice.
2. Complete a water outage notice form for each customer whose water service is impacted. As specified in Supplement A found online: https://www.denverwater.org/sites/default/files/contractor-notification.pdf.

B. Verification:
1. Use data to be provided by the ENGINEER to verify the location of the service line within the property. Use visible means to verify the location such as stop box, meter pit, service line entrance at the premises.
2. Verify the service line is a non-copper material using one of the methods described in AWWA C810, such as observation in the meter pit, observation where the service line enters the premises, observation at a hydro-excavated pothole, or observation at a test pit.

C. Document by use of digital photographs or digital video the pre-construction condition of landscape and hardscape features of each premise to receive a service line replacement.

3.3 INSTALLATION

A. Connection to Water Main:
1. Taps for 2 inch and smaller domestic, irrigation, or fire service lines shall be made by the following:
   a. DW Meter Shop.
   b. Authorized Master Meter Distributor.
   c. Prequalified CONTRACTOR with the prior approval of the ENGINEER.
2. Taps for 3 inch and larger domestic irrigation, or fire service shall be made by the following:
   a. DW.
   b. Prequalified CONTRACTOR with the prior approval of the ENGINEER.
3. 2 inch and smaller tap procedure:
   a. Make connection using a corporation stop the same size as the service line through bronze tapping saddle.
   b. Taps shall be made after satisfying the following conditions:
      1) The main has been released by the ENGINEER following conditions and testing as follows:
         a) Main and appurtenances are installed and verified by the ENGINEER, and pertinent notes and measurements are made.
         b) Disinfection and chlorination testing.
         c) Hydrostatic testing.
         d) Valve and valve box inspection.
      2) License application has been completed, signed by the authorized individual, and submitted to the ENGINEER for new development projects.
      3) Street cut and occupancy permits have been obtained from the AHJ.
      4) Existing utilities are located and marked.
      5) Water main valves are marked.
      6) The tapping location on the main has been excavated and the surface of the main cleaned.
      7) Connections to metallic water mains shall be electrically insulated using insulating fittings and gaskets approved by the ENGINEER.
      8) Install service lines with enough slack to prevent pullout from the corporation stop.
      9) Replace and repair existing PE encasement disturbed by the tapping procedure.
      10) Minimum spacing of adjacent taps on the same side of main shall be 5 feet.
      11) Minimum spacing of adjacent taps on opposite side of main shall be 2 1/2 feet.
      12) Minimum spacing of tap and main line pipe fitting shall be 3 feet.
4. 3 inch and larger tap procedure:
   a. Taps shall be made by a tee connection or tapping sleeve.
   b. The developer's contractor may install a cut-in sleeve or tapping sleeve on developer projects.
   c. For developer projects, if DW installs the connection:

1) The developer's contractor shall excavate the trench exposing the water main on all sides.
2) DW will provide and install the cut-in tee or tapping sleeve at cost to the developer.
3) The developer's contractor shall connect to the outlet, install piping, set the valve box, and backfill the trench.

d. Connections to metallic water mains shall be electrically insulated using insulating fittings and gaskets approved by the ENGINEER.
e. Install service lines with enough slack to prevent pullout from the corporation stop.
f. Replace and repair existing PE encasement disturbed by the tapping procedure.
g. Minimum spacing of adjacent taps on the same side of main shall be 5 feet.
h. Minimum spacing of adjacent taps on opposite side of main shall be 2 1/2 feet.
i. Minimum spacing of tap and main line pipe fitting shall be 3 feet.

B. Replacement of Non-Copper Service Line:

1. Install new service line using one of the methods described in AWWA C810:
   a. Open cut.
   b. Trenchless on new route.
   c. Trenchless on existing route.
2. Replace service line, including the meter and the meter pit. Replace the entire service line from the water main to the first fitting inside the dwelling or premises.
3. If service line is removed from the ground, cut or bend pipe into manageable sections and dispose of in accordance with applicable state and federal regulations.
4. Use dielectric fittings to connect dissimilar metals.
5. If the existing meter is an inside setting, relocate it to an outside setting as follows:
   a. Install with inlet and outlet spuds in horizontal position in concrete or composite meter pit or vault as shown on the Drawings.
   b. Install meter in coppersetter or yoke.
   c. Install coppersetter for a 1 inch and smaller meter with meter spuds 18 inches below the meter pit lid.
   d. The meter shall sit horizontally with the register pointing up.
   e. Install larger meter in vault as show on the Drawings.
   f. Deviations in height, spacing, pipe location, and mounting supports shall be approved in advance by the ENGINEER.
6. If service line is less than 3/4 inches, install new 3/4 inch service line.
7. The CONTRACTOR shall be a licensed plumber by the AHJ to perform work in the public ROW and have a current plumbing license to install service lines inside Denver, Total Service, and Read and Bill Contract Areas where work is to be performed.

C. Abandonment and Removal of Service Lines and Tap Cuts:

1. General:
   a. Remove or abandon service lines as show on the Drawings.
   b. Cut taps to be abandoned or relocated at the main or fireline to ensure water cannot be removed from the system.
   c. Tap cuts shall be witnessed by the ENGINEER.
   d. Service line changes shall be made in accordance with DW's Operating Rules.
   e. Tap cuts shall be coordinated through the ENGINEER or the Sales Administration Section.
   f. Service lines shall be metered until disconnected from the main and inspected by the ENGINEER.
2. 2 inch and smaller service line abandonment procedure:
   a. Excavate service line connection where the corporation stop is inserted into main.
   b. Close the corporation stop.
   c. Remove service tubing or piping from the corporation stop.
   d. Scar threads on the corporation stop and remove a minimum of 12 inches of service line.
   e. Remove curb or valve box over curb stop and cut off at least 18 inches below final grade.
   f. Deliver the meter to the ENGINEER or the Meter Shop for final test and reading.
   g. The meter shall not be reused in the system.
   h. The meter pit shall be cut off 18 inches below final grade and filled with sand. The meter pit may be removed completely.
3. 3 inch and larger service line abandonment procedure:
   a. Excavate over service tee on water main.
   b. Remove valve at the main and plug the connecting fitting, tee, or tap.
   c. Remove the property line valve box and cut off at least 18 inches below final grade.
   d. Deliver the meter to the ENGINEER or the Meter Shop for final test and reading.
   e. The meter shall not be reused in the system.
   f. The meter vault shall be cut off 18 inches below final grade and filled with sand. The meter vault may be removed completely.
4. Inside meter setting abandonment: Prior to demolishing the building or the structure with the inside meter setting, install meter pit or vault with the new meter and AMR/AMI device in the outside meter setting, or cut and abandon the tap as described in this Section.

3.4 RESTORATION

A. If open cut method is used, replace landscaping to prior condition at trench and where disturbed by CONTRACTOR activities. Repair damage to irrigation system.

B. If a trenchless method is used, replace landscaping to prior condition at pits and where disturbed by CONTRACTOR activities. Repair damage to irrigation system.

3.5 STARTUP

A. Provide residents with the OWNER's flyer regarding resident flushing of service lines.

3.6 SUPPLEMENTS

A. Supplement A – Water Outage Notice

END OF SECTION

WATER OUTAGE NOTICE

Contractor Responsible for Water Shut-off: ______________________________________
Office number: ______________________ On-site number: ___________________________

It will be necessary to shut off the water supply to the premises on:
Date: ________________________ **Time:** __________ **TO** __________
Reason: ____

Water service in this area will be shut off due to maintenance. During this outage, please help crews by only turning water faucets on periodically to check for running water, which indicates work is complete.

This work will cause inconveniences, including street and parking closures, heavy equipment noise, and excavation in the street and possibly private property. Once maintenance is finished, crews will flush the water mains, which may cause discolored or cloudy water. After service is restored, run a cold faucet at full pressure until water is clear.

For more details about what to expect and how to flush faucets, visit denverwater.org/service-interruptions.

Please consider sharing this information with others at your property and in your neighborhood.

Special instructions for regulated food facilities: Inside the City and County of Denver, regulated food facilities are not permitted to conduct open food handling when water is not available, per Denver food safety regulations. For more information, contact the Denver Department of Environmental Health (720-913-1311 or phicomments@denvergov.org) or, outside of Denver, your local health department.

NOTIFICACIÓN DE CORTE EN EL SUMINISTRO DE AGUA

Contratista responsable del corte en el servicio agua: ______________________________
N.º de oficina: ______________________ N.º en la obra ______________________________

Será necesario cortar el suministro de agua para la propiedad:
Fecha: ________________________ **Hora:** _________ **HASTA** ________
Motivo ____

El servicio de agua en esta área será interrumpido debido a trabajos de mantenimiento. Durante este corte en el suministro de agua, ayude a los equipos de trabajo abriendo los grifos solo periódicamente para comprobar si el agua ya empieza a fluir, lo cual indica que los trabajos de mantenimiento han finalizado.

Esta obra ocasionará inconvenientes, entre estos, cierre de calles y de sitios para estacionar, ruido de maquinaria pesada, excavaciones en la calle y posiblemente en propiedad privada. Una vez que hayan terminado los trabajos de mantenimiento, los equipos purgarán el agua de las cañerías maestras, lo cual podría ocasionar que el agua se vea descolorida o turbia. Después de que se restablezca el servicio, abra uno de los grifos y deje correr el agua fría a máxima presión hasta que esta se vea transparente.

Para obtener más detalles sobre lo que se debe esperar y cómo purgar los grifos, visite denverwater.org/service-interruptions.

Piense en la posibilidad de compartir esta información con otras personas en su propiedad y en su vecindario.

Instrucciones especiales para plantas de alimentos regulados: En concordancia con las normas de seguridad alimentarias de Denver, cuando no hay agua disponible, no se permite la manipulación de alimentos expuestos dentro de las plantas de alimentos regulados de la ciudad y condado de Denver. Para obtener más información, póngase en contacto con el Departamento de salud ambiental de Denver (720-913-1311 o phicomments@denvergov.org), o con su Departamento de salud local si se encuentra fuera del área de Denver.

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for valves for water utility piping.
B. Related Sections:
   1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   2. SECTION 09 97 13.04 – WAX TAPE COATINGS

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250
B. American Water Works Association (AWWA):
   1. C111 – Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
   2. C207 –Steel Pipe Flanges for Waterworks Service – Sizes 4 Inch Through 144 Inch (100 mm Through 3,600 mm)
   3. C508 –Swing-Check Valves for Waterworks Service – 2 In. Through 48 In. (50 mm Through 1,200 mm) NPS
   4. C509 – Resilient-Seated Gate Valves for Water Supply Service
   5. C512 – Air Release, Air/Vacuum and Combination Air Valves for Wastewater Service
   6. C515 – Reduced-Wall, Resilient-Seated Gate Valves for Water Supply Service
   7. C517 – Resilient-Seated Cast Iron Eccentric Plug Valves
   8. C550 – Protective Interior Coatings for Valves and Hydrants
   9. C800 – Underground Service Line Valves and Fittings
C. ASTM International (ASTM):
   1. A 27 – Standard Specification for Steel Castings, Carbon, for General Application
   2. A 48 – Standard Specification for Gray Iron Castings
   3. A 536 – Standard Specification for Ductile Iron Castings
   4. B 61 – Standard Specification for Steam or Valve Bronze Castings
   5. B 62 – Standard Specification for Composition Bronze or Ounce Metal Castings
   6. B 98 – Standard Specification for Copper-Silicon Alloy Rod, Bar and Shapes
   7. B 127 – Standard Specification for Nickel-Copper Alloy Plate, Sheet, and Strip
   8. B 139 – Standard Specification for Phosphor Bronze Rod, Bar, and Shapes
   9. B 164 – Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire
   10. B 194 – Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar
   11. B 584 – Standard Specification for Copper Alloy Sand Castings for General Applications
   12. B 763 – Standard Specification for Copper Alloy Sand Castings for Valve Applications
   13. D 1784 – Standard Specification for Rigid Poly (Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
D. NSF International/American National Standards Institute (NSF/ANSI):
   1. 61 – Drinking Water System Components – Health Effects
   2. 61, Annex G – Weighted Average Lead Evaluation Procedure to a 0.25% Lead Requirement
   3. 372 – Drinking Water System Components – Lead Content
E. The Society for Protective Coatings/NACE International (SSPC/NACE):
   1. SSPC SP 6/NACE No. 3 – Commercial Blast Cleaning

1.3 SUBMITTALS

A. Shop Drawings:
   1. Product data sheets for the make and model.
   2. Complete catalog information, descriptive literature, specifications, and identification of the materials of construction.
   3. Factory mechanical drawings of the complete actuator assembly including the electric motor, pedestal, and rod extensions.
   4. Open/close and throttling sizing calculations.
   5. Maximum torque capabilities of the operator mechanism and the operating torque requirement for each valve under the specified operation condition.
   6. Factory electrical drawings showing the schematic representation of the complete power and control circuitry and wiring diagrams showing interconnections, wire designations, and terminal numbers for remote operation and position indication by the OWNER.
   7. Factory installation and services information giving full installation and adjustment instructions and part listings for field replaceable parts.
   8. Listings of normal starting and running currents and full nameplate data from the motor.
   9. Provide drawings in DWG or DXF electronic format.
   10. Shop and field painting systems proposed.
B. Quality Control Submittals:
   1. Certificate of compliance for the following:
      a. Gate valves in accordance with AWWA C509 or AWWA C515.
      b. Eccentric plug valves in accordance with AWWA C517.
      c. Swing check valves in accordance with AWWA C508.
      d. Combination air valves in accordance with AWWA C512.
      e. NSF/ANSI 61.

2. Tests and inspection data.
3. Manufacturer's certificate of proper installation.
4. Installation O&M manuals.

1.4 QUALITY ASSURANCE

A. Valves:
1. Include actuators, handwheels, chain wheels, extension stems, floor stands, worm gear actuators, operating nuts, chains, and accessories for a complete installation in accordance with the Contract Documents.
2. Suitable for intended service; renewable parts shall not be of a lower quality than specified.
3. The same size as adjoining pipe.
4. Ends shall suit adjacent piping.
5. Buried valves shall be installed below the frost line.
6. Resilient-seated valves shall have no leakage (drop-tight) in either direction at the valve rated design pressure. Other valves shall have no leakage (drop-tight) in either direction at the valve rated design pressure unless otherwise specified in this Section or in the stated valve standard.
7. Size actuators to operate valves for the full range of pressures and velocities.
8. Open by turning clockwise.
9. Recycled system valves: Counter-clockwise to open with a pentagon wrench nut.
10. Factory-mount actuator and accessories.
11. Bolt holes for flanges for valves having flange insulation kits shall be 1/4 inch larger than the standard size.
12. Suitable for exposure to chlorinated water.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Type V104 Gate Valve:
1. Potable:
   a. Apollo, 102T LF
   b. Crane, LF438
   c. Milwaukee, Gate UP105
   d. Nibco, 113-LF
   e. Stockham, LFB-103
2. Recycled:
   a. Apollo, 106T
   b. Crane, 437
   c. Milwaukee, Gate 1140
   d. Nibco, T-133
   e. Stockham, B-128

B. Type V125 Resilient-Seated Gate Valve:
1. American AVK
2. American Flow Control/American Cast Iron Pipe Company
3. Clow
4. EJ
5. Kennedy
6. Mueller
7. U.S. Pipe and Foundry Company

C. Type V130 Resilient-Seated Insertion Valve:
1. Team Industrial Services; Team InsertValve

D. Type V200 Globe Valve:
1. Crane Co., 7TF, threaded end
2. Stockham, B-22T, threaded end
3. Stockham, B-24T, soldered end

E. Type V301 Ball Valve:
1. Apollo, 76F series, threaded end
2. Milwaukee, 10 series, threaded end
3. Nibco, T-580 Series

F. Type V307 Ball Valve:
1. Apollo, 71 series
2. Milwaukee; BA100, threaded end
3. Milwaukee; BA150, soldered ends
4. Nibco; T-580 Series

G. Type V402 Eccentric Plug Valve:
1. Dezurik
2. Pratt
3. Val-Matic

H. Type V462 Gauge Cock:
1. Ernst Gage Co.
2. Lunkenheimer
3. United Brass Works, Figure 973

I. Type V464 Corporation Stop:
   1. AY McDonald
   2. Cambridge Brass
   3. The Ford Meter Box Co.
   4. Mueller Co.
J. Type V605 Check Valve:
   1. Potable:
      a. Apollo, 161T-LF, 161-S-LF
      b. Crane, LF37
      c. Nibco, S-43-Y-LF, T-413-Y-LF
      d. Stockham, LFB-319Y
   2. Recycled:
      a. Apollo, 164T
      b. Crane, 437
      c. Milwaukee, Check 508
      d. Nibco, T-413-B
      e. Stockham, B-345
K. Type V606 Check Valve:
   1. Crane, 383
   2. Stockham, G-931
L. Type V608 Swing Check Valve:
   1. Cla-Val Flex-Check, Model 584
   2. Val-Matic Swing-Flex, Series 500
M. Type V609 Check Valve:
   1. Val-Matic Wafer Style Silent Check Valve, 1400 Series
N. Type V610 High Surge Check Valve:
   1. Cla-Val Surge Blocker, Series 587
   2. Val-Matic Surgebuster, Series 7200
O. Type V615 PVC Swing Type Check Valve:
   1. ASAHI/America
   2. Spears
P. Type V690 Flap Gate:
   1. Rodney Hunt Co., Series FV-AC or FV-AR
   2. Waterman Industries, Inc., Model F-20 or F-25
Q. Type V747 Combination Air Release and Air Vacuum Valve:
   1. SST body:
      a. International Valve; Vent-Tech WTR-C Series
      b. Vent-O-Mat; Series RBX
   2. CI body:
      a. GA Industries; Figure 945
      b. Val-Matic; Series 200
R. Type V940 Solenoid Valve:
   1. ASCO
   2. Skinner
S. Floor Stand and Extension Stem:
   1. Clow, Figure F-5515
   2. Mueller Co.
T. Floor Box and Stem:
   1. Clow, No. F-5695
   2. Neenah Foundry, R 7506
U. Chain Wheel and Guide:
   1. Clow Corp., Figure F-5680
   2. DeZurik Corp., Series W
   3. Walworth Co., Figure 804
V. Rust-Preventive Compound:
   1. Bel-Ray, Rust Preventative Coating Product #15600
   2. Houghton, Rust Veto 2186
   3. Rust-Oleum, Rust Inhibitor

2.2 MATERIALS

A. Potable Water Applications:
   1. Brass and bronze valve components and accessories that have surfaces in contact with potable water shall be alloys containing less than 16% zinc and 2% aluminum and shall be certified to comply with NSF/ANSI 61, NSF 61 Annex G, and NSF/ANSI 372.
   2. Approved alloys are of the following designations:
      a. ASTM B 61, ASTM B 62, ASTM B 98 (Alloy No. C65100, C65500, or C66100), ASTM B 139 (Alloy No. C51000), ASTM B 584 (Alloy No. B89520, B89833, C83600, C87850, C89836, C90300, or C94700), ASTM B 164, ASTM B 194, ASTM B 127, and ASTM B 763 (Alloy No. C99500).

b. SST alloy 18-8 may be substituted for bronze.

B. Recycled Water Applications: Brass and bronze goods that have surfaces not in contact with potable water shall be manufactured in accordance with AWWA C800 using alloy UNS No. C83600, commercially known as 85-5-5, in accordance with ASTM B 62.

C. Valves:

1. Gate valves:

a. General:

1) Suitable for frequent operation and long periods of inactivity.
2) Operate with flows in either direction and provide zero leakage past the seat.
3) Iron body resilient-seated with non-rising stems.
4) If the resilient seats are bonded to the gates, the gates shall be completely encapsulated with the material, except for guide tabs or slots.
5) Valve bodies shall be designed to allow for the lifting of the valves by the bonnet flange, gland flanges, or other appurtenances.
6) Valve stems shall be made of bronze in accordance with ASTM B 763, Copper Alloy No. C99500; SST in accordance with ASTM A 276, Type 304, Type 316, or AISI 420; or copper alloy in accordance with ASTM B 98, Copper Alloy No. C66100/H02.
7) The stem seal shall consist of two O-rings.
8) The bonnet gland bolts and nuts shall be in accordance with ASTM F 593, Type 304 SST or electroplated with zinc or cadmium. The hot-dip galvanized process is not acceptable.
9) Flanges sized and drilled in accordance with ANSI B16.1, Class 125. Machined to a flat surface with a serrated finish in accordance with AWWA C207.
10) Mechanical joint components shall be in accordance with AWWA C111 with tee head bolts and hexagon nuts fabricated from a high strength, low alloy steel known in the industry as Cor-Ten, Usalloy, or Durabolt.
11) Accessories for the mechanical joint shall consist of the gasket, gland, and fasteners and shall be furnished and packaged separately from valves. Each package shall be labeled in a manner that provides for proper identification and have the number of units listed per package or bundle.

b. Type V104 gate valve smaller than 3 inches:

1) Potable: All-bronze, screwed bonnet and ends, single solid wedge gate, rated 200 psi. CWP, 125 psi SWP.
2) Recycled: All-bronze, screwed bonnet and ends, single solid wedge gate, rated 150 psi SWP, 300 psi WOG.

c. Type V125 resilient-seated gate valve, 3 inch through 20 inch, for water service:

1) Except as modified or supplemented herein, resilient-seated gate valves shall be in accordance with AWWA C509 or AWWA C515 and be UL listed.
2) Operating pressure for 3 inch through 12-inch valves shall be 200 psi; 14 inch through 20-inch valves shall be 150 psi.
3) Supplied with 2-inch square wrench nuts. Valves installed in the recycled water system shall have EPDM seats.
4) Provide handwheel for exposed valves and 2-inch wrench nuts for buried valves.
5) Bevel gear shall be bury duty rated, grease filled for life, totally enclosed gearing, and fully sealed with nitrile rubber O-rings.
6) Bevel gear housing shall be DI and bevel gears shall be AISI/SAE 4340 steel with the input shaft supported by a ball bearing.
7) Gear reduction sized to limit maximum input torque required to operate valve in all conditions to 80 lb-ft.
8) Accessories for the mechanical joint shall consist of the gasket, gland, and fasteners and shall be furnished and packaged separately from valves. Each package shall be labeled in a manner that provides for proper identification and have the number of units listed per package or bundle.
9) Each valve, after shop assembly, shall be operated and hydrostatically tested in accordance with AWWA C509 or AWWA C515.
10) Valves, 3 inches through 12 inches, shall be installed with the stem positioned vertically in buried horizontal water lines without gearing, bypasses, rollers, or tracks.
11) Valves, 14 inches through 20 inches, shall be installed horizontally in buried horizontal water lines without bypasses, rollers, or tracks.
12) Horizontal installations shall include a bevel gear to rotate the input shaft vertical and provide a mechanical advantage. The valve bonnet shall be installed below the frost line.

d. Recycled water:

1) Valve operator fitted with a pentagon wrench nut.
2) Nut coated with epoxy, Pantone 2577U in color.
3) Label valves and operators in vaults with inert plastic labels stating “Recycled Water Facilities” in white letters on purple background.

e. Type V130 resilient seated insertion valves 4 inches through 12 inches:

1) Designed and manufactured in accordance with AWWA C515.
2) Minimum working pressure shall be 250 psi. Designed to handle full water system hydraulic forces.
3) Iron body, resilient seated insertion valves with non-rising stems.

4) If the resilient seats are bonded to the gates, the gates shall be completely encapsulated with the material, except for guide tabs or slots.
5) Supplied with 2-inch square wrench nuts. Open clockwise.
6) Installed with the stem positioned vertically in buried horizontal water lines without gearing, bypasses, rollers, or tracks.
7) Valve installation shall result in full host pipe coupon removal by Manufacturer-certified installers in accordance with the Manufacturer's installation manuals.
8) Valve stems shall be made of bronze in accordance with ASTM B 763, Copper Alloy No. C99500; SST in accordance with ASTM A 276, Type 304, Type 316, or AISI 420; or copper alloy in accordance with ASTM B 98, Copper Alloy No. C66100/H02.
9) The stem seal shall consist of three O-rings.
10) The valve seat shall be synthetic rubber, Buna-N or EPDM. Valves installed in the recycled water system shall have EPDM seats.
11) Split restraint devices shall consist of multiple gripping wedges incorporated into a follower gland meeting the requirements of AWWA C110.
12) Mechanical joint restraint shall be in accordance with AWWA C600. Set screw pressure point type restraint hardware is not permitted.
13) Each valve, after shop assembly, shall be operated and hydrostatically tested in accordance with AWWA C515.

2. Globe valves:
   a. Type V200 globe valve 3 inches and smaller: All-bronze, union bonnet, inside screw, rising stem, PTFE disc, rated 150 psi SWP, 300 psi WOG.
3. Ball valves:
   a. Type V301 ball valve, 2 inches and smaller for general water service: Type 316 SST body, full port, SST ball, SST seat with stellite overlay, PTFE chevron packing, SST shaft, flanged ANSI Class 150.
   b. Type V307 ball valve 2 inches and smaller for general water and air service: Two-piece, bronze, end entry type, RPTFE seats, Teflon packing, hand lever actuator, rated 150 lb SWP, 600 lb WOG.
4. Plug valves:
   a. Type V402 eccentric plug valve:
      1) Except as modified or supplemented herein, eccentric plug valves shall be in accordance with AWWA C517.
      2) Class 150 rating, capable of bi-directional flow and shutoff.
      3) Gray or DI body and plug, Buna-N encapsulated plug, self-adjusting U-type or V-type packing, SST shaft radial bearings, top and bottom grit seals, flanged ends.
      4) The seat shall be 99% nickel alloy, welded into the body.
      5) Flanges in accordance with ASME B16.1, Class 125; machined to a flat surface with a serrated finish in accordance with AWWA C207; shall not be coated with the same coating as the body.
      6) For valves 4 inches and larger, provide manual worm gear actuators with position indication; sized to actuate with a shutoff pressure differential equal to the design pressure and a flow velocity of 30 fps; furnished with handwheels unless otherwise specified or shown on the Drawings; 3 inch and smaller valves shall be lever operated.
   b. Type V462 gauge cock: 1/8 inch to 3/8-inch bronze body, hexagon end pattern, tee head, female ends, rated 125 psi SWP.
   c. Type V464 corporation stop: In accordance with AWWA C800 type, tapered threaded inlet, except when connecting to tapped fittings which require IPS tapered threads, outlet compression connection, or IPS threads to suit connecting pipe, rated 150 psi.
5. Check and flap valves:
   a. Type V605 check valve, 2 inches and smaller:
      1) Potable: All-bronze, body and cap threaded or soldered ends and cap, Y-pattern, swing type disc, rated 200 psi CWP, 125 psi SWP.
      2) Recycled: All-bronze, body and cap threaded or soldered ends and cap, Y-pattern, swing type disc, rated 300 psi CWP, 150 psi SWP.
   b. Type V606 check valve, 2 1/2 inches through 12 inches: Flanged end, CI body, bronze mounted swing type, solid bronze hinges, SST hinge shaft, outside lever and weight, rated 125 psi SWP, 200 psi WOG.
   c. Type V608 swing check valve, 2 inches and larger:
      1) Except as modified or supplemented herein, swing check valves shall be in accordance with AWWA C508.
      2) Suitable for frequent operation and long periods of inactivity.
      3) Working pressure shall be 150 psi
      4) Flanged ends, in accordance with ANSI B16.1, Class 125. Machined to a flat surface with a serrated finish in accordance with AWWA C207.
      5) DI body, ASTM A 536, domed access cover. Threaded port and plug to accept back flow plunger. Top access port allowing the removal of the disc without removing the valve from the service line.
      6) Full pipe size flow area. Seating surface on a 45-degree angle.
      7) Disc shall be one-piece construction, precision molded with an integral O-ring type sealing surface with steel and nylon reinforcement.
      8) 35-degree disc stroke.

9) Installed in a horizontal position.
10) Valve position indicator, backflow plunger, cushion device for added surge protection.
11) Bolts and nuts in accordance with ASTM F 593, Type 304 SST or electroplated with zinc or cadmium.
12) Operated and hydrostatically tested in accordance with AWWA C508.

d. Type V609 check valve, spring-loaded interval plunger: Wafer body, bronze plunger, SST spring.
e. Type V610 swing check valve, 2 inches and larger, for high surge applications:
   1) Except as modified or supplemented herein, swing check valves shall be in accordance with AWWA C508.
   2) Suitable for frequent operation and long periods of inactivity.
   3) Working pressure shall be 150 psi.
   4) Flanged ends, in accordance with ANSI B16.1, Class 125. Machined to a flat surface with a serrated finish in accordance with AWWA C207.
   5) DI body, ASTM A 536, domed access cover. Threaded port and plug to accept back flow plunger. Top access port allowing the removal of the disc without removing the valve from the service line.
   6) Full pipe size flow area. Seating surface on a 45-degree angle.
   7) Disc shall be one-piece construction, precision molded with an integral O-ring type sealing surface with steel and nylon reinforcement.
   8) 35-degree disc stroke.
   9) Installed in a horizontal position.
   10) Valve position indicator, backflow plunger, cushion device for added surge protection.
   11) Bolts and nuts in accordance with ASTM F 593, Type 304 SST or electroplated with zinc or cadmium.
   12) Operated and hydrostatically tested in accordance with AWWA C508.
   13) Disc accelerator:
       a) One-piece construction and provide rapid closure of the valve in high head applications.
       b) Constructed of AISI Type 304 SST.
       c) Enclosed within the valve and field-adjustable and replaceable without removal of the valve from the line.
       d) Securely held in place captured between the cover and disc. Formed with a large radius to allow smooth movement over the disc surface.

6. Type V615 PVC swing type check valve, 4 inches and smaller:
   a. In accordance with ASTM D 1784, Type I, Grade 1 PVC body, flanged ends, rated 150 psi at 73°F, EPDM seat and seal, external counterbalance measure, and top entry access.
   b. Type V690 flap gate:
      1) CI body, bronze mounted, flanged frame type, dual pivot-point hinge arms, hinge arms bronze, hinge pins Type 304 SST, seat bronze and impacted into grooves in body and cover flap, lubrication fittings for each pivot.
      2) Type 316 SST anchor bolts or CI wall thimble as shown on the Drawings.
7. Miscellaneous valves:
   a. Type V747 combination air release and air vacuum valve, 1 inch to 6 inches:
      1) General: Except as modified or supplemented herein, valves shall be in accordance with AWWA C512.
      2) Shop-assembled and shipped as a complete unit ready for field installation. Suitable for frequent operation and long periods of inactivity.
      3) Valve body and cover:
         a) The combination air valve shall be the single body type for valves 4 inch and smaller; dual body allowed on 6-inch valves.
         b) Material shall be one of the following:
            (1) CI: ASTM A 48, Class 35A.
            (2) Cast steel: ASTM A 27, Grade U60-30.
            (3) DI: ASTM A 536, Grade 65-45-12.
            (4) SST: AISI Type 304.
      4) Internal parts:
         a) Each valve shall be supplied with SST trim, which includes the float, float arm, guide bushings, plug, and connecting hardware.
         b) Float shall be SST. Lever frame shall be Delrin. Other internal parts shall be fabricated from bronze or SST.
      5) Valve seats shall be synthetic rubber, Buna N or EPDM. Valves installed in the recycled water system shall have EPDM seats.
      6) Size of orifices: Small orifice minimum diameter shall be 3/32 inch for 4-inch valves and smaller and 3/16 inch for 6-inch valves.
      7) Inlet: 2-inch and smaller valves shall be NPT threaded; 4 inch and larger valves shall be flanged; ANSI B16.1, Class 125. Each flange face shall be machined to a flat surface with a serrated finish in accordance with AWWA C207.
      8) Maximum operating pressure: 150 psig.
      9) Plugs: Valves shall be provided with 1/4 inch minimum NPT pipe plugs in the bottom of the body.
      10) Discharge connection: 1 inch through 6-inch valves shall include standard NPT screwed discharge connection.

11) Testing: Each shop-assembled valve shall be given a hydrostatic test of two times the rated operating pressure and during the test; air shall be injected to test the ability to release entrained air to the atmosphere under operating pressure.
12) Certification: The Manufacturer shall submit a sworn statement that the inspection and the specified tests have been made and the results thereof comply with the requirements of the applicable Standards specified in this Section.
13) Installation: Vertical position in-plant, in an underground concrete manhole or concrete vault as applicable.

b. Type V940 solenoid valve, 2 inches and smaller:
1) Two-way internal pilot operated diaphragm type, brass body, resilient seat suitable for air or water, solenoid coil molded epoxy, NEMA Class A, 120 VAC, 60 Hz, unless otherwise shown on the Drawings; solenoid enclosure NEMA 250, Type 4 unless otherwise shown on the Drawings; size and normal position, open or closed when de-energized, as shown on the Drawings.
2) Minimum operating pressure differential no greater than 5 psig, maximum operating pressure differential no less than 125 psig.

2.3 ACCESSORIES

A. Actuators:
1. General: Valves shall be equipped with actuators. The valve actuator types, as specified in this Section, describe only the general characteristics of the actuator. The actuator shall be compatible with the valve with which it will be used. The actuator shall be sized to operate the valve for the full range of pressures and velocities imposed by the service.
2. Manual actuators:
a. Actuator force shall not exceed the lesser of 80 lbs or the applicable AWWA standard under any operating condition, including initial breakaway; supply a gear reduction actuator when force exceeds 80 lbs.
b. Actuator shall be a self-locking type or equipped with a self-locking device.
c. Position indicator on quarter-turn valves.
d. Painted in accordance with the requirements for exposed valves.
e. Chain wheel operator with tiebacks, extension stem, floor stands, and other accessories to permit operation from normal operation level.
f. Valve handles shall be able to take wheels, a chain, and a padlock.

B. Tagging: 1/2 inch diameter heavy brass or SST tag for each valve operator bearing the valve tag numbers shown on the valve schedule and the P&ID Drawing.

C. Limit Switch:
1. Factory-installed limit switch by the Actuator Manufacturer.
2. SPST, rated at 5 A, 120 VAC.

D. Extension Bonnet for Valve Operator: Complete with stem and accessories for the valve and the operator.

E. Floor Stand and Extension Stem:
1. Non-rising, indicating type.
2. Complete with stem, coupling, handwheel, stem guide brackets, and yoke attachment.
3. Stem guide: Space such that stem L/R ratio does not exceed 200.
4. Anchor bolts: Type 304 SST.

F. Floor Box and Stem:
1. Plain type, for support of non-rising type stem.
2. Complete with stem, operating nut, and stem guide brackets.
3. Stem guide: Space such that stem L/R ratio does not exceed 200.
4. Anchor bolts: Type 304 SST.

G. Chain Wheel and Guide:
1. Chain wheel direct-mount type.
2. Complete with chain, galvanized or cadmium plated.

H. CI Valve Box:
1. Designed for traffic loads, three-piece, adjustable screw type, with minimum of 6 inch ID shaft:
a. Box: CI with a minimum depth of 9 inches.
b. Lid: CI, a minimum depth of 3 inches, marked as shown on the Drawings.
c. Extensions: CI.

I. CI Curb Stop Valve Box:
1. Designed for traffic loads, adjustable screw type, with a minimum of 2 3/4 inch ID shaft:
a. Box: CI with a minimum depth of 9 inches.
b. Lid: CI with a minimum depth of 3/4 inch marked as “WATER”.
c. Extensions: CI.

2.4 FINISHES

A. Internal Surfaces and External Surfaces of Buried Valves:
1. Ferrous surfaces except machined or bearing surfaces.
2. In accordance with AWWA C550.
3. Coated with a two-part thermosetting epoxy in two or more uniform coats or with fusion-bonded epoxy.
4. MDFT 10 mil, except where limited by valve operating tolerances.

B. External Surfaces of Exposed Valves:
1. Prepared in accordance with SSPC SP 6/NACE No. 3.

2. Coated with one coat of anti-corrosive epoxy primer.
3. MDFT 3 mil.
4. Flange faces shall be coated with rust-preventive compound, Houghton Rust Veto M.P., or Rust-Oleum R-9, 3 mil.
5. Safety isolation valves and lockout valves with handles, handwheels, or chain wheels shall be safety yellow.

C. Field Coating: As specified in SECTION 09 97 13.04.

PART 3 EXECUTION

3.1 INSTALLATION

A. Flange Ends:
1. Flanged valve bolt holes shall straddle the vertical centerline of pipe.
2. Clean flanged faces insert gasket and bolts and tighten nuts progressively and uniformly.

B. Screwed Ends:
1. Clean threads by wire brushing or swabbing.
2. Apply joint compound.

C. Valve Orientation:
1. As specified in this Section or as shown on the Drawings.
2. Install the operating stem vertical when a valve is installed in horizontal runs of pipe having centerline elevations 4 1/2 feet or less above the finished floor.
3. Install the operating stem horizontal in horizontal runs of pipe having centerline elevations between 4 1/2 feet and 6 3/4 feet above the finished floor.
4. Orient the butterfly valve shaft so that unbalanced flows or eddies are equally divided to each half of the disc, e.g., the shaft is in the plane of rotation of the eddy.
5. If no plug valve seat position is shown on the Drawings, locate as follows:
   a. Horizontal flow: The flow shall produce an unseating pressure and the plug shall open into the top half of valve.
   b. Vertical flow: Install seat in the highest portion of the valve.

D. Install a line size ball valve and union upstream of each solenoid valve, in-line flow switch, or other in-line electrical device, excluding magnetic flow meters, for isolation during maintenance.

E. Locate the valve to provide accessibility for control and maintenance. Install access doors in finished walls and plaster ceilings for valve access.

F. Extension Stem for Operator: Where the depth of the valve is such that its centerline is more than 3 feet below grade, furnish an operating extension stem with a 2-inch operating nut to bring the operating nut to a point 6 inches below the surface of the ground or box cover.

G. Torque Tube: Where the operator for the quarter-turn valve is located on a floor stand, furnish an extension stem torque tube of a type properly sized for maximum torque capacity of the valve.

H. Floor Box and Stem: The steel extension stem length shall locate operating nut in floor box.

I. Chain Wheel and Guide: Install chain wheel and guide assemblies or chain lever assemblies on manually operated valves over 6 3/4 feet above the finished floor. Where chains hang in normally traveled areas, use appropriate L type tie-back anchors.

3.2 QUALITY CONTROL

A. Tests and Inspections:
1. The valve may be tested while testing pipelines or as a separate step.
2. Test that valves open and close smoothly with operating pressure on one side and atmospheric pressure on the other, in both directions for two-way valve and applications.
3. Inspect air and vacuum valves as the pipe is being filled to verify that venting and seating is fully functional.
4. Count and record the number of turns to open and close the valve; account for any discrepancies with the Manufacturer's data.
5. Set, verify, and record set pressures for relief and regulating valves.
6. Resilient seated valves shall have zero leakage. Metal seated valves are allowed 0.1 gpm/ft of seat periphery.

B. Manufacturer’s Field Service: As specified in SECTION 01 44 33.

END OF SECTION

SECTION 33 14 20
FIRE HYDRANTS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for fire hydrants.

B. Related Sections:

1. SECTION 31 23 33 – TRENCH BACKFILL
2. SECTION 33 05 19 – DUCTILE-IRON PIPE FOR WATER TRANSMISSION AND DISTRIBUTION

1.2 REFERENCES

A. American Water Works Association (AWWA):

1. C111 – Rubber Gasket Joints for Ductile-Iron Pressure Pipe and Fittings
2. C502 – Dry-Barrel Fire Hydrants
3. C550 – Protective Interior Coatings for Valves and Hydrants
4. C600 – Installation of Ductile-Iron Water Mains and Their Appurtenances

B. ASTM International (ASTM):

1. A 242 – Standard Specification for High-Strength Low-Alloy Structural Steel

C. National Fire Protection Association (NFPA):

1. NFPA 1963—Standard for Fire Hose Connections

D. NSF/ANSI:

1.3 SUBMITTALS

A. Quality Control:

1. The Manufacturer shall submit a written statement that the inspection and the specified tests have been completed and that results comply with the requirements of this Section.
2. Each factory assembled unit shall be hydrostatic tested in accordance with AWWA C502. Shop tests for the body and main valve shall be conducted at a pressure of 300 psi.
3. UL certification: Dry barrel fire hydrants shall be UL listed, and a copy of the UL certification shall be provided to DW, if requested.

1.4 QUALITY ASSURANCE

A. Fire hydrants shall be designed and manufactured in accordance with AWWA C502.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Ship fire hydrants in rigid, secure packaging protected from damage and weather.

B. Handle fire hydrants securely with rigging and pick points that minimize unbalanced forces on the assembly.

C. Store on improved surfaces or solid blocking a minimum of 8 inches above grade to prevent prolonged contact with the ground or moisture.

1.6 WARRANTY

A. Warranty for 1 year from acceptance of product unless the Manufacturer provides a longer warranty period.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Dry-Barrel Fire Hydrants:

1. City and County of Denver and Total Service contract areas:
   a. American Cast Iron Pipe/Waterous, Pacer WB-67-250
   b. Kennedy, K-81DD
   c. Mueller Company, Centurion Model A-403
2. Distributor contract areas:
   a. American Cast Iron Pipe/Waterous, Pacer WB-67-250
   b. American AVK, Series 27
   c. Clow, Medallion F-2545
   d. Kennedy, K-81D and K-81DD
   e. Mueller Company, Centurion Model A-403

2.2 MATERIALS

A. Fire hydrants shall be designed for a working pressure of 150 psi.

1. Brass and bronze components that have surfaces in contact with potable water shall be certified to comply with NSF/ANSI 61.

B. Inlet Connection:

1. The hydrant base shall be provided with a mechanical joint inlet to accommodate 6-inch DI pipe complete with plain rubber gasket, gland, bolts, and nuts in accordance with AWWA C111.
2. Bolts and nuts shall be a high strength, low alloy, corrosion resistant steel Cor-Ten or equal with a minimum yield of 50,000 psi in accordance with ASTM A 242.
3. Two lugs shall be incorporated into the base for the rodding of pipe.
4. Mechanical joint accessories shall be attached to the hydrant for shipment.

C. Main Valve Assembly:

1. The main valve opening size shall be at least 5 1/4 inches.
2. The main valve shall be the compression type that closes with water pressure.
3. The main valve shall be a replaceable type fabricated of a resilient material with a threaded bottom plate or nut, with a seal to prevent leakage of the hydrant shaft.
4. The seat ring shall be bronze with a machined face and external threads for threading into a bronze drain ring or a bronze-bushed shoe to provide bronze to bronze seating for the main valve.

5. The assembly shall be sealed with O-rings.
6. The upper valve plate material shall be bronze or epoxy-coated DI.
7. The valve assembly shall include one or more drain valves that work automatically with the main valve to drain the barrel when the main valve is in the closed position.
8. Drain tubes shall be bronze-lined and sized large enough for the barrel to drain within 12 minutes when sized for a 5 foot trench depth.
9. The components of the main valve assembly shall be designed so that removal of the assembly from the barrel may be accomplished without excavation.

D. Operating Shaft and Nut:
1. The upper and lower operating rods shall be SST.
2. Bronze or DI and pentagon shaped with a finished height of 1 1/8 inch.
3. The dimensions from point to flat shall be between 1 1/4 inch and 1 3/8 inch from the top to the bottom of the nut. Bushings in the bonnet shall be constructed to prevent the operating nut from traveling during opening or closing operation.
4. House a gasket or seal to prevent moisture or foreign materials from entering the lubricant reservoir.
5. Hydrants shall be grease lubricated or of a dry top design where an oil reservoir will provide permanent lubrication of the operating nut threads.
6. A stop nut located in the hydrant bonnet on the operating shaft shall prevent the over travel of the main valve when it is being opened.
7. The hydrant shall open by turning the operating nut clockwise and shall have an arrow on top of the bonnet to designate the direction of opening.

E. Pumper Nozzle and Cap:
1. The pumper nozzle shall be 4 1/2 inches nominal diameter with 5 3/8 inch OD threads having six threads per inch; threads shall be right hand.
2. A sample nozzle will be furnished upon request.
3. Furnish with a synthetic rubber gasket installed in a retaining groove.
4. The dimensions and shape of the nozzle cap nut shall be the same as the operating shaft nut.
5. Furnish cap with a security chain; the end shall be securely attached to the upper barrel section of the hydrant.

F. Hose Nozzles and Caps:
1. The two hose nozzles shall be 2 1/2 inch nominal diameter with seven and one-half threads per inch (2.5 to 7.5 NHT).
2. Threads shall be right hand NST.
3. Nozzle caps shall be furnished with security chains; each end shall be securely attached to the upper barrel section of the hydrant.

G. Nozzle Attachment:
1. Outlet nozzles shall be fastened into the barrel by mechanical means and secured by a SST pin or screw, bronze wedge, or DI retainer.
2. Nozzles shall be sealed using O-rings.

H. Coatings:
1. The upper exposed section of the hydrant shall be thoroughly cleaned and painted with a prime coat of a rust inhibitive primer followed by a 10 mil DFT shop coat of heavy duty alkyd enamel paint.
2. The paint color shall be yellow, similar to Federal Color No. 13538.
3. Exposed exterior surfaces below the ground line shall be coated with asphalt varnish in accordance with AWWA C502.
4. The interior of the hydrant shall be coated with an epoxy coating in accordance with AWWA C502.
5. The hydrant shoe and connecting gland shall be lined and coated with fusion-bonded epoxy in accordance with AWWA C550.
6. Traffic Features: Hydrants shall be equipped with traffic features that include a breakaway flange or lug system with a shaft coupling.

PART 3 EXECUTION

3.1 PREPARATION

A. Clean fire hydrants to remove any dirt, debris, shipping straps, or any other items that would interfere with installation.
B. Inspect components and check for any damage, out of round, bent, or otherwise inoperable condition. Do not install if any defects are found.

3.2 INSTALLATION

A. Hydrants shall be field staked for location and grade.
B. The final location shall be in accordance with plans.
C. Fire hydrants shall be set so that the elevation of the center of the traffic flange is 3 inches above the ground line or top of the curb.
D. Hydrants shall stand plumb with a minimum horizontal clearance of 5 feet.
E. Each hydrant shall be connected to the street main by a 6-inch DI branch line.
F. Existing hydrant branch lines that are any material other than DI pipe shall be replaced in their entirety with DI pipe from the hydrant tee or tapping sleeve to the hydrant.
G. An independent 6-inch gate valve shall be installed on each fire hydrant branch.
H. The valve shall be firmly anchored to a mechanical joint tee with a 6-inch anchor coupling (also called a swivel adapter or a locked hydrant adapter) or to a mechanical joint anchor tee (also called a swivel tee or a locked hydrant tee).
I. The fire hydrant branch shall be anchored to the valve by mechanical joints.

J. Exception: When making a wet tap for a fire hydrant, a tapping valve and saddle shall be used in place of the mechanical joint tee, swivel adaptor, and valve.
K. Drainage shall be provided at the base of the hydrant by placing rock from the bottom of the trench to at least 12 inches above the barrel flange of the hydrant and to a minimum distance of 12 inches around the elbow.
L. The minimum distance from the bottom of the trench to the bottom of the hydrant elbow shall be 6 inches.
M. The minimum amount of rock placed shall be 1/3 cy.
N. The rock shall be 1 1/2-inch crushed granite.
O. To protect the hydrant from corrosion, the branch line and fittings from the hydrant base up to and including the tee shall be encased in landscaping felt.
P. The type of PE and the way it is installed shall be as specified in SECTION 33 05 19.
Q. Bedding and pipe zone material shall be as specified in SECTION 31 23 33 and used from a point 6 inches below to a point 6 inches above the branch line.

3.3 PROTECTION

A. Protection of Fittings: Buried DI pipe fittings shall be PE wrapped in accordance with AWWA C600.

3.4 STARTUP

A. Verify nuts and bolts are properly installed and torqued to the specifications.
B. Crack open the fire hydrant and partially open the isolation valves to pressurize system and bleed out air in system.
C. Close the fire hydrant and inspect for leaks. Hold this condition for a minimum of 30 minutes, isolating, draining, and repairing leaks if required.
D. Close isolation valves and backfill with the proper bedding and pipe zone material.
E. Open isolation valves and connect a fire hose, routing to the nearest gutter that can handle the flow.
F. Open the fire hydrant from closed to fully open and back to closed two times to check for proper operation and tight sealing when it is closed.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for backflow prevention assemblies.

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):
   1. A112.1.2 – Air Gaps in Plumbing Systems (For Plumbing Fixtures and Water-Connected Receptors)

B. American Society of Safety Engineers (ASSE):
   1. 1013 – Performance Requirements for Reduced Pressure Principle Backflow Preventers and Reduced Pressure Principle Fire Protection Backflow Preventers

C. American Water Works Association (AWWA):
   1. C510 – Double Check Valve Backflow Prevention Assembly (DC)
   2. C511 – Reduced-Pressure Backflow Prevention Assembly (RP)
   3. C550 – Protective Interior Coatings for Valves and Hydrants
   4. C800 – Underground Service Line Valves and Fittings

D. ASTM International (ASTM):
   1. B 61 – Standard Specification for Steam or Valve Bronze Castings
   2. B 62 – Standard Specification for Composition Bronze or Ounce Metal Castings
   3. B 584 – Standard Specification for Copper Alloy Sand Castings for General Applications

E. NSF international/American National Standards Institute (NSF/ANSI):
   1. 61 – Drinking Water System Components – Health Effects
   2. 61, Annex G – Weighted Average Lead Evaluation Procedure to a 0.25% Lead Requirement
   3. 372 – Drinking Water System Components – Lead Content

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. DC BFPA:
   1. University of Southern California Foundation for Cross-Connection Control and Hydraulic Research (USC FCCCHR)

B. RP BFPA:
   1. University of Southern California Foundation for Cross-Connection Control and Hydraulic Research (USC FCCCHR)

2.2 MATERIALS

A. RP BFPAs:
   1. In accordance with ASSE 1013 or AWWA C511.
   2. Operation: Continuous pressure applications.
   3. Pressure loss: 12 psig maximum, through middle 1/3 of flow range.
   4. Body: Bronze for nominal pipe size 2 and smaller; CI with interior lining in accordance with AWWA C550 or that is FDA approved steel with interior lining in accordance with AWWA C550 or that is FDA approved SST for nominal pipe size 2 1/2 and larger.
   5. End connections: Threaded for nominal pipe size 2 and smaller; flanged for nominal pipe size 2 1/2 and larger.
   6. Configuration: Designed for horizontal, straight through vertical inlet, horizontal center section, and vertical outlet vertical flow.
   7. Accessories:
      a. Valves: Ball type with threaded ends on inlet and outlet of nominal pipe size 2 and smaller; OS&Y gate type with flanged ends on inlet and outlet of nominal pipe size 2 1/2 and larger.
      b. Air-gap fitting: ASME A112.1.2, matching BFPA connection.

B. BFPA Test Kits: Factory calibrated, with gauges, fittings, hoses, and carrying case with test procedure instructions.

C. Potable Water Applications:
   1. Type V642:
      a. RP BFPAs shall be bronze body and trim.
      b. Maximum pressure drop at rated gpm flow shall not exceed 14 psig.
      c. Each BFPA shall have two gate valves, two independently acting poppet type check valves, one pressure differential relief valve, and four test cocks.
      d. Furnish each BFPA with an air-gap drain funnel.
      e. BFPAs shall have USC approval and be sized as described herein.
   2. Type V680:
      a. RP BFPAs shall be bronze body and trim.
      b. Maximum pressure drop at rated gpm flow shall not exceed 14 psig.
      c. Each BFPA shall have two OS&Y gate valves, two independently acting poppet type check valves, one pressure differential relief valve, and four test cocks.
      d. OS&Y valves shall be installed with NEMA 4 supervisory switches.
      e. Furnish each BFPA with an air-gap drain funnel.
      f. BFPAs shall have UL, FMG, and USC approval and be sized as described herein.
   3. Brass and bronze valve components and accessories that have surfaces in contact with potable water shall be alloys containing less than 15% zinc and 2% aluminum and shall be certified to comply with NSF/ANSI 61, NSF/ANSI 61 Annex G, and NSF/ANSI 372.
   4. Approved alloys: ASTM B 61, ASTM B 62, and ASTM B 584 (Alloy No. B84400).

D. Recycled Water Applications: Brass and bronze goods that have surfaces not in contact with potable water shall be manufactured in accordance with AWWA C800 using alloy UNS No. C83600, commercially known as 85-5-5, in accordance with ASTM B 62.

E. DC BFPA:
   1. Except as modified or supplemented herein, shall be in accordance with AWWA C510.
   2. Rated 175 psi SWP.

F. RP BFPA: Except as modified or supplemented herein, shall be in accordance with AWWA C511.

PART 3 EXECUTION

3.1 INSTALLATION

A. Install BFPAs of the type, size, and capacity as shown on the Drawings. Include valves and test cocks. Install in accordance with the requirements of the plumbing and health department and the AHJ.

B. Do not install BFPAs that have a relief drain in the vault or in other spaces subject toflooding.

C. Do not install bypass piping around BFPAs.

D. Support nominal pipe size 2 1/2 and larger BFPAs, valves, and piping near the floor and on brick or concrete piers.

E. Install a DC BFPA in accordance with the Manufacturer's specifications, in a manhole 2 inch and smaller and in a vault for 2 1/2 inch and larger.

F. Install RP BFPAs in accordance with the Manufacturer's specifications.
   1. Installations within a building to be designed for the mechanical room in accordance with AHJ code.
   2. Installations outside are required at grade in a hot box with electrical service.

3.2 STARTUP

A. The licensee is required to have a certified ABPA or ASSE tester inspect and test an existing or newly installed containment BFPA on dedicated and recycled water service lines, if applicable, upon installation and annually thereafter. Tests shall be conducted at the expense of the licensee. BFPAs shall be repaired or replaced at the licensee's expense when found to be defective. Records of tests, repairs, and replacements shall be kept by the licensee and a copy of the annual test provided to DW.

B. Installed BFPAs that fail to meet the requirements of this Section, but were approved assemblies at the time of installation, may remain if they have been properly maintained and pass annual testing. If the BFPA is replaced, the replacement shall be USC FCCCHR approved.

C. The tester shall:
   1. Complete BFPA testing and submit test reports within 5 days of DW's setting of the meter and turning on of the water service.
   2. Submit a copy of the official ABPA or ASSE certification to DW's Cross Connection Control Group each time the certification is renewed.
   3. Submit a copy of the test kit calibration certification annually.
   4. Have a dedicated recycled water test gauge.
   5. Complete the BFPA test report and submit a copy of the containment BFPA report to DW's Cross Connection Control Group within 5 days. Incomplete or illegible test reports will not be accepted. Test reports shall be supplied on DW's test form which can be obtained online from www.denverwater.org.
   6. Indicate containment or containment by isolation on the test report.
   7. The submission of isolation test results to DW is not required by CDPHE.
   8. Indicate the type of usage (i.e., domestic, irrigation, fire, or recycled) on the test report.
   9. Confirm the DW service address, meter number, BFPA serial number, size, Manufacturer and model, location, and record the values on the test report.
   10. Contact DW's Cross Connection Control Group for discrepancies regarding the meter or BFPA.
   11. Sign, date, and include the time of the test on the report.
   12. Required test reports shall be submitted to DW's Cross Connection Control Group:
       a. Phone: 303-628-5969
          Fax: 303-794-8325
          Email: CrossConnectionControl@denverwater.org
          Mailing Address: Denver Water
          Attn: Cross Connection Control
          6100 W. Quincy Avenue
          Denver, CO 80235

3.3 ADJUSTING

A. Failed Assemblies:
   1. If the BFPA fails and cannot be repaired on the day of its failure, notify the DW Cross Connection Control Group by the certified ABPA or ASSE tester within 24 hours. A copy of the failed test report shall be submitted to the Cross Connection Control Group within 3 days.
   2. The Property Owner is responsible for coordinating the necessary repairs to the BFPA and retesting the unit within 15 days. The Property Owner shall submit a passing test report to the DW Cross Connection Control Group. Failure to comply may result in the suspension of water service.
   3. If the premises has a high hazard BFPA and is deemed a threat to public health (via the private plumbing system), it is at the discretion of DW to suspend the dedicated water service line immediately. The Property Owner shall repair or replace the BFPA before water service will be restored.

B. Exemptions: Single family residential customers are exempt from DW's cross connection control requirements unless the premises is served by a fire suppression system, a dual water supply, or other known hazards. Dual water supply conditions require a Dual Water Supply Agreement to be in effect between DW and the Property Owner.

C. For questions or concerns related to cross connection control, contact DW's Cross Connection Control Group:
   1. Phone: 303-628-5969
   2. Email: CrossConnectionControl@denverwater.org

END OF SECTION

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SECTION 33 15 00
RUBBER-SEATED BUTTERFLY VALVES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for 3 inch through 72 inch rubber-seated butterfly valves.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 40 27 95 – ELECTRIC VALVE AND GATE ACTUATORS

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):

1. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Class 125

B. American Water Works Association (AWWA):

1. C207 – Steel Pipe Flanges for Waterworks Service, Sizes 4 In. Through 144 In. (100 mm Through 3,600 mm)
2. C210 – Liquid-Epoxy Coatings and Linings for Steel Water Pipe and Fittings
3. C504 – Rubber-Seated Butterfly Valves
4. C509 – Resilient-Seated Gate Valves for Water-Supply Service
5. C550 – Protective Interior Coatings for Valves and Hydrants
6. M49 – Quarter-Turn Valves: Head Loss, Torque, and Cavitation Analysis

C. ASTM International (ASTM):

1. D 429 – Standard Test Methods for Rubber Property – Adhesion to Rigid Substrates

D. The Society for Protective Coatings/NACE International (SSPC/NACE):

1. SP 10/NACE No. 2 – Near-White Blast Cleaning

1.3 COORDINATION

A. Type V504 butterfly valves: Except as modified or supplemented herein, butterfly valves supplied under this Section shall be designed and manufactured in accordance with AWWA C504 for valves up to 72 inches in diameter.

B. Provide butterfly valves as listed in Supplement A, and as shown on the Drawings.

C. Valves supplied under this Section may include two installation types: Buried or in-plant. The type of valves, class of valves and type of actuators to be supplied are identified in Supplement A.

D. Valves covered by this Section will be referred to as either standard valves or recycled water system valves.

E. Recycled water system valves shall be identical to standard valves as specified herein, except that the valves shall open with a counter-clockwise rotation of the handwheel or operating nut, the operating nut shall be five-sided, and painted purple matching Pantone 2577U color.

F. Valves shall be identified by the tag/item numbers listed in Supplement A.

1.4 SUBMITTALS

A. Shop Drawings:

1. Make and model of each equipment assembly.
2. Weights of valve assemblies and individual components.
3. Manufacturer's catalog information, descriptive literature, Specifications, and identification of materials of construction.
4. Detailed structural and mechanical drawings showing the equipment fabrications and interface with other items. Include dimensions, size, and locations of connections to other work, and weights of equipment associated therewith.
5. Submit the following calculations in accordance with AWWA M49 for each valve and service condition:
   a. Minimum required shaft torque curves for both opening and closing cycles in 10-degree increments.
   b. Valve actuator torque capacity.
   c. Shaft sizing if the valve is beyond the scope of AWWA C504.

B. Quality Control Submittals:

1. Manufacturer's certificate of proper installation as specified in SECTION 01 78 23.
2. Manufacturer’s proof-of-design test documentation in accordance with AWWA C504.
   a. Actuator.
   b. Valve.

C. O&M Manual: As specified in SECTION 01 78 23.

D. Extra Materials: Furnish, tag, and box for shipment and storage any special tools required to maintain or maintenance valve.

E. Supplements listed in this Section.

1.5 QUALITY ASSURANCE

A. Valve Manufacturer Qualifications: A minimum of 5 years of documented experience in the Work of this Section.

1.6 WARRANTY

A. The Equipment Supplier shall provide a full, unconditional 1-year warranty covering:

1. Valve.
2. Gear actuator.
3. Electric operator.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Valves:

1. DeZurik
2. Henry Pratt
3. Mueller

4. M&H Valve
5. Val-Matic

B. Valve Actuators:
1. Buried valves:
   a. Auma Model GS
   b. Limitorque, Type HBC
   c. EIM, Type WD
   d. Rotork, IW
2. In-plant and submerged valves:
   a. Worm gear actuators:
      1) Auma Model GS
      2) EIM, Type WO
      3) Limitorque, Type PT
      4) Rotork IW
   b. Traveling nut actuators:
      1) Manufactured by the Valve Manufacturer

C. Finishes for Internal Surfaces:
1. Epoxy Coating:
   a. Amercoat 370
   b. Amerlock 400
   c. Corvel ECA-1626
   d. Tnemec Series 141F Pota-Pox 80

D. Finishes for External Surfaces:
1. Flange faces:
   a. Houghton, Rust-Veto M.P.
   b. Rust-Oleum, R-9

2.2 MATERIALS

A. General:
1. Service: Valves shall be suitable for throttling service and/or frequent operation as well as service involving long periods of inactivity. Valves shall be capable of operating satisfactorily with flows in either direction. Valves shall be suitable for use in potable and recycle service.
2. Installation:
   a. Buried: Valves specified as buried in Supplement A shall be for buried service in horizontal waterlines with the valve shaft horizontal and operating nut shaft vertical. The body of valves shall be buried and the actuators shall be installed in manholes. Actuators for buried type installations shall be worm gear type only.
   b. In-plant: Valves specified as in-plant in Supplement A shall be for service inside buildings or other structures in a relatively dry environment, protected from weather. Unless otherwise shown on the Drawings, the valves shall be installed with the valve shaft horizontal. The actuator shall be directly mounted to the valve body. Manual actuated in-plant installation shall be a worm gear or traveling nut type. Electric actuated in-plant valves shall be worm gear type only.
3. Shut off pressure: The maximum static differential pressure across the valve will be the same as the class of the valve. At rated pressure, the valve shall be bubble tight for flows in either direction.

B. Class of Valve: In accordance with AWWA C504, Class 150B.

C. Valve Bodies: Short body pattern. Disc stops on the body will not be allowed.

D. Valve Discs: Gray iron or DI. Discs having hollow chambers that can entrap water will not be allowed.

E. Valve Seat:
1. Rubber seats may be applied to either the body or the disc. The mating seat surface, in either case, shall be Type 304 SST or sprayed in accordance with AWWA C504.
2. Rubber seats shall be EPDM, peroxide cured.
3. Rubber seats shall be full circle 360-degree seal with no segmenting or breaks in the rubber seat.
4. 24-inch diameter and smaller: Rubber seats mounted in the groove of the valve body may be bonded to the body. Bonded seats shall withstand a 75-lb pull in accordance with ASTM D 429, test procedure Method B (90-degree stripping).
5. 30-inch diameter and larger: Rubber seats mounted in the valve body or the disc shall be retained by mechanical means such that the seat can be adjusted to provide a tight shutoff. The valve shaft shall not penetrate the rubber seat.
6. Seat retaining hardware shall be Type 304 SST, the same as the mating seat surface material.

F. Valve Shaft: The valve shaft shall be Type 304 SST.

G. Shaft Seal:
1. For valves 24 inches in diameter and smaller:
   a. Self-compensating V-type packing.
   b. O-ring type contained in a corrosion resistant cartridge.
2. For valves 30 inches in diameter and larger:
   a. Self-compensating V-type packing.
   b. Adjustable packing with bronze or SST pull down packing gland follower.

3. On buried valves, the shaft seal area and exposed valve shaft shall be totally enclosed to prevent infiltration of material around the shaft seal and valve shaft during backfilling. Adjustable packing glands shall be accessible either through the bonnet or by removing the enclosure around the packing gland.

H. Valve Bearings: Valves furnished with an externally adjustable thrust bearing shall have the external adjusting mechanism enclosed in an O-ring sealed watertight housing.

I. Type of Valve Ends:
1. Valves shall be furnished with flanged ends. Dimensions and drilling shall be in accordance with ASME B16.1, Class 125. Flanges shall be finished to true plane surfaces within a tolerance limit of 0.005 inch. The finished face shall be normal to the longitudinal valve axis within a maximum angular variation tolerance of 0.002 in/ft (0.017%) of flange diameter. Flanges shall be machined to a flat surface with a serrated finish in accordance with AWWA C207.
2. Flanges shall have full-sized bolt holes through the flanges, drilled and tapped holes will be acceptable only in the areas where the shaft passes through the body. Flanges with all holes tapped are not allowed.
3. If required in Supplement A, flange bolt holes shall be over drilled by an additional 1/8 inch in accordance with AWWA C207 to accommodate flange insulators.

J. Valve Bonnet: Buried valves shall be furnished with a separate one piece CI or fabricated steel extension bonnet with (if applicable) access openings fitted with removable covers, located to permit access to the stuffing box for tightening the adjustable packing. The extension bonnet shall be 24 inches in length and shall be of a single diameter over its entire length. The minimum thickness of the removable cover shall be 14 gauge (0.0747 inch) and shall be attached to the extension sleeve with a minimum of four 1/4-inch diameter cap screws. Gasketing of the opening is not required.

K. Name Plates: Corrosion-resistant nameplates shall be provided. There shall be one valve nameplate attached to the valve body. The valve nameplates shall include at a minimum, the manufacture date, pressure class, shop order number, tag/item number identified in Supplement A and the serial number. There shall be one actuator nameplate attached to the valve actuator.

L. Valve Actuators:
1. Design details:
   a. Worm gear actuators shall have high tensile bronze worm gears, and a worm of hardened alloy steel. Gearing of the manual actuator shall be totally enclosed and sealed for food grade and accepted and formulated for a temperature range of –10°F to 150°F. The Manufacturer shall fill the gear case with lubricant to 90% of full prior to shipment from the factory.
   b. Traveling nut actuators shall be manufactured by the Valve Manufacturer and shall be capable of withstanding 450 ft-lbs of input torque.
   c. Primary gearing shall be supplemented by spur gear attachment to comply with the following conditions of operation for valves:
      1) Buried valves: Minimum number of turns for complete opening or closing of valve disc shall not be less than 40.
   d. Unless otherwise specified in Supplement A, valves shall be furnished with manual actuators. The maximum velocity for actuator design shall be based on operating requirements shown in Supplement A.
   e. Valves requiring electric actuators as identified in Supplement A, shall be as specified in SECTION 40 27 95. Electric actuator torque capacity shall be a minimum of 1.5 times the maximum valve operating torque, including seating and unseating torques. Mechanical gear reduction for electrically actuated butterfly valves shall be worm gear type.
   f. Actuators shall be provided with handwheels of suitable size to open the valves with the specified maximum pull; the handwheel diameter shall not exceed 2 feet.
   g. Actuators, including buried service, shall have a mechanical valve position indicator.
   h. Standard valves: Actuators shall be equipped with 2-inch square wrench nuts in accordance with AWWA C509. See Supplement A for opening direction of the valves.
   i. Recycled water system valves: The actuators shall be equipped with a five-sided operating nut as shown on the Drawings. The valves shall open with a counter-clockwise rotation of the nut. The nuts shall be painted purple as specified in this Section.

2.3 FINISHES

A. Internal Surfaces: Internal ferrous surfaces except machined or bearing surfaces shall be prepared for coating by blasting to a near white metal finish in accordance with SSPC SP 10/NACE No. 2. These surfaces shall then be coated with a two-part thermosetting polyamide epoxy in two or more uniform coats, or with fusion-bonded epoxy, to a minimum DFT of 10 mils. The epoxy coating shall be in accordance with AWWA C550.

B. External Surfaces:
1. External surfaces except machined or bearing surfaces shall be carefully prepared by removing dirt, grease, and rust and shall be cleaned to the extent that the coating will bond to the surfaces.
2. Buried valves: The exterior of each valve except flange faces shall be shop-coated in accordance with AWWA C210 or AWWA C550, to a minimum DFT of 16 mil.
3. In-plant valves: The exterior of each valve except flange faces shall be shop-coated with one coat of polyamide anti-corrosive epoxy primer to a DFT of not less than 3 mils.

C. Flange faces shall be shop-coated with a rust-preventive compound prior to shipment.

D. After above painting is completed, a lubricant compatible with the rubber seat shall be applied to the surface of this seat and the mating metal surface to prevent bonding of the two surfaces during shipment and storage. Following application of the seal lubricant, the valve disc shall be placed in a slightly open position for shipment.

PART 3 EXECUTION

3.1 INSTALLATION

A. In accordance with the Manufacturer's instructions and the Shop Drawings.

B. Orient valve so the seat adjustment is from the downstream side of the valve disc or as shown on the Drawings.

C. Prior to installation, rust-preventive compounds shall be removed and the flange faces cleaned.

D. Valve Assembly:

1. Buried and in-plant valves shall be shipped fully assembled.
2. Valves and their respective parts shall be identified by their item or tag number in accordance with Supplement A. Tag numbers shall be on the valve nameplates or on separate waterproof tags attached to the valves.

3.2 QUALITY CONTROL

A. OWNER Witness Testing:

1. The Manufacturer shall test the valves and furnish certified copies of the reports on the performance test, leakage test, hydrostatic test, and holiday test.
2. The Manufacturer shall provide 21-day notice prior to completion of factory tests for site visit accommodations or preparations for virtual OWNER witness testing.
3. The ENGINEER or the ENGINEER’s Representative shall be present for factory testing. The OWNER will pay for ENGINEER or the ENGINEER’s Representative’s travel, lodging, transportation, and meal expenditures for on-site OWNER witness testing.

B. Functional Tests: Operate each valve two complete open-close cycles.

C. Manufacturer's Services:

1. Manufacturer's Representative: Present at the site for a minimum of 2 person-days per valve for inspection, functional and performance testing, and completion of the Manufacturer's certificate of proper installation.

3.3 SUPPLEMENTS

A. Supplement A – Butterfly Valve Schedule

END OF SECTION

SUPPLEMENT A
BUTTERFLY VALVE SCHEDULE

TAG NO.	LOCATION	SIZE (IN)	AWWA CLASS	ACTUATOR TYPE/DIRECTION OF ROTATION	OPERATION	INSTALLATION TYPE/SERVICE	INSULATING FLANGE (OVERSIZED FLANGE BOLT HOLES)

Abbreviations:
OR Open Right
OL Open Left

Operation: Open/Close, Throttling, or Modulating
Installation: In-Plant, Buried, or Submerged
Service: Standard or Recycle System

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SECTION 33 19 13
WATER METERS FOR SERVICE LINE INSTALLATIONS

PART 1 GENERAL

1.1 SUMMARY
- A. Section includes general information, products, and execution for water meters for service line installations.
- B. Related Sections:
  1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
  2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
  3. SECTION 01 91 00 (.01 or .02) – COMMISSIONING

1.2 REFERENCES
- A. American Society of Mechanical Engineers (ASME):
  1. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250
- B. American Water Works Association (AWWA):
  1. C116 – Protective Fusion-Bonded Coatings for the Interior and Exterior Surfaces of Ductile-Iron and Gray-Iron Fittings
  2. C207 – Steel Pipe Flanges for Waterworks Service – Sizes 4 In Through 144 In. (100 mm Through 3,600 mm)
  3. C510 – Double Check Valve Backflow Prevention Assembly
  4. C622 – Pipe Bursting of Potable Water Mains 4 In. (100 mm) to 36 In. (900 mm)
  5. C700 – Cold-Water Meters – Displacement Type, Metal Alloy Main Bronze Main Case
  6. C701 – Cold Water Meters – Turbine Type, for Customer Service
  7. C702 – Cold Water Meters – Compound Type
  8. C703 – Cold Water Meters – Fire Service Type
  9. C707 – Encoder-Type Remote-Registration Systems for Cold-Water Meters
- C. ASTM International (ASTM):
  1. A 48 – Standard Specification for Gray Iron Castings
- D. Denver Water (DW):
  1. Engineering Standards, 16th Edition
- E. NSF International (NSF):
  1. 61 – Drinking Water System Components – Health Effects
  2. 372 – Drinking Water System Components – Lead Content

1.3 DEFINITIONS
- A. AMR: The technology of automatically collecting consumption, diagnostic, and status data from water meter or energy metering devices and transferring that data to a central database for billing, troubleshooting, and analyzing.
- B. AMI: An integrated system of smart meters, communications networks, and data management systems that enables two-way communication between utilities and customers.
- C. ERT: Technology used to transmit data from utility meters over a short range so a utility vehicle can collect meter data without a worker physically inspecting each meter.
- D. Magnetic Drive Meters: Meters that measure fluid flow by the voltage induced across the liquid by its flow through a magnetic field.
- E. Nutating Disc: A type of meter that operates by having a disc mounted to a central ball. When fluid enters the chamber, it causes the disc to wobble (nutate), transferring the displaced volume to the register.
- F. Oscillating Piston: A type of meter that contains a precision machined chamber containing a cylindrical piston that oscillates as liquid flows through it.

1.4 SUBMITTALS
- A. Warranty documentation.
- B. O&M documentation as specified in SECTION 01 78 23.
- C. Product Data:
  1. Manufacturer.
  2. Material.
  3. Equipment drawings and data.
  4. Provide list, which indicates use, operating range, total range, and location for manufactured components.
  5. Include data substantiating that materials are in accordance with the requirements.
- D. Informational Submittals: Product certificates for each type of meter from the Manufacturer.
- E. Quality Control:
  1. The Manufacturer shall submit a written statement that the inspection and the specified tests have been completed and the results comply with the requirements of these standards and are in accordance with NSF/ANSI 61 and NSF/ANSI 372 certifications.
  2. Documentation tag.
- F. Closeout Submittals:
  1. As-Built Drawings: Submit complete As-Built Drawings of Work, including interface with other Work.
  2. Record actual locations of components and instrumentation.

1.5 QUALITY ASSURANCE
- A. Meters shall adhere to the referenced AWWA and NSF standards.
- B. Documentation Tag:
  1. Firmly attached to meter.
  2. Identifying characteristics:
     - a. Nominal size.

b. Manufacturer.
c. Meter number.
d. Register type and model number.
3. Manufacturer's serial number.
4. DW meter number.
5. Form 39 bar code representation of the DW meter number.
6. Manufacturer's certified test results.

C. Meter Number:
1. The DW meter number shall be plainly stamped or engraved on the meter main case.
2. Heat stamped in a contrasting color on the plastic register cap.
3. Attached to the meter in form 39 bar code using a separate tag.
4. Paper or plastic number labels affixed to the register are not acceptable.
5. Manufacturer's serial numbers shall run consecutively for each meter in the group ordered and stamped on the top of the register cap.

D. Flanged In-Line Basket Strainers:
1. The Manufacturer shall submit a written statement that the inspection and the specified tests have been completed and that results comply with the requirements of these Standards.
2. Components in contact with potable water shall be certified to comply with NSF/ANSI 61, and a copy of the NSF/ANSI 61 certification shall be provided to DW, if requested.

1.6 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00.

1.7 WARRANTY

A. The manufacturer shall provide a full unconditional 1-year warranty covering the components of the meters, registers, and register boxes.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Meter Registers and Register Boxes:
1. Badger Meter, Inc.
   a. HR-E
   b. HR-E LCD
2. Mueller Systems – Hersey Products, Inc.
   a. Translator Encoder Register
3. Neptune Technology Group
   a. ProCoder

B. Magnetic Drive Displacement Type Water Meters:
1. Badger Meter, Inc.
   a. Recordall Disc Series
2. Mueller Systems – Hersey Products, Inc.
   a. 400 IIS Model
   b. 500 IIS Model
3. Neptune Technology Group
   a. T-10 Meter

C. Magnetic Drive Compound Type Water Meters:
1. Badger Meter, Inc.
   a. Recordall Compound Series Meter
2. Neptune Technology Group
   a. TRU/FLO Compound Meter

D. Magnetic Drive Turbine Type Water Meters:
1. Badger Meter, Inc.
   a. Recordall Turbo Series Meter
2. Neptune Technology Group
   a. High performance (HP) Turbine Meter

E. Magnetic Drive Turbine Type Fire Service Water Meters:
1. Badger Meter, Inc.
   a. Fire Series Assembly
2. Neptune Technology Group
   a. HP Fire Service Turbine Meter

F. Fire Hydrant Meters:
1. Badger Meter, Inc.
   a. Model FHM Fire Hydrant Meter
2. Neptune Technology Group
   a. Fire Hydrant Meter

G. BFPA Manufacturers:
1. For use with Fire Hydrant Meters
2. USC FCCCHR reduced pressure

H. Flanged In-Line Basket Strainers:
1. Badger Meter, Inc.

2. Neptune Technology Group

2.2 MATERIALS

A. Components in contact with potable water shall be certified to comply with NSF/ANSI 61 and NSF/ANSI 372.

2.3 COMPONENTS

A. Meter Registers and Register Boxes:
   1. Required for magnetic drive type meters.
   2. General:
      a. Meters shall be compatible with the AMR/AMI system in use by the OWNER and furnished with registers in accordance with AWWA C707 with the following additional requirements or exceptions.
         1) The AMR system: Itron Model 100W series ERT.
         2) ERTs: Return to the Manufacturer at their end of life to divert unnecessary waste from the landfill.
         3) AMI system: Badger Orion Cellular LTE Endpoint.
   3. Registers and register boxes:
      a. Registers:
         1) Electronic pulser or electronic digital encoder with a permanent potted wire connection for the AMI or ERT unit.
         2) Factory-wired and potted to a 5 feet long minimum wiring harness with a female, watertight, quick-connect terminal approved by Itron.
            a) Wire lengths will be indicated by DW.
         3) Delivered preprogrammed to provide electronic readings for up to nine digits, as appropriate for the brand of meter.
         4) Electronic precision for a pulser register shall be 1 gallon; an encoder register shall be 50 gallons or less.
         5) Compatible with both:
            a) Itron Model 100W series ERTs using Itron WYSIWYG ROCLs.
            b) Badger Orion Cellular LTE Endpoint.
         6) Straight reading, magnetic drive, U.S. gallons that are permanently sealed and protected from the environment.
         7) Protected from tampering by the inclusion of a formed joint that can be unsealed only by the destruction of one or more of the components that form the joint.
      b. The register box shall attach to the outer case of the meter by an interior or exterior locking device.
   4. Mechanical register dials:
      a. Manufactured in accordance with AWWA C700, Table 4.
      b. Number wheels or stationary zeros used for billing purposes (1,000 gallons and up) shall have black numbers against a white background.
      c. Digits under 1,000 gallons, whether stationary or movable, shall have white numbers with a black background or shall be indicated by a box on the dial face.
      d. Register equipped with a test hand and test index circle or a test hand and graduated test number wheel.
   5. Register cap:
      a. Register boxes equipped with a register cap that completely covers the register lens.
      b. Register cap capable of being moved to another register in the event the meter is moved.

B. Magnetic Drive Displacement Type Water Meters:
   1. In accordance with AWWA C700.
   2. Size: 5/8 inch through 2 inches nominal diameters.
   3. Meter description:
      a. Nutating disc or oscillating piston type.
      b. Meters of size 1 1/2 inches and 2 inches:
         1) Internal parts easily removable to not disturb the connections to the pipeline and for removal of the meter.
         2) SST mounting bolts.
         3) Flange gaskets.
   4. Meter main cases and flanges:
      a. Constructed of copper alloy in accordance with AWWA C700.
      b. Flanges:
         1) For 1 1/2 inches and 2 inches, two-hole, oval type and shall not contain slotted holes.
         2) An integral part of the main case and composed of the same material.
         3) Not removable from the main case.
      c. Serrated finish in accordance with AWWA C702.
      d. A test port supplied on the outlet side of the meter.
   5. Registers and register boxes: Provide in accordance with the requirements of this Section.
   6. Bottom plates:
      a. Breakable design for 5/8 inch through 1-inch meters.
      b. CI construction.
      c. Coated with baked enamel to protect from corrosion.
      d. Provided with a plastic line that does not prevent the bottom plate from breaking as designed.
   7. Piston/disc spindles, thrust rollers, thrust roller bearing plates, and measuring chamber diagrams:
      a. In accordance with AWWA C700.
      b. Monel, SST, or a suitable engineering plastic.

8. Drive spindle or upshaft:
    a. SST or a suitable engineering plastic.
    b. Driving pawl and magnet securely fastened to the drive spindle in a manner that prevents the loss of the pawl during normal operation of the water meter.
9. External fasteners: SST in accordance with AWWA C700.

C. Magnetic Drive Compound Type Water Meters:
1. In accordance with AWWA C702.
2. Size: 3 inches through 6 inches.
3. Meter description:
    a. Displacement section: Disc or oscillating piston type.
    b. Main line: Turbine type.
    c. Design:
        1) Internal parts easily removable to not disturb the connections to the pipeline and for removal of the meter.
        2) SST mounting bolts.
        3) Furnish flange gaskets.
4. Meter main cases and flanges:
    a. Copper alloy in accordance with AWWA C702.
    b. Flanges:
        1) Four-hole, round type and shall not contain slotted holes.
        2) Integral part of the main case and composed of the same material.
        3) Not removable from the main case.
        4) Machined flat and have a serrated finish in accordance with AWWA C207.
    c. A test port supplied on the outlet side of the meter.
    d. Registers and register boxes: Provide in accordance with the requirements of this Section.
5. Piston/disc spindles, thrust rollers, thrust roller bearing plates, and measuring chamber diagrams:
    a. In accordance with AWWA C702.
    b. Monel or SST.
6. Drive spindle or upshaft:
    a. SST or a suitable engineering plastic.
    b. Driving pawl and magnet securely fastened to the drive spindle in a manner that prevents the loss of the pawl during normal operation of the water meter.
7. External fasteners: SST in accordance with AWWA C702.
8. Torrent section:
    a. Constructed in accordance with AWWA C702.
    b. Provided with SST fasteners.

D. Magnetic Drive Turbine Type Water Meters:
1. In accordance with AWWA C701.
2. Size: 1 1/2 inches through 12 inches.
3. Description:
    a. Designed for easy removal of internal parts, the strainer, and the meter.
    b. Strainers:
        1) Furnished with each meter.
        2) Integral part of the main case for 1 1/2 inch and 2-inch meters.
        3) SST internal parts.
        4) Casing provided with a removable top plate with SST fasteners.
    c. SST mounting bolts.
    d. Flange gaskets.
4. Meter main cases and flanges:
    a. Copper alloy in accordance with AWWA C701.
    b. For 1 1/2 inch and 2-inch meters, flanges shall be two-hole, oval type
    c. For 3 inch and larger meters, flanges shall be round in accordance with AWWA C701.
    d. For 12 inch and larger meters, flanges may be CI with a corrosion-resistant coating approved by DW.
    e. Flanges:
        1) Integral part of the main case and composed of the same material.
        2) Not removable from the main case.
        3) Shall not have slotted holes.
        4) Machined flat and have a serrated finish in accordance with AWWA C207.
    f. A test port supplied on the outlet side of the meter.
5. Registers and register boxes: Provide in accordance with the requirements of this Section.
6. Measuring turbines: Constructed with materials in accordance with AWWA C701.
7. Turbine spindles: Monel or SST.
8. External fasteners: SST in accordance with AWWA C701.

E. Magnetic Drive Turbine Type Fire Service Water Meters:
1. General:
    a. In accordance with AWWA C703.
    b. Main casings, internal parts, and strainers shall be designed for easy removal.
    c. Strainers, SST mounting bolts, and flange gaskets shall be furnished with each meter.

2. Size: 3-inch through 10-inch.
3. Main cases: Constructed of CI in accordance with AWWA C703.
4. Flanges:
    a. Integral part of the main case.
    b. Composed of the same material as the case.
    c. Not removable from the main case.
    d. Shall not have slotted holes.
    e. Machined to a flat surface with serrated finish in accordance with AWWA C207.
    f. A test port supplied on the outlet side of the meter.
5. Mainline Meter: Turbine type; UL listed or FMG approved.
6. Bypass Meter: Turbine type or compound type; ball valves shall be installed directly upstream of the meter and downstream of the bypass meter check valve.
7. Registers and register boxes: Provide in accordance with the requirements of this Section.
8. Coating: Main cases shall have a polymerized coating in accordance with AWWA C116.

F. Fire Hydrant Meters:
1. In accordance with AWWA C701.
2. Description:
    a. Meter housing:
        1) Aluminum.
        2) Straightening vanes.
        3) Strainer.
        4) Fire hose couplings.
        5) Gate valve: Positioned after the meter or required BFPA.
    b. Registers:
        1) Straight read.
        2) Permanently sealed.
        3) Magnetic drive.
        4) 100 U.S. gallon sweep.
    c. Measuring element: Easily removable for required maintenance.
    d. Installations:
        1) Requires the installation of a DW approved BFPA.
        2) BFPA shall be completely supported.
        3) Fire hydrants that are used and subsequently damaged by a CONTRACTOR will be repaired by DW at the expense of the CONTRACTOR.
    e. Approved BFPA: An approved USC FCCCHR BFPA RP shall be installed with fire hydrant meters and a gate valve.
    f. Backflow prevention: Manufactured in accordance with AWWA C510 and AWWA C622 and meeting USC FCCCHR specifications.

G. Flanged In-Line Basket Strainers:
1. General:
    a. Fabricated from CI in accordance with ASTM A 48, Class 35B.
    b. Approved by the NFPA and/or UL and used for turbine meters where required.
    c. Unless approved in advance by the Meter Inspector, the same brand as the meter.
2. Flanges:
    a. Sized and drilled in accordance with ASME B16.1, Class 125.
    b. Machined to a flat surface with a serrated finish in accordance with AWWA C207.
3. Cover plates:
    a. Strainers provided with a removable, bolted top cover plate for the inspection and removal of the basket and debris.
    b. A 3/4-inch drain valve and a 3/4-inch vent valve provided on the bottom and the top, respectively.
4. Baskets:
    a. Fabricated from SST alloy UNS S31600 or high impact plastic with a net open area of at least four times the nominal size of the pipe in which the strainer is installed.
    b. Easily removable for periodic inspection and maintenance.
5. Working pressure:
    a. Strainers designed for a working pressure of 150 psi.
    b. Maximum head loss shall be 4 psi at maximum rated flow capacity.

PART 3 EXECUTION

3.1 GENERAL

A. Meters:
1. Meter installations can proceed after the meter is tested and numbered by DW.
2. Registers and associated AMR/AMI devices shall be fully compatible with the meter reading system in use where the meter is installed.
3. The Meter Inspection Supervisor will determine the AMR/AMI system to be used.
4. Meter installations, 3 inch and larger, will be inspected by DW prior to backfilling and upon completion of the installation.

5. Meter installations, 2 inch and smaller, will be inspected by DW after final grade is established at a minimum of 5 feet radially around the meter setting.
6. AMR/AMI device will be installed by DW personnel at the time the meter installation is inspected and at the expense of the Owner of the premises.
7. Meters shall be the same size as the corporation stop or service tee and that portion of the service pipe between the meter and the corporation stop.
8. Meters smaller than 3/4 inch shall not be installed unless it is to serve as a replacement for an existing meter of the same size.
9. DW may allow for the installation of a meter that is smaller than the service pipe provided the service pipe is reduced to the size of the meter for a distance of no less than 10 times the larger pipe diameter on the inlet side of the meter, or 5-feet, whichever is longer.

B. Outside Meter Setting:
1. Outside meters shall be installed with the inlet and outlet spuds in a horizontal position and housed in a concrete or approved composite meter pit or vault in accordance with the Standard Drawings.
2. Meter shall be installed in an approved coppersetter or yoke.
3. Coppersetters for 1 inch and smaller meters shall be installed with the meter spuds located 18 inches below the meter pit lid to facilitate maintenance and replacement.
4. The meter shall sit horizontally with the meter register pointing up.
5. Larger meters shall be installed in vaults in accordance with the Standard Drawings.
6. Deviations in installation height, spacing, pipe location, mounting supports, and other details need to be approved in advance in writing by the Meter Inspector.

C. Inside Meter Setting:
1. Inside meter settings are not permitted on water service connections without the written approval of the Meter Inspection Supervisor prior to the installation of the service connection at the main.
2. An inside meter setting request shall be accompanied by an explanation for its need, a site plan drawing to scale showing exact locations of the proposed water facilities with building footprints and paved areas, an indication of the means by which DW will gain access to the meter during normal business hours, and a detailed, dimensioned plan and profile of the meter room that shows piping, equipment, and other water-related facilities such as fire sprinkler controls and BFPAs.
3. Existing inside meter settings on water service connections are permitted to remain provided there are no changes made to the tap, the service line, or the meter setting.
4. The meter shall be relocated to an outside meter pit or vault if the structure containing an inside meter is to be reconstructed, considerably remodeled, or the service line is to be reconstructed, relocated, or replaced.
5. Inside meter settings are for use with 1 1/2 inch and larger meters where there is inadequate room for the proper installation of a meter vault after exhausting other reasonable alternatives.
6. Inside settings will be permitted for industrial and commercial properties and multi-family premises where full-time, on-site management is provided and directly accessible from a public ROW.
7. Safe, unimpeded access during DW's normal working hours shall be provided by the licensee.
8. Written approval to use an inside meter shall be obtained from the Meter Inspection Supervisor prior to tapping the water main.
9. If the tap is already installed, written approval shall be obtained prior to converting the stub-in to a service line.
10. Specific details of meter type, location, access requirements, AMR/AMI configuration, piping, valves, and other requirements will be assessed and approved on a case-by-case basis by the Meter Inspection Supervisor in consultation with the Meter Inspector.
11. An inside meter installation shall be in accordance with the CAD drawing files as detailed in DW's CAD Standards External Requirements.
12. Where approved, inside meter installations shall be in accordance with the following requirements:
    a. The total length of the service line measured from the street main to the inlet valve of the meter shall be 60 feet or less.
    b. The space containing the meter shall be heated to prevent the freezing of pipes and equipment and shall contain a floor drain within 10 feet of the meter.
    c. The space shall be accessible to DW's meter maintenance and meter reading employees during DW's normal working hours with minimal delay.
    d. The meter shall be located immediately adjacent to the point where the domestic service enters the building through the foundation wall with a minimum amount of exposed pipe before the meter.
    e. Meters shall be bolted in place in a flanged DI pipe system with a BSTC on the outlet side of the meter.
    f. Gate valves shall be used on the meter inlet and outlet and on the bypass. Valves shall be non-rising stem, clockwise opening, and mounted vertically. The bypass pipe shall be no greater than 6 feet above the floor and a minimum of 2 1/2 feet above the meter; allow for at least 2 feet of clearance to the wall.
    g. For any installation where a BFPA is not required, a check valve shall be installed 5 feet downstream of the meter.
    h. The top of the meter shall be a maximum of 40 inches above the floor.
    i. BFPAs, PRVs, and other components shall be installed after the meter and downstream bypass tee. In most cases, there shall be 5 feet of pipe between the bypass tee and the first component.
    j. One or more indoor AMI devices or outdoor remote AMR devices are required for inside meter settings, the location of which will be determined during the review of the inside meter request.

D. AMR and AMI Equipment:

1. Meters, with the exception of those in Master Meter Contract Areas, shall be equipped with the AMR/AMI device determined by DW and installed in accordance with DW's instructions in a location that allows for the collection of a radio signal by collection equipment.
2. Special metering and AMR/AMI systems may be required for services connected to water mains in easements.
3. The register of each meter shall be equipped with an AMR/AMI device and mounted, as directed by the Meter Inspector.
4. In most cases, the meter shall be equipped with the latest model of Itron Pit ERT.
5. In special circumstances identified by the Meter Inspector, AMI or a remote AMR device may be required at a distance of up to 150 feet of wire length from the meter pit to the vault and mounted on the outside of the building, on a post, or on another structure.
6. The signal wire (Belden #9451) for remote AMR device installations shall be run through 1-inch PVC conduit at a minimum.
   a. For most installations on 1 inch and smaller meters, the AMR/AMI device shall be mounted through the CI meter pit lid or beneath the composite meter pit or vault lid .
   b. For most installations on 1 1/2 inch and larger meters, the AMR/AMI device shall be mounted beneath the manhole lid. For some installations on 3 inch and larger meters, a remote AMR device with the signal cable in a conduit may be required. This determination will be made on a case-by-case basis. The Meter Inspector will provide direction as to the type and location of the AMR/AMI device required during the mandatory Pre-Construction Meeting for meter installations. One AMR/AMI device is required for each meter register.
   c. For existing meter installations of any size, DW will make determinations to change the meter pit or vault lid and AMR device mounting at its discretion and cost. Such installations may incorporate adapters and special mounting equipment selected and approved by DW.
   d. Where inside meter settings are approved in advance in writing by the Meter Inspection Supervisor, AMI or remote AMR devices shall be installed on the outside of the building as directed by DW. The licensee shall provide the approved signal cable in a conduit from the location of the meter to the mounting location of the AMR device; the length of the signal cable shall not exceed 150 feet.
   e. Special circumstances: Any meter setting , including inside meter settings, will need to be approved in writing by DW's Meter Inspector before construction. If it is necessary to obtain radio signals using drive by equipment from a public street or via a meter reading network, DW may require the installation of a remote AMR device, radio repeater, network collector, and/or other special equipment or installation configuration installed at the expense of the licensee. Some meter reading devices may require the licensee to provide a mounting location and an electric power source.

E. Meter Bypass Line:

1. A bypass line is required for 1 1/2 inch and larger meters except those used for irrigation-only service, whether installed in an outside or an inside setting.
2. Bypass lines shall contain an independent isolation valve and shall not contain tees, plugs, or other outlets through which water could be withdrawn.
3. Bypass lines permit the customer to have water while the meter is being repaired or replaced and may only be activated by DW.
4. Bypass lines for 1 1/2 inch and 2-inch meters shall be integral to the meter yoke with an appropriately sized ball valve.
5. Bypass lines for 3 inch and larger meters shall be connected to the main line at tees before and after the meter and shall include a gate valve with wheel operator.
6. Bypass lines shall be locked in the closed position when not in use.

F. Flanged In-Line Basket Strainers:

1. Spacing between the strainer and the meter is critical to the accurate measurement of water for billing purposes.
2. Strainers shall be installed in accordance with the Meter Manufacturer's installation guidelines.
3. Only strainers designated for bolt on design shall be directly connected to the water meter.
4. Recommended or required lengths of straight pipe before and after the strainer shall be observed.

G. Construction: The CONTRACTOR shall be a licensed plumber by the AHJ to perform work in the public ROW and have a current plumbing license to install service lines inside Denver, Total Service, and Read and Bill Contract Areas where work is to be performed.

3.2 STARTUP

A. Startup and commissioning requirements for the equipment specified herein as specified in SECTION 01 91 00.

3.3 ADJUSTING

A. Adjust faces of meters and gauges to the proper angle for best visibility.

END OF SECTION

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SECTION 33 41 17
SUBDRAINAGE PIPES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for subdrainage pipes.

B. Related Sections:

1. SECTION 01 33 00 – SUBMITTAL PROCEDURES
2. SECTION 31 23 22 – ZONED FILL
3. SECTION 33 05 31.26 – POLYVINYL CHLORIDE PIPE SLEEVE

1.2 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):

1. Standard Specifications for Highway Bridges

B. American Water Works Association (AWWA):

1. C900 – Polyvinyl Chloride (PVC) Pressure Pipe and Fabricated Fittings, 4 In. Through 60 In. (100 mm Through 1,500 mm)

1.3 SUBMITTALS

A. Submit the following as specified in SECTION 01 33 00.

1. Pipe data:
   a. Details and materials for pipe connections and anticipated field fabricated joints.
   b. Locations of slotted (drain) pipe and solid (discharge) pipe.
2. Installation plan:
   a. Manufacturer's installation instructions.
   b. Method for connecting pipes to manholes.
   c. Method to protect pipe and hold pipe in place during backfill.
   d. Method for working backfill material under haunches.
   e. Method for cleaning pipe after installation.
3. Testing and inspection plan: Details, procedures, and sequences of testing and inspection of drain and outfall.

B. Certifications:

1. Manufacturer's certification that raw materials and pipe meet specification requirements.
2. Certifications that filter and drain materials meet specifications.

C. Samples:

1. Three samples, 1 foot long, of each size of slotted/perforated pipe and solid pipe sampled from each lot of pipe to be used in Work.
2. Label each sample with the Project name, the specifications number, and the Manufacturer's name, product name, date of manufacture, and Manufacturer's lot identification number.
3. Ship the samples to DW.

D. Survey Reports: Location (northing, easting, station, offset, and elevation) of pipe alignments.

1.4 QUALITY ASSURANCE

A. Inspect the interior of toe drain using CCTV after the toe drain pipe has been installed and prior to pipe being placed into service. Provide a digital copy of the inspection to the ENGINEER for review and approval prior to pipe being placed into service. The ENGINEER will review the footage to determine if the toe drain is free of abnormalities, bulges, cracks, and obstructions and will determine if the joints have separated. Any damage to the toe drain as a result of placement, backfilling, or other CONTRACTOR-related activities will be repaired or replaced at no cost to the OWNER.

B. Coordinate inspections with the ENGINEER. Notify the ENGINEER, in writing, of the date and time pipe will be ready for inspection, at least 5 calendar days before inspection is required.

C. Provide safe access and working conditions for inspections.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Store and handle pipe in accordance with the Manufacturer's recommendations.

B. Do not use rope, cable, or chain slings for handling pipe. Canvas slings not less than 4 inches wide may be used for handling pipe.

C. Protect pipe from damage and prevent soil from getting inside pipe when lowering pipe into trench, laying pipe, and positioning pipe.

PART 2 PRODUCTS

2.1 MATERIALS

A. PVC Drain and Discharge Pipes:

1. PVC pipes as specified in SECTION 33 05 31.26, Schedule 80 or in accordance with AWWA C900, DR 25 min.
2. Discharge pipes shall be solid, without slots or perforations.
3. Drain pipes shall be slotted, meeting the following requirements:
   a. Pipe slots:
      1) Minimum of four rows of slots at 3 inch maximum row spacing.
      2) Each row shall consist of three pipe slots spaced at 120 degrees.
      3) Maximum slot length of 4 inches and maximum slot width of 1/8 inch.
      4) Minimum Inlet area: 5 sq in/ft of pipe.
      5) Evenly distribute perforations in rows around length and circumference of pipe.
      6) Remove burrs from pipe slotting.
4. Joining system: Integral bell and spigot with elastomeric gaskets.
   a. Schedule 80 – solvent welding as specified in SECTION 33 05 31.26.

b. AWWA C900 – integral bell and spigot with elastomeric gaskets.
5. Fittings:
a. Includes bends.
b. In accordance with selected drain pipe specifications.
c. Material: As specified for pipe.

B. Filter Sand and Drain Gravel Materials:
1. Filter sand and drain gravel as specified in SECTION 31 23 22.
2. Gradations of filter sand and drain gravel materials will be verified in-place after compacting filter.

PART 3 EXECUTION

3.1 INSTALLATION

A. Pipe:
1. Lay pipe to the elevations, lines, and grades shown on the Drawings or as approved.
2. Cap or plug ends of pipe during periods when no work is occurring.
3. Protect pipe ends from damage. Remove or replace broken, cracked, or unsuitable pipe and replace at no additional cost to the OWNER.
4. Before and during the assembly of a joint, keep parts free of mud, oil, or grease. Keep pipe interior free from deposits of mud, sand, gravel, or other foreign matter and in good working condition until the Work is complete and accepted.
5. Joining pipe:
a. Couplings shall have a close fit with pipe and shall maintain the alignment of pipe and prevent the separation of joints.
b. Joining shall be as specified in SECTION 33 05 31.26 or in accordance with AWWA C900.
6. Maintain in correct position and alignment during installation and subsequent construction operations.
7. Angle points and curvilinear drain alignments:
a. Construct bends using the Manufacturer's standard pipe bends. Maximum bend shall be 22.5 degrees. A minimum length of 5 feet of straight pipe shall be installed between bends.
b. Making curvilinear alignments in the field by pulling pipe into radius bends less than 150 feet will not be allowed.
c. A maximum bend of 3 degrees at pipe joints is allowed.
8. Keep excavations dry.

B. Backfill:
1. Maintain pipe grade and alignment during placement of material adjacent to and over pipe. Provide complete circumferential support for pipe to prevent uneven pressures and unacceptable ring deflections.
2. Use special compaction techniques adjacent to pipe as specified in SECTION 31 23 22.
3. Fill trenches above drain materials.
4. Do not backfill until installed pipe has been inspected and approved by the ENGINEER.
5. Do not permit heavy equipment travel over pipe until backfill material has been placed to a minimum depth of 3 feet over the top of the pipe, or to a greater depth when recommended by the Pipe Manufacturer.
a. After minimum earth covers are in place, the maximum equipment loading allowed over the pipe shall be H-20 loading in accordance with the AASHTO Standard Specifications for Highway Bridges.
b. If pipe is damaged during backfill operations the CONTRACTOR will repair or replace it at no additional cost to the OWNER.

3.2 CLEANING

A. Toe Drain Pipe:
1. Maintain inside of pipes clean during construction.
2. Before performing final video inspection, clean drain lines and outfalls to remove deposits of mud, sand, gravel, or other foreign matter.
3. If inspection indicates more than one cup of material over a 100 foot length of drain pipe, the system shall be flushed and re-inspected at no additional cost to the OWNER.

END OF SECTION

SECTION 33 41 18
HDPE PIPE AND INSTALLATION

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for HDPE pipe and installation.

B. Related Sections:
   1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
   2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   3. SECTION 33 05 31.13 – POLYVINYL CHLORIDE PIPE FOR WATER TRANSMISSION AND DISTRIBUTION
   4. SECTION 33 14 11 – WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL

1.2 REFERENCES

A. American Association of State Highway and Transportation Officials (AASHTO):
   1. M 252 – Standard Specification for Corrugated Polyethylene Drainage Pipe
   2. M 294 – Standard Specification for Corrugated Polyethylene Pipe, 300- to 1500-mm (12- to 60-in.) Diameter

B. American Society of Mechanic Engineers (ASME):
   1. B16.5 – Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard

C. ASTM International (ASTM):
   1. D 2321 – Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and other Gravity-Flow Applications
   2. D 3350 – Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
   3. F 477 – Standard Specification for Elastomeric Seals (Gaskets) for Joining Plastic Pipe
   4. F 714 – Standard Specification for Polyethylene (PE) Plastic Pipe (DR-PR) Based on Outside Diameter
   5. F 2164 – Standard Practice for Field Leak Testing of Polyethylene (PE) and Crosslinked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure
   6. F 2620 – Standard Practice for Heat Fusion Joining of Polyethylene Pipe and Fittings

D. NSF International/American National Standards Institute (NSF/ANSI):
   1. 61 – Drinking Water System Components – Health Effects

1.3 SUBMITTALS

A. Warranty documentation as specified in SECTION 01 60 00.

B. O&M documentation as specified in SECTION 01 78 23.

C. HDPE Pipe Manufacturer's storage, handling, installation, and joining specifications.

D. Complete Manufacturer specifications and QC test data for HDPE pipe and fittings certifying the HDPE pipe supplied meets the chemical, physical, and manufacturing requirements specified.

E. Manufacturer Data and Shop Drawings for the following:
   1. Tracer wire and termination boxes.
   2. Utility marker tape.
   3. Pipeline markers.
   4. Restrained flexible couplings.
   5. Flange adapters.
   6. Non-shrink grout.
   7. Polyurethane sealer.
   8. Silicone sealer.
   9. Silicone foam.

F. HDPE pipe fusion welder certifications and qualifications.

G. Tracer wire continuity test procedure and the CONTRACTOR qualifications.

H. Field Testing Results:
   1. Welding data logger test reports for each welded joint.
   2. Hydrostatic pressure test results.

I. Calculations:
   1. Horizontally directional drilled casing: Calculations for proposed SDR wall thickness to withstand earth, live, and groundwater service loads and the pullback load.

1.4 QUALITY ASSURANCE

A. Provide and maintain a QC program.

B. General: Materials shall be free from defects impairing strength and durability and be of the best quality for the purposes specified or shown on the Drawings. It shall have structural properties sufficient to solely sustain or withstand strain and stresses to which it is normally subjected and be true to detail.

C. Manufacturer's Qualifications:
   1. Provide piping and appurtenances that are the standard product in regular production by Manufacturers whose products have proven reliable in similar service for at least 5 years.
   2. Provide piping and appurtenances of the same type from a single Manufacturer.

D. Make field measurements prior to installation of the Work. Any deviations in measurements between the field conditions and the Drawings shall be immediately reported to the ENGINEER.

E. HDPE Installer and Welder Qualifications: The personnel operating the fusion joining equipment shall be trained by the Manufacturer or the Manufacturer's Representative within the last 12 months.

F. Delivery, handling, and storage shall be in accordance with the Manufacturer's recommendations. The pipe or appurtenance shall not be dumped, dropped, or thrown. Interiors of piping shall be completely free of dirt and foreign matter.

G. Certify that lining for potable water lines is certified to NSF/ANSI 61.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Delivered Pipe:
   1. Pipe shall be clean and shall not contain any chemical residues from the pipe manufacturing operation.
   2. Reject any pipe containing greasy residues or diesel soot.

B. Inspection:
   1. Examine the pipe identification marks to verify that pipe meets the contract Specifications.
   2. Reject pipe with scratches penetrating more than 10% of the pipe wall thickness.
   3. Remove rejected pipe from the site.

C. Store and handle the pipe as recommended by the Manufacturer.

D. Seal the ends of the pipe to protect the inside from contamination during storage.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Pressurized HDPE Pipe or Fittings:
   1. Isco Industries, LLC
   2. JM Eagle
   3. JCM
   4. Poly Pipe
   5. Romac
   6. Smith-Blair

B. Sealing of Sleeves and Penetrations:
   1. Non-shrink grout:
      a. Master Builders Masterflow #713
   2. Polyurethane sealer:
      a. Vulkem 116/Mameco International
   3. Silicone sealer:
      a. Dow-Corning #790
   4. Silicone foam:
      a. Chase #CTC PR-855 Chase-Foam
      b. Dow Corning #3-6548 Silicone RTV Foam

C. Buried Piping Identification Tape:
   1. As specified in SECTION 33 14 11.

2.2 MATERIALS

A. Pressurized HDPE Pipe and Fittings:
   1. The outside of piping, valves, and fittings shall bear the Manufacturer's standard marking for type, pressure, etc. in accordance with ASTM F 714.
   2. Pipe and fittings shall be equal to or better than the grade specified.
   3. Piping material shall be new and free from defects and shall be subject to standard mill test before being shipped.
   4. Pipe shall be cut off even and reamed full bore. Piping shall be installed clean of chips, burrs, or oil.
   5. Pipe designated for potable water use shall be NSF/ANSI 61 certified.
   6. No salvaged or used pipe shall be used without the written approval of the ENGINEER or the OWNER. Wherever such approval is given, the ends of the pipe shall be recut, square, new threads on screwed pipe cut, and the pipe cleaned of rust, dirt, scale, and foreign matter before installation.
   7. Furnish HDPE pipe and any necessary elbows and fittings for a complete installation including flanged HDPE connections to steel pipe where shown on the Drawings. The CONTRACTOR is responsible to verify the HDPE pipe, HDPE fittings, and associated appurtenances are compatible.

B. Pressurized HDPE Pipe:
   1. Manufacture to dimensions and tolerances in accordance with ASTM F 714, and factory inspect in accordance with industry standards.
   2. HDPE pipe iron pipe size as shown on the Drawings.
   3. Directional drilled casing: SDR wall thickness shall be selected to withstand earth, live, and groundwater service loads and the pullback load.

C. Pressurized Pipe Resin:
   1. Extra-high-molecular weight, high-density ethylene/hexene copolymer PE 4710 resin with a minimum ASTM D 3350 cell classification number of 445474C.

D. Pressurized Fittings:
   1. Manufactured from the same resin type, grade, and cell classification as the pipe, and conforming to the same physical properties.
   2. Manufactured by injection molding or by extrusion and machining or fabricated from PE pipe in accordance with specified pipe dimensions.
   3. Fully pressure-rated with a working pressure equal to that of pipe for 50-year service at 73.4°F, with a safety factor of 2.
   4. Pipe flanges where shown on the Drawings. Supply materials to adequately assemble joints.
   5. Flange fittings shall have compatible wall thickness to each corresponding pipe. Do not use stub ends to substitute flange adapters. Include ASME B16.5 Standard Class D backup rings for the direct burial application unless otherwise shown on the Drawings.

6. Restrained flexible couplings shall be in accordance with the Pipe Manufacturer's recommendations and submitted to the ENGINEER for approval.
7. Tapping sleeves shall be as specified in SECTION 33 05 31.13.

E. Pressurized Pipe Joining Methods:
1. Join pipes and fittings by thermal butt fusion welding methods, in accordance with the Manufacturer's specified procedures and applicable ASTM procedures. Other joining methods shall only be used as approved by the ENGINEER.

F. Gravity HDPE Pipe:
1. Type: Dual wall corrugated pipe and smooth interior drainage pipe in accordance with AASHTO M 252 or M 294, Type S or SP.
2. Joint Type: Integral bell and gasketed spigot, soil tight, in accordance with ASTM F 477.

G. Landscape Drains:
1. Type: Concrete or PVC storm drain inlets.
2. Duty: H-20 rated.
3. Grates: DI, size as shown on the Drawings.

H. Buried Piping Identification Tape:
1. As specified in SECTION 33 14 11.

PART 3 EXECUTION

3.1 PREPARATION

A. Verify lines, grades, and measurements before installing pipes.

B. Confirm location of pipe, fittings, and connections. Coordinate pipe installation with structure installation.

3.2 INSTALLATION

A. Tracer wire and termination boxes shall be installed as shown on the construction Drawing details. Termination boxes shall not exceed 1,000 feet spacing. Tracer wire shall also be provided on HDPE piping including blowoff assemblies and air valves and terminate in a 3 foot minimum coil above ground. Tracer wire shall be tested in the presence of the ENGINEER for continuity. Final acceptance will not be granted until continuity is to the satisfaction of the ENGINEER.

B. Magnetic detectable tape shall be installed as shown on the construction Drawing details. Magnetic detectable tape shall also be provided on HDPE piping including blowoff assemblies.

C. Inspect pipe and fittings prior to assembly. Mark and remove from the jobsite materials that are damaged or do not meet these Specifications.

D. Dragging the pipe along the ground surface is prohibited.

E. Pressure Pipe:
1. Install pipe in accordance with the most stringent requirements of the approved HDPE Pipe Installation Plan, this Section, or ASTM D 2321.
2. Allow pipe to sufficiently cool in accordance with the Manufacturer's recommendations prior to making connection or backfilling at anchored joints, flanges, fittings, or other locations where excessive pull-out forces could develop.
3. Joining:
   a. Thermal butt-weld joints in strict accordance with ASTM F 2620 and the Manufacturer's instructions. Use heat-fusion equipment and welding procedures required by the Pipe Manufacturer.
   b. The fusion equipment shall be equipped with a Datalogger. Submit records of the welds (heater temperature, fusion pressure, and a graph of the fusion cycle) verifying welding in accordance with the Manufacturer's requirements.
   c. Produce joint-weld strengths equal to or greater than the tensile strength of the pipe.
   d. Socket fusion is prohibited.
   e. The fusion equipment operator shall receive training using the recommended procedure. Verify the fusion equipment is in good operating condition and the operator has been trained within the past 12 months. The ENGINEER may require a field bend test of a butt fusion weld and samples for possible tensile strength testing at the start of the project to verify acceptable welds will be produced.
   f. Install flanged fittings and restrained flexible couplings for connecting to steel pipe where shown on the Drawings.
   g. Do not join more than one fitting to the pipe prior to placing in the trench. Join additional fittings in the trench using flanges.
   h. Saddle fusion, socket fusion, electrofusion, solvent cement, adhesive, threaded type, or any other joining methods are prohibited.
4. HDPE flange adapter installation:
   a. Flanges with backing rings shall be attached to HDPE pipe and fittings using thermal butt-fusion.
   b. The flanges/backing rings shall be aligned and centered relative to the pipe.
   c. Flanges/backing rings shall be square with the valve or other flange before the tightening of bolts.
   d. Bolts shall not be used to draw flanges into alignment. Bolt threads shall be lubricated, and flat washers shall be used under flange nuts. Bolts shall be tightened using a star-tightening pattern in accordance with the Manufacturer's recommendations. Re-tighten the flange bolts 24 hours after the first tightening using the same pattern. The final tightening torque shall be as indicated by the Manufacturer.

F. Bedding and Backfill Placement:
1. Restrain pipe as necessary to prevent movement during backfill operations.
2. Install compacted earthen bedding or install flowable fill pipe bedding.
3. Where earthfill pipe bedding material is installed, spread the initial layer of bedding smooth and uniform to the required depth to provide a continuous support beneath the pipe. After each pipe section is in final position,

deposit and compact bedding material uniformly under the haunches and around each side of the pipe to prevent pipe displacement. Deposit in maximum 6-inch lifts and compact each lift. Install bedding and pipe zone material so total pipe deflection in any direction does not exceed the Manufacturer's specified allowances for pipe, or 7% of nominal diameter, whichever is more stringent.

4. Provide backfill outside the pipe zone. Processed excavated material may be used.
5. Adjust moisture content as necessary to obtain specified compaction. Do not allow backfill to free fall into the trench or allow heavy, sharp pieces of material to be placed as backfill until after at least 2 feet of backfill has been provided over the top of the pipe.
6. Compaction of the haunching material shall be accomplished by hand with tampers or suitable power compactors while not disturbing the pipe from its line and grade. Do not use heavy-duty power-driven impact type compactors for compaction with less than 5.5 feet of cover over the top of the pipe.
7. Backfill to grade with proper allowances for topsoil, crushed rock surfacing, and pavement thicknesses, wherever applicable.
8. When trench underlies or is next to structures, backfill around or under structures with the same class backfill as specified for the structure.

G. Tapping shall be as specified in SECTION 33 05 31.13.

H. Buried piping identification tape shall be as specified in SECTION 33 14 11.

3.3 QUALITY CONTROL

A. Pressurized Pipe:

1. Cut out and remove sections of pipe with cuts or gouges in excess of 10% of the wall thickness and replace with undamaged pipe.
2. Make the necessary provisions for conveying the water from the OWNER-designated source to the points of use.
3. Pressure test pressure pipelines using water. Perform test operations in the presence of the ENGINEER.
4. Prior to hydrostatic testing, thoroughly clean and flush or blow out pipelines, as appropriate. Test pipelines in sections to ensure that in-line valves are leak tight. No section of the pipeline shall be tested until all field-placed concrete or mortar has attained an age of at least 14 days or 75% of design strength minimum. Make the test by closing valves when available or by placing temporary bulkheads in the pipe and filling the line slowly (less than 1/2 fps) with water. Ensure that test bulkheads are suitably restrained to resist the thrust of the test pressure without damage to, or movement of, the adjacent pipe. Ensure that air vents are open during filling and blow-off valves are closed.
5. Fill the pipeline at a rate that will not cause any surges or exceed the rate at which the air can be released through the air valves at a reasonable velocity and all the air within the pipeline is properly purged. During this period, examine bulkheads, valves, and connections for leaks. If leaks are found, take corrective measures satisfactory to the ENGINEER.
6. During the initial expansion time of 4 hours, the PE pipe will expand and require makeup water to maintain pressure.
7. The hydrostatic test is complete when the pressure remains steady (within 5% of the target value) for 1 hour. The test pressure for distribution and transmission pipelines shall be 1 1/2 times the working pressure of 200 psig.
8. Test duration shall not exceed 8 hours under any condition. If the test is not completed during this time, the pipeline shall be drained and allowed to relax for 8 hours prior to re-testing.
9. Inspect each joint for visual leakage. If during the ASTM F 2164 Testing Phase no visual leakage is observed and the pressure remains steady, a passing test may be recorded. Any indication of leakage shall result in a failed hydrostatic pressure test. In the case of pipelines that fail to pass the prescribed leakage test, determine the cause of the leakage, take corrective measures necessary to repair the leaks, and re-test the pipelines. Continue until the pipeline passes the test.
10. Submit a test report which includes the following:
    a. Date, time, and duration of test.
    b. Number of joints tested, passed, and failed.
    c. Results of re-tested joints after repair.

END OF SECTION

SECTION 40 05 00
PROCESS PIPING – GENERAL

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for process piping.

B. Related Sections:

1. SECTION 01 60 00 – MATERIAL AND EQUIPMENT
2. SECTION 09 90 00 – PAINTING AND COATING
3. SECTION 09 97 13.05 – HEAT SHRINK COATINGS
4. SECTION 13 47 16 – ISOLATION AND BONDING FOR CATHODIC PROTECTION
5. SECTION 33 05 19 – DUCTILE-IRON PIPE AND FITTINGS FOR WATER TRANSMISSION AND DISTRIBUTION
6. SECTION 33 05 24.23 – STEEL PIPE FOR WATER TRANSMISSION
7. SECTION 33 05 31.13 – POLYVINYL CHLORIDE PIPE FOR WATER TRANSMISSION AND DISTRIBUTION
8. SECTION 33 14 11 – WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL
9. SECTION 33 14 19 – VALVES FOR WATER UTILITY PIPING
10. SECTION 33 41 18 – HDPE PIPE MATERIAL AND INSTALLATION
11. SECTION 40 05 06 – COUPLINGS, ADAPTORS, AND SPECIALS FOR PROCESS PIPING
12. SECTION 40 42 13 – PIPING INSULATION
13. SECTION 40 80 01 – PROCESS PIPING LEAKAGE TESTING

1.2 REFERENCES

A. American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME):

1. A13.1 – Scheme for the Identification of Piping Systems

B. American Society of Mechanical Engineers (ASME):

1. B1.20.1 – Pipe Threads, General Purpose (Inch)
2. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250
3. B16.3 – Malleable Iron Threaded Fittings: Classes 150 and 300
4. B16.5 – Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard
5. B16.9 – Factory-Made Wrought Buttwelding Fittings
6. B16.11 – Forged Fittings, Socket-Welding and Threaded
7. B16.21 – Nonmetallic Flat Gaskets for Pipe Flanges
8. B18.2.2 – Nuts for General Applications: Machine Screw Nuts, Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)
9. B31.3 – Process Piping
10. B31.9 – Building Services Piping
11. B36.10M – Welded and Seamless Wrought Steel Pipe

C. American Water Works Association (AWWA):

1. C110 – Ductile-Iron and Gray Iron Fittings
2. C115 – Flanged Ductile-Iron Pipe with Ductile-Iron or Gray-Iron Threaded Flanges
3. C151 – Ductile-Iron Pipe, Centrifugally Cast
4. C205 – Cement-Mortar Protective Lining and Coating for Steel Water Pipe – 4 In. (100 mm) and Larger –Shop Applied
5. C207 – Steel Pipe Flanges for Waterworks Service, Sizes 4 In. through 144 In. (100 mm through 3,600 mm)
6. C210 – Liquid-Epoxy Coatings and Linings for Steel Water Pipe Fittings
7. C219 – Bolted, Sleeve-Type Couplings for Plain-End Pipe
8. C220 – Stainless-Steel Pipe, 1/2-In. (13 mm) and Larger
9. C226 – Stainless-Steel Fittings for Waterworks Service, Sizes 1/2 In. through 72 In. (13 mm through 1,800 mm)
10. C606 – Grooved and Shouldered Joints
11. Manual M11 – Steel Pipe – A Guide for Design and Installation

D. ASTM International (ASTM):

1. A 47 – Standard Specification for Ferritic Malleable Iron Castings
2. A 53 – Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless
3. A 105 – Standard Specification for Carbon Steel Forgings for Piping Applications
4. A 106 – Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service
5. A 153 – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
6. A 182 – Standard Specification for Forged or Rolled Alloy and Stainless Steel Pipe Flanges, Forged Fittings, and Valves and Parts for High-Temperature Service
7. A 183 – Standard Specification for Carbon Steel Track Bolts and Nuts
8. A 193 – Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
9. A 194 – Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
10. A 197 – Standard Specification for Cupola Malleable Iron
11. A 216 – Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
12. A 234 – Standard Specification for Piping Fittings of Wrought Carbon Steel and Alloy Steel for Moderate and High Temperature Service

13. A 240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
14. A 269 – Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service
15. A 307 – Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength
16. A 312 – Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes
17. A 320 – Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service
18. A 351 – Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
19. A 403 – Standard Specification for Wrought Austenitic Stainless Steel Piping Fittings
20. A 536 – Standard Specification for Ductile Iron Castings
21. A 563 – Standard Specification for Carbon and Alloy Steel Nuts
22. A 774 – Standard Specification for As-Welded Wrought Austenitic Stainless Steel Fittings for General Corrosive Service at Low and Moderate Temperatures
23. A 778 – Standard Specification for Welded, Unannealed Austenitic Stainless Steel Tubular Products
24. D 638 – Standard Test Method for Tensile Properties of Plastics
25. D 1330 – Standard Specification for Rubber Sheet Gaskets
26. D 1693 – Standard Test Method for Environmental Stress-Cracking of Ethylene Plastics
27. D 1784 – Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
28. D 1785 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120
29. D 2000 – Standard Classification System for Rubber Products in Automotive Applications
30. D 2464 – Standard Specification for Threaded Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
31. D 2466 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 40
32. D 2467 – Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe Fittings, Schedule 80
33. D 2564 – Standard Specification for Solvent Cements for Poly(Vinyl Chloride) (PVC) Plastic Piping Systems
34. F 437 – Standard Specification for Threaded Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
35. F 439 – Standard Specification for Chlorinated Poly (Vinyl Chloride) (CPVC) Plastic Pipe Fittings, Schedule 80
36. F 441 – Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80
37. F 493 – Standard Specification for Solvent Cements for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe and Fittings
38. F 656 – Standard Specification for Primers for Use in Solvent Cement Joints of Poly(Vinyl Chloride) (PVC) Plastic Pipe and Fittings
39. F 2389 – Standard Specification for Pressure-rated Polypropylene (PP) Piping Systems

E. Chlorine Institute (CI):
1. Pamphlet 6 – Piping Systems for Dry Chlorine
2. Pamphlet 95 – Gaskets for Chlorine Service

F. Manufacturers Standardization Society (MSS):
1. SP-43 – Wrought and Fabricated Butt-Welding Fittings for Low Pressure, Corrosion Resistant Applications

G. NSF International/American National Standards Institute (NSF/ANSI):
1. 61 – Drinking Water System Components – Health Effects

1.3 DEFINITIONS

A. Buried Piping: Piping installed underground embedded in the pipe zone or backfill material.

B. Concrete embedded or encased piping: Piping installed in concrete with or without reinforcing steel.

C. Exposed Piping: Piping which is not buried, submerged, wetted, concrete embedded, or encased.

D. Submerged: Piping installed below the top of the liquid surface.

E. Unrestrained Joint: Shop-installed or field-installed pipe joint which, due to its construction, will separate or move as if to separate under the forces imposed by the test pressure shown on the Pipe Schedule or 25 psi, whichever is greater; this shall include, but not be limited to, flexible couplings, flanged coupling adapters, transition couplings, expansion joints, and insulating couplings.

F. Wetted: Piping installed above the top of the liquid surface in a structure intended to contain liquids.

1.4 SUBMITTALS

A. Product Data: Pipe corrosion protection.

B. Action Submittals:
1. Shop-fabricated piping:
   a. Detailed pipe fabrication drawings showing straight sections, special fittings and bends, dimensions, coatings, and other pertinent information.
   b. Layout drawings showing the location of each pipe section and each special length; number or otherwise designate the laying sequence on each piece.
2. Pipe wall thickness: Identify wall thickness and rational method or standard applied to determine wall thickness for each size of each different service including exposed, submerged, buried, and concrete-encased installations for CONTRACTOR-designed piping. Welded steel pipe wall thickness shall be in accordance with AWWA Manual M11 and as specified in SECTION 33 05 24.23.
3. Hydraulic thrust restraint for restrained joints: Details including materials, sizes, assembly ratings, and pipe attachment methods shall be as specified in SECTION 31 23 33 SECTION 33 05 19 and 33 05 31.13.

C. Informational Submittals:
1. Manufacturer's certification of compliance for pipe, fittings, and factory-applied resins and coatings.
2. Non-destructive inspection and testing procedures.

3. Test logs.
4. Pipe Coating Applicator certification.
5. Process piping leakage testing as specified in SECTION 40 80 01.

1.5 QUALITY ASSURANCE

A. Design Requirements:
   1. Where pipe diameter, thickness, pressure class, pressure rating, or thrust restraint is not shown on the Drawings or specified, design the piping system in accordance with:

B. Do not manufacture pipe until required Shop Drawings and design calculations have been approved by the ENGINEER. No changes are permitted from the initial approved design unless unforeseen field conditions arise that make such changes necessary as determined by the ENGINEER.

C. Process Piping: ASME B31.3.

1.6 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 01 60 00, and:
   1. Flanges: Securely attach metal, hardboard, or wood protectors over the entire flange surface.
   2. Threaded or socket welding ends: Fit with metal, wood, or plastic plugs or caps.
   3. Linings and coatings: Prevent excessive drying.
   4. Cold weather storage: Locate products to prevent the coating from freezing to the ground.
   5. Handling: Use heavy canvas or nylon slings to lift the pipe and the fittings.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Pipe:
   1. DI:
      a. As specified in SECTION 33 05 19
   2. PVC:
      a. As specified in SECTION 33 05 31.13
   3. CPVC:
      a. ASAHI/America
      b. Charlotte Pipe
      c. Spears
   4. PP:
      a. ASAHI/America
      b. Nibco

B. Joints:
   1. Flanges:
      a. As specified on the piping data sheets located in the Supplements in this Section.
   2. Grooved end system:
      a. Anvil International, Inc., Gruvlok
      b. Victaulic
   3. Mechanical joint restraint:
      a. As specified in SECTION 33 05 19 and SECTION 33 05 31.13

C. Primer and Solvent Cement – Chemical Service
   1. Primer
      a. Weld-On P-70
   2. Solvent Cement
      a. Weld-On 724

D. Pipe Corrosion Protection:
   1. Coatings: As specified in SECTION 09 90 00
   2. Heat-shrink wrap: As specified in SECTION 09 97 13.05
   3. PE encasement, bagging: As specified in SECTION 33 05 19
   4. Insulating flanges, couplings, and unions: As specified in SECTION 13 47 16

E. SST Fittings:
   1. Crawford, Swagelok
   2. Parker-Hannifin, Ferulok

F. Pipe Labels:
   1. Brady Signmark, B-915 Brady Snap-On and Strap-On Pipe Markers
   2. Seton Identification Products, Ultra-Mark Pipe Markers

2.2 MATERIALS

A. Piping:
   1. As specified on the Pipe Schedule and on the piping data sheets located in the Supplements in this Section.
   2. Diameters shown on the Drawings:
      a. Standardized products: Nominal size.
      b. Fabricated steel piping: The pipe diameter specified is the minimum finished inside diameter in inches after lining as specified in SECTION 33 05 24.23.

B. Joints:
   1. Grooved end system:
      a. Rigid type.

b. The use of flexible grooved joints is allowed where shown on the Drawings or with prior approval by the ENGINEER.
c. Flanges: Furnish with grooved type flange adapters of the same Manufacturer as the grooved end couplings.
2. Mechanical joint restraint:
a. As specified in SECTION 33 05 19 and SECTION 33 05 31.13.
b. Rated operating deflection shall be no less than 2 1/2 degrees.
3. Flanged joints:
a. As specified on the piping data sheets located in the Supplements in this Section.
b. Suitable for the pressure specified in the Pipe Schedule.
c. Higher pressure rated flanges as required to mate with the equipment when the equipment flange is of a higher pressure rating than required for the piping.
4. Threaded joints: NPT taper pipe threads shall be in accordance with ASME B1.20.1.
5. Solvent weld joints:
a. As specified on the piping data sheets located in the Supplements in this Section.
b. Primer and solvent cement used for chemical lines shall be compatible with chemical service in accordance with Manufacturer provided data.

C. Gasket lubricant shall be supplied by the Pipe Manufacturer.
D. Pipe Corrosion Protection:
1. Coatings: As specified in SECTION 09 90 00.
2. Insulating flanges, couplings, and unions:
a. Materials:
1) In accordance with the applicable piping material specified on the piping data sheet. Complete assembly shall have an ASME B31.9 rating equal to or higher than that of the joint and the pipeline.
2) Galvanically compatible with the piping.
3) Resistant for intended exposure, operating temperatures, and products in the pipeline.
b. Union type, 2 inches and smaller:
1) Screwed or solder-joint.
2) O-ring sealed with molded and bonded insulation to the body.
c. Flange type, 2 1/2 inches and larger: Flanged, complete with bolt insulators, dielectric gasket, bolts, and nuts.
d. Flange insulating kits: As specified in SECTION 13 47 16.

E. Thrust ties shall be fabricated lugs and rods in accordance with the details shown on the Drawings.
F. Vent and drain valves shall be as shown on the Drawings
G. SST tube fittings shall be as specified on the piping data sheets.
H. Pipe Identification:
1. Pipe labels:
a. Snap-on, reversible type with lettering and directional arrows, sized for the outside diameter of the pipe and the insulation.
b. Provided with ties or straps for 6 inch and larger diameter pipes.
c. Designed to firmly grip pipe so labels remain fixed in vertical pipe runs.
d. Material: Heavy duty vinyl or polyester, suitable for exterior use, and resist damage or fading from washdown, sunlight, mildly corrosive atmosphere, dirt, grease, and abrasion.
e. Color field and letter height: In accordance with ANSI/ASME A13.1.
f. Message: Piping system name as shown on the Pipe Schedule.

2.3 FABRICATION

A. Mark each pipe length on the outside with the following:
1. Size or diameter and class.
2. Manufacturer’s identification and pipe serial number.
3. Location number on laying drawing.
4. Date of manufacture.

B. Code markings in accordance with approved Shop Drawings.
C. Flanged pipe shall be fabricated in the shop, not in the field, and delivered to the Work site with flanges in place and properly faced. Threaded flanges shall be individually fitted and machine tightened on matching threaded pipe by the Manufacturer.

2.4 FINISHES

A. Factory prepare, prime, and finish coat as specified on the piping data sheets and the Pipe Schedule.
B. Galvanizing shall be hot-dip applied in accordance with ASTM A 153; electroplated zinc or cadmium plating are not acceptable.

PART 3 EXECUTION

3.1 PREPARATION

A. Verify the size, material, joint types, elevation, horizontal location, and pipe service of existing pipelines to be connected to new pipelines or new equipment.
B. Inspect the size and location of structure penetrations to verify the adequacy of wall pipes, sleeves, and other openings.
C. Welding Electrodes: Verify proper grade and type, free of moisture and dampness, and undamaged coating.
D. Additional Requirements: As specified in the Pipe Schedule and in SECTION 09 90 00.
E. Notify the ENGINEER in writing at least 2 weeks prior to field fabrication of pipe or fittings.
F. Inspect pipe and fittings before installation, clean ends thoroughly, and remove foreign matter and dirt from inside the pipe.

G. Repair damaged coatings and linings using original coating and lining materials in accordance with the Manufacturer's instructions.
H. Field Finishing:
   1. Notify the ENGINEER in writing at least 3 days prior to the start of any surface preparation or coating application Work.
   2. As specified in SECTION 09 90 00, SECTION 33 14 11, SECTION 33 05 24.23, and SECTION 33 05 19.

3.2 INSTALLATION

A. General:
   1. Join pipe and fittings in accordance with the Manufacturer's instructions.
   2. Remove foreign objects prior to assembly and installation.
   3. Flanged joints:
      a. Install perpendicular to pipe centerline.
      b. Bolt holes: Straddle vertical centerlines; aligned with connecting equipment flanges or as shown on the Drawings.
      c. Use torque-limiting wrenches to ensure uniform bearing and proper bolt tightness.
      d. Plastic flanges: Install an annular ring filler gasket at the joints of the raised face flange.
      e. Raised face flanges: Use a flat-face flange when joining with a flat-faced DI, CI, or steel flange.
      f. Verify compatibility of the mating flange to the adapter flange gasket prior to selecting grooved adapter flanging.
      g. Threaded flanged joints shall be shop-fabricated and delivered to the site with flanges in place and properly faced.
   4. Threaded and coupled joints:
      a. In accordance with ASME B1.20.1.
      b. Produce sufficient thread length to ensure full engagement when screwed home in the fittings.
      c. Countersink pipe ends; ream and clean chips and burrs after threading.
      d. Make connections with not more than three threads exposed.
      e. Lubricate male threads only with thread lubricant or tape as specified on the piping data sheets.
   5. Grooved end joints:
      a. Piping shall be grooved in accordance with the Manufacturer's latest published instructions and accurately cut with tools in accordance with the coupling Manufacturer's standards and AWWA C606.
      b. Install grooved joint couplings and gaskets in accordance with the Manufacturer's latest published installation instructions.
   6. Pipe connections at concrete structures:
      a. General:
         1) Design and install thrust protection.
         2) Install flexible couplings to facilitate piping installation in accordance with the approved Shop Drawings.
      b. Flexible joints at concrete backfill or encasement: Install within 18 inches or 1/2 pipe diameter, whichever is less, from the termination of any concrete backfill or concrete encasement.
      c. Flexible joints at concrete structures: Install 18 inches or less from the face of the structure; the joint may be flush with the face.
   7. PVC and CPVC piping:
      a. Provide a Schedule 80 threaded nipple where necessary to connect to the threaded valve or the fitting.
      b. Use a strap wrench for tightening threaded plastic joints. Do not overtighten fittings.
      c. Do not thread Schedule 40 pipe.
   8. DI piping:
      a. Cutting pipe: Cut pipe with milling type cutter, rolling pipe cutter, or abrasive saw cutter; do not flame cut.
      b. Dressing cut ends:
         1) General: As required for the type of joint to be made.
         2) Rubber gasketed joints: Remove sharp edges or projections.
         3) Push-on joints: As specified in SECTION 33 05 19.
         4) Flexible couplings, flanged coupling adapters, and grooved end pipe couplings: As recommended by the Coupling or Adapter Manufacturer.

B. Exposed Piping:
   1. Piping runs:
      a. Parallel to building or column lines and perpendicular to floor.
      b. Piping upstream and downstream of flow measuring devices shall provide straight lengths as required for accurate flow measurement.
   2. Group piping wherever practical at common elevations; install to conserve building space and not interfere with the use of space and other Work.
   3. Unions or flanges: Provide at each piping connection to equipment or instrumentation on the equipment side of each block valve to facilitate installation and removal.
   4. Install piping so that no load or movement exceeding that stipulated by the Equipment Manufacturer is imposed upon the equipment connection; install to allow for contraction and expansion without stressing pipe, joints, or connected equipment.
   5. Piping clearance:
      a. Over walkway and stairs: A minimum of 7 feet 6 inches measured from walking surface or stair tread to the lowest extremity of the piping system including flanges, valve bodies or mechanisms, insulation, or hanger and support systems.

b. Between equipment or equipment piping and adjacent piping: A minimum of 3 feet measured from the equipment extremity and the extremity of the piping system including flanges, valve bodies or mechanisms, insulation, or hanger and support systems.
c. From adjacent work: Minimum 1 inch from the nearest extremity of the completed piping system including flanges, valve bodies or mechanisms, insulation, or hanger and support systems.
d. Do not route piping in front of or interfering with access ways, ladders, stairs, platforms, walkways, openings, doors, or windows.
e. Headroom in front of openings, doors, and windows shall not be less than the top of the opening.
f. Do not install piping containing liquids or liquid vapors in transformer vaults or electrical equipment rooms.
g. Do not route piping over, around, in front of, behind, or below electrical equipment including controls, panels, switches, terminals, boxes, or other similar electrical work.

C. Buried Pipe: As specified in SECTION 09 90 00, SECTION 33 05 19, SECTION 33 05 24.23, SECTION 33 05 31.13, SECTION 33 14 11, and SECTION 33 14 19.

D. Concrete Encased:
1. Provide reinforced concrete pipe encasement where shown on the Drawings and where otherwise required. Some piping may be required to be concrete encased for pipe strength requirements that are included in the Contract Documents. Piping under and within the influence of buildings, utility trenches, vaults, slabs, and other structures shall be concrete encased; see details on the Drawings for encasement requirements.
2. Where concrete encased piping crosses structure construction and expansion joints, provide flexible piping joints to coincide with structure joints to prevent excessive pipe stress and breakage.

E. Pipe Corrosion Protection:
1. DI pipe:
   a. Exposed/wetted: As specified in SECTION 09 90 00 and the Pipe Schedule.
   b. Buried: Wrap with PE bagging as specified in SECTION 33 05 19 and the Pipe Schedule.
   c. Submerged or embedded: Field coat as specified in SECTION 09 90 00 and the Pipe Schedule.
2. Carbon steel pipe:
   a. Exposed: As specified in SECTION 09 90 00 and the Pipe Schedule.
   b. Submerged or embedded: Shop coat as specified in SECTION 09 90 00 and the Pipe Schedule.
3. PVC and CPVC pipe, exposed: Shall not be painted.
4. Piping accessories:
   a. Exposed: Field paint black and galvanized steel, brass, copper, and bronze piping components as specified in SECTION 09 90 00 as applicable to the base metal material.
   b. Buried: As specified in SECTION 09 90 00, SECTION 33 05 19, SECTION 33 05 24.23, SECTION 33 05 31.13, SECTION 33 14 11, and SECTION 33 14 19.
5. PE encasement: As specified in SECTION 33 05 19.
6. Insulating flanges, couplings, and unions:
   a. Applications:
      1) Dissimilar metal piping connections.
      2) Cathodically protected piping penetration to buildings and watertight structures.
      3) Submerged to unsubmerged metallic piping connections.
      4) Where required for electrically insulated connection.
   b. Pipe installation:
      1) Insulating joints connecting immersed piping to non-immersed piping shall be installed above the maximum water surface elevation.
      2) Submerged carbon steel, DI, or galvanized piping in reinforced concrete shall be isolated from the concrete reinforcement steel.
      3) Align and install insulating joints in accordance with the Manufacturer's recommendations to avoid damaging insulating materials.

F. Slab, Floor, Wall, and Roof Penetrations:
1. Application and installation: As specified in SECTION 40 05 06.

G. Branch Connections:
1. Do not install branch connections smaller than 1/2 inch nominal pipe size, including instrument connections.
2. When a line of lower pressure connects to a line of higher pressure, the requirements of the piping data sheet for higher pressure rating prevails up to and including the first block valve in the line carrying the lower pressure.
3. Threaded pipe tap connections:
   a. DI piping: Connect only at a tapping boss of a fitting, valve body, or equipment casting. Service saddles shall not be used unless shown on the Drawings.
   b. Welded steel or alloy piping: Connect only with welded threadolet as specified on the piping data sheet.
   c. Limitations: Threaded taps in the pipe barrel are not acceptable.

H. Vents and Drains: At high and low points in piping that are required for a completed system. Install vents on high points and drains on low points of pipelines.

I. Insulation: As specified in SECTION 40 42 13.

J. Colors:
1. Pipe identification painting:
   a. Color code non-submerged piping; paint fittings and valves the same color as pipe, except equipment isolation valves.
   b. Piping color coding: As specified in SECTION 09 90 00.

c. On exposed SST piping, apply color 24 inches in length along the pipe axis at connections to equipment, valves, or branch fittings, at wall boundaries, and at intervals along piping not greater than 9 feet o.c.

2. Colors: As specified in SECTION 09 90 00.

3.3 QUALITY CONTROL

A. Pressure Leakage Testing: As specified in SECTION 40 80 01 and the Pipe Schedule.

3.4 CLEANING

A. General:

1. Following assembly and testing and prior to disinfection and final acceptance, flush pipelines, except as specified in this Section, with water at 2 1/2 fps minimum flushing velocity until foreign matter is removed.
2. Blow clean of loose debris plant process air, carbon dioxide, natural gas, and instrument air lines with compressed air at 4,000 fpm; do not flush with water.
3. If it is impractical to flush large diameter pipe at 2 1/2 fps or blow at 4,000 fpm velocity, clean in-place from inside by brushing and sweeping, then flush or blow the line at lower velocity.
4. Insert cone strainers in flushing connections to attached equipment and leave in-place until cleaning is complete.
5. Remove accumulated debris through drains 2 inches and larger or by removing spools and valves from piping.

B. Chlorine Pressure Piping: Clean and dry in accordance with the requirements of CI Pamphlet 6, and meet the following requirements:

1. Blow clean of loose debris dry chlorine gas or liquid and instrument lines with compressed air at 4,000 fpm; do not flush with water.
2. Chlorine piping shall be cleaned using a solvent cleaner as specified in CI Pamphlet 6. Detergent and water washing and steam cleaning shall not be used.
3. Chlorine piping shall be dried in accordance with CI Pamphlet 6. Dry to -40°F with dry compressed commercial grade 5.9 (99.999%) nitrogen. Drying shall continue until the measured dew point at a minimum of six ENGINEER-approved locations is equal to or below -40°F. Provide equipment for measuring the dew point.

C. Chlorine Gas Vacuum Piping: Blow pipe clean of loose debris with instrument-grade clean and dry compressed air. Ensure the pipe is open, not valved off, at the end of the section to be cleaned so the pipe does not become pressurized. Do not pressurize PVC with compressed air. Do not flush chlorine gas vacuum piping with water. After cleaning, purge the air with nitrogen gas.

D. Pressure testing of neat polymer lines shall be performed with food grade mineral oil. Lines shall be air-dried to eliminate moisture following the cleaning and pressure testing.

3.5 SUPPLEMENTS

A. Supplement A – Carbon Steel Pipe and Fittings – General Service
B. Supplement B – Carbon Steel Pipe and Fittings – Liquid/Gaseous Chlorine Pressure Service
C. Supplement C – DI Pipe and Fittings
D. Supplement D – Type 304 SST Pipe, Tube, and Fittings
E. Supplement E – Type 316 SST Pipe, Tube, and Fittings
F. Supplement F – PVC Pipe and Fittings
G. Supplement G – CPVC Pipe and Fittings
H. Supplement H – LLDPE Tubing Inside HDPE Containment Pipe
I. Supplement I – PP Pipe, Tubing, and Fittings
J. Supplement J – Flexible Reinforced PVC Tubing
K. Supplement K – Double Wall Containment Piping

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SUPPLEMENT A CARBON STEEL PIPE AND FITTINGS – GENERAL SERVICE		
Item	**Size**	**Description**
Pipe	All	Black carbon steel, in accordance with ASTM A 106, Grade B seamless ASTM A 53, Grade B seamless or ERW Threaded, butt-welded, grooved end, and flanged joints
	Welded:	
	2 inch 2 1/2 inch thru 10 inch	Schedule 80 Schedule 40
	12 inch thru 16 inch	Schedule 30
	18 inch thru 24 inch	Schedule 20
	Greater than 24 inch	Wall thickness as specified in SECTION 33 05 24.23
	Grooved:	
	2 1/2 inch thru 6 inch	Schedule 40
	8 inch thru 12 inch	Schedule 30
	14 inch	Standard weight
Joints	2 inch and smaller	Threaded or flanged at equipment as required
	2 1/2 inch and larger	Butt-welded or flanged at valves and equipment, or grooved end in accordance with AWWA C606
Fittings	2 inch and smaller	Threaded: Malleable iron, in accordance with ASTM A 197 or ASTM A 47, 150 lb or 300 lb, dimensions in accordance with ASME B16.3
	2 1/2 inch and larger	Butt-welded: Wrought carbon steel butt-welding, in accordance with ASTM A 234, Grade WPB in accordance with ASME B16.9; fitting wall thickness to match adjoining pipe; long radius elbows Grooved end: Malleable iron in accordance with ASTM A 47 or DI in accordance with ASTM A 536, grooved ends to accept couplings without field preparation
Branch Connections	2 inch and smaller	Threaded, straight, or reducing tees in conformance with the fittings specified above
	2 1/2 inch and larger	Butt-welded or grooved end tee in conformance with the fittings specified above
Flanges	2 inch and smaller	Forged carbon steel, in accordance with ASTM A 105, Grade II, ASME B16.5 Class 150 or Class 300 socket weld or threaded, 1/16 inch raised face
	2 1/2 inch and larger	Butt-welded systems: Forged carbon steel, in accordance with ASTM A 105, ASME B16.5 Class 150 or Class 300 slip-on or welding neck, 1/16 inch raised face; weld neck bore to match pipe internal diameter; use weld neck flanges when abutting butt-weld fittings Grooved end adapter flange: Malleable iron in accordance with ASTM A 47 or DI in accordance with ASTM A 536 CI mating flange: Class D or E, hub or ring type in accordance with AWWA C207, 125 lb drilling in accordance with ASME B16.1, Class F hub type in accordance with AWWA C207, or Class 300 lb, drilling in accordance with ASTM A 105, ASME B16.5
Unions	2 inch and smaller	Threaded malleable iron, in accordance with ASTM A 197 or ASTM A 47, 150 lb or 300 lb WOG, in accordance with ASME B16.3
Couplings	2 1/2 inch and larger	Grooved end: Rigid joint malleable iron, in accordance with ASTM A 47 or DI in accordance with ASTM A 536 Screwed end: Malleable iron, in accordance with ASTM A 197 or ASTM A 47

SUPPLEMENT A CARBON STEEL PIPE AND FITTINGS – GENERAL SERVICE		
Item	**Size**	**Description**
Bolting	All	Flanges: Carbon steel in accordance with ASTM A 307 Grade A hex head bolts with hex head nuts in accordance with ASTM A 563 Grade A. Use 1/8 inch undersize bolting material for insulating flanges, no overbore holes Grooved end couplings: Carbon steel, in accordance with ASTM A 183 bolts and nuts, 110,000 psi minimum tensile strength
Gaskets	All	Water, steam, and air services: 1/16 inch thick, compressed inorganic fiber with nitrile binder, rated to 700°F and 1,000 psi Blind flanges shall be gasketed covering the entire inside face with the gasket cemented to the blind flange Grooved couplings: EPDM in accordance with ASTM D 2000 for water and air to 230°F, nitrile for oil service to 180°F
Lining	1 inch through 10 inch 10 inch and larger	Liquid-epoxy: In accordance with AWWA C210 Cement-mortar: In accordance with AWWA C205
Coating	All	As specified in SECTION 09 90 00 and the Pipe Schedule
Thread Lubricant	2 inch and smaller	General service: Teflon tape

SUPPLEMENT B CARBON STEEL PIPE AND FITTINGS – LIQUID/GASEOUS CHLORINE PRESSURE SERVICE		
Item	**Size**	**Description**
Pipe	All	Black carbon steel, in accordance with ASTM A 106, Grade B seamless. Schedule 80 dimensions in accordance with ASME B36.10M
Joints	1 1/2 inch and smaller	Threaded or flanged at valves and equipment as required
Fittings	1 1/2 inch and smaller	Forged carbon steel in accordance with ASTM A 105, Class 3000, dimensions in accordance with ASME B16.11
Branch Connections	1 1/2 inch and smaller	Threaded, straight, or reducing tees in conformance with the fittings specified above
Flanges	1 1/2 inch and smaller	Forged carbon steel, in accordance with ASTM A 105, Class 300 threaded, 1/16 inch raised face, dimensions in accordance with ASME B16.5
Unions	1 1/2 inch and smaller	Threaded forged carbon steel, in accordance with ASTM A 105, Class 3000, 2-bolt ammonia style, handlebar type with lead gaskets of 2% to 4% antimony
Bolting	All	Alloy steel, in accordance with ASTM A 193, Grade B7, quenched and tempered stud bolts and cap screws, dimensions in accordance with ASME B18.2.1 Carbon steel heavy hex nuts, in accordance with ASTM A 194, Grade 2H, dimensions in accordance with ASME B18.2.2
Gaskets	All flanges	Confined: Raised face flanges: 1/8 inch thick, chemical lead with 2% to 4% antimony Unconfined: Raised face flanges: 1/8 inch thick, composite PTFE in accordance with CI Pamphlet 95
Lining	All	Bare
Coating	All	In accordance with the Piping Schedule
Thread Lubricant	1 1/2 inch and smaller	Teflon tape

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SUPPLEMENT C DI PIPE AND FITTINGS	
Item	**Description**
General	Materials in contact with potable water shall be in accordance with NSF/ANSI 61
Pipe	Exposed: 250 psi minimum working pressure in accordance with AWWA C151 Buried: As specified in SECTION 33 05 19
Fittings	Lined same as pipe Exposed: 250 psi minimum working pressure Grooved end: Rigid type radius cut in accordance with AWWA C606 Mechanical-joint: In accordance with AWWA C110 Flanged: In accordance with AWWA C110, ASME B16.1, Class 125 Gray CI shall not be allowed Buried: As specified in SECTION 33 05 19
Joints	Exposed: 250 psi minimum working pressure Grooved end: Rigid type radius cut in accordance with AWWA C606 Mechanical-joint: DI in accordance with ASTM A 536 Flanged: In accordance with AWWA C115, ASME B16.1, Class 125 DI, threaded; gray CI shall not be allowed Buried: As specified in SECTION 33 05 19
Couplings	Exposed: 250 psi minimum working pressure Grooved end: DI in accordance with ASTM A 536 Mechanical-joint: In accordance with AWWA C219, DI in accordance with ASTM A 536 Buried: As specified in SECTION 33 05 19
Flanges	Exposed: 125 lb flat face, DI ASME B16.1, Class 125 in accordance with AWWA C110, or AWWA C606; gray CI shall not be allowed Buried: As specified in SECTION 33 05 19
Bolting	Grooved end joints: Manufacturer’s standard 125 lb flat-faced flange: Carbon steel hex head bolts, in accordance with ASTM A 307, Grade A and ASTM A 563, Grade A carbon steel hex head nuts Buried: As specified in SECTION 33 05 19
Gaskets	Grooved end joints: Halogenated butyl in accordance with ASTM D 2000 and AWWA C606 Flanged: 1/8 inch thick, SBR, hardness 80 (Shore A), rated to 200°F, in accordance with ASME B16.21, AWWA C207, and ASTM D 1330, Grades 1 and 2 Full face for 125 lb flat-faced flanges, flat-ring type for 250 lb raised-face flanges; blind flanges shall be gasketed covering the entire inside face with the gasket cemented to the blind flange Buried: As specified in SECTION 33 05 19
Lining	As specified in SECTION 33 05 19 and the Pipe Schedule
Coating	Exposed: As specified in SECTION 09 90 00 and the Pipe Schedule Buried: As specified in SECTION 33 05 19 and the Pipe Schedule
Joint Lubricant	Manufacturer's standard

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SUPPLEMENT D TYPE 304 SST PIPE, TUBE, AND FITTINGS		
Item	**Size**	**Description**
Pipe	2 1/2 inch and smaller	Schedule 40S: In accordance with ASTM A 312, Type 304L seamless, pickled and passivated
	3 inch thru 6 inch	Schedule 10S: In accordance with ASTM A 778 and AWWA C220 for 4 inch and larger, as-welded grade, Type 304L, pickled and passivated
	8 inch and larger	Schedule 5S: In accordance with ASTM A 778 and AWWA C220, as-welded grade, Type 304L, pickled and passivated
Tubing	All	In accordance with ASTM A 269, Type 304 SST, seamless, fully annealed hydraulic tubing, 0.065 inch wall thickness minimum
Joints	1 1/2 inch and smaller	Threaded or flanged at equipment as required or shown on the Drawings
	2 inch and larger	Butt-welded or flanged at valves and equipment
Tubing Joints	All	Flareless compression fitting
Fittings	1 1/2 inch and smaller	Threaded: Forged 1,000 CWP minimum, in accordance with ASTM A 182, Grade 304L Class 150, ASTM A 351, Grade CF8/304; AWWA C226
	2 inch and 2 1/2 inch	Butt-welded: In accordance with ASTM A 403 and AWWA C226, Grade WP304L in accordance with ASME B16.9 and MSS SP-43, annealed, pickled and passivated; fitting wall thickness to match adjoining pipe; long radius elbows
	3 inch and larger	Butt-welded: In accordance with ASTM A 774 and AWWA C226 Grade 304L in accordance with MSS SP-43, as-welded grade, pickled and passivated; fitting wall thickness to match adjoining pipe; long radius elbows
Tubing Fittings	All	Flareless compression type forged: In accordance with ASTM A 182, Grade F304
Branch Connections	1 1/2 inch and smaller	Tee or reducing tee in conformance with the fittings above
	2 inch and larger	Butt-welding tee or reducing tee in accordance with the fittings above
Tubing Branch Connections	All	Compression type tees or reducing tees in accordance with the tubing fittings above
Flanges	All	Forged SST: In accordance with ASTM A 182, Grade F304L, ASME B16.5 Class 150 or Class 300, slip-on weld neck or raised face Cast carbon steel: In accordance with ASTM A 216 Grade WCA, drilled, ASME B16.5 Class 150 or Class 300 Van Stone Type with SST stub ends, in accordance with ASTM A 240 Type 304L as-welded grade, in accordance with MSS SP-43, wall thickness same as pipe Blind flanges, exposed to the atmosphere and not buried nor immersed in liquid, may be SST or Class 125 DI or Class 150 carbon steel with gaskets as specified herein
Unions	2 inch and smaller	Threaded forged: In accordance with ASTM A 182, Grade F316, 2,000 or 3,000 lb WOG, integral ground seats, AAR design in accordance with ASME B16.11, bore to match pipe
Bolting	All	Forged flanges: Type 304 SST hex head bolts in accordance with ASTM A 320 Grade B8 and hex head nuts in accordance with ASTM A 194 Grade 8
Gaskets	All Flanges	Water and sewage service: 1/8 inch thick, red SBR, hardness 80 (Shore A), rated to 200°F, in accordance with ASME B16.21, AWWA C207, and in accordance with ASTM D 1330, Grade 1 and Grade 2 Air service: Premium grade 1/8 inch thick EPDM ring type gasket, rated for 275˚F service
Thread Lubricant	2 inch and smaller	General service: 100% virgin PTFE Teflon tape

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SUPPLEMENT E TYPE 316 SST PIPE, TUBE, AND FITTINGS		
Item	**Size**	**Description**
Pipe	2 1/2 inch and smaller	Schedule 40S: In accordance with ASTM A 312, Type 316 seamless, pickled and passivated
	3 inch thru 6 inch	Schedule 10S: In accordance with ASTM A 778 and AWWA C220 for 4 inch and larger, as-welded grade, Type 316L, pickled and passivated
	8 inch and larger	Schedule 5S: In accordance with ASTM A 778 and AWWA C220, as-welded grade, Type 316L, pickled and passivated
Tubing	All	In accordance with ASTM A 269, Type 316 SST, seamless, fully annealed hydraulic tubing, 0.065 inch wall thickness minimum
Joints	1 1/2 inch and smaller	Threaded or flanged at equipment as required or shown on the Drawings
	2 inch and larger	Butt-welded or flanged at valves and equipment
Tubing Joints	All	Flareless compression fitting
Fittings	1 1/2 inch and smaller	Threaded: Forged 1,000 CWP minimum, in accordance with ASTM A 182 and AWWA C226, Grade F316 or cast Class 150, ASTM A 351, Grade CF8M/316
	2 inch and 2 1/2 inch	Butt-welded: In accordance with ASTM A 403 and AWWA C226, Grade WP316L in accordance with ASME B16.9 and MSS SP 43, annealed, pickled and passivated; fitting wall thickness to match adjoining pipe; long radius elbows
	3 inch and larger	Butt-welded: In accordance with ASTM A 774 and AWWA C226 Grade 316L in accordance with MSS SP 43, as-welded grade, pickled and passivated; fitting wall thickness to match adjoining pipe; long radius elbows
Tubing Fittings	All	Flareless compression type forged: In accordance with ASTM A 182, Grade F316
Branch Connections	1 1/2 inch and smaller	Tee or reducing tee in conformance with the fittings above
	2 inch and larger	Butt-welding tee or reducing tee in accordance with the fittings above
Tubing Branch Connections	All	Compression type tees or reducing tees in accordance with the tubing fittings above
Flanges	All	Forged SST: In accordance with ASTM A 182, Grade F316L, ASME B16.5 Class 150 or Class 300, slip-on weld neck or raised face Cast carbon steel: In accordance with ASTM A 216 Grade WCA, drilled, ASME B16.5 Class 150 or Class 300 Van Stone Type with SST stub ends, in accordance with ASTM A 240 Type 316L as-welded grade, in accordance with MSS SP-43, wall thickness same as pipe Blind flanges, exposed to the atmosphere and not buried nor immersed in liquid, may be SST or Class 125 DI or Class 150 carbon steel with gaskets as specified herein
Unions	2 inch and smaller	Threaded forged: In accordance with ASTM A 182, Grade F316, 2,000 or 3,000 lb WOG, integral ground seats, AAR design in accordance with ASME B16.11, bore to match pipe
Bolting	All	Forged flanges: Type 316 SST hex head bolts in accordance with ASTM A 320 Grade B8M and hex head nuts in accordance with ASTM A 194 Grade 8M

SUPPLEMENT E TYPE 316 SST PIPE, TUBE, AND FITTINGS		
Item	**Size**	**Description**
Gaskets	All Flanges	Water and sewage service: 1/8 inch thick, unless otherwise specified, red SBR, hardness 80 (Shore A), rated to 200°F, in accordance with ASME B16.21, AWWA C207, and ASTM D 1330, Grade 1 and Grade 2
Thread Lubricant	2 inch and smaller	General service: 100% virgin PTFE Teflon tape

SUPPLEMENT F
PVC PIPE AND FITTINGS

Item	Size	Description
General	All	Materials in contact with potable water shall be in accordance with NSF/ANSI 61
Pipe	All	Schedule 80 PVC: Type I, Grade I or Class 12454-B in accordance with ASTM D 1784 and ASTM D 1785; pipe shall be manufactured with titanium dioxide for UV protection Floor-mounted /trip-hazard pipe: Schedule 120 Threaded nipples: Schedule 80 PVC
Fittings	All	Schedule to match pipe above: In accordance with ASTM D 2466 and ASTM D 2467 for socket weld type and ASTM D 2464 for threaded type; fittings shall be manufactured with titanium dioxide for UV protection; fittings above 3 inches shall not be threaded; provide metal reinforcement for threaded female fittings
Joints	All	Solvent socket weld except where connection to threaded valves and equipment may require future disassembly, use flanges in this case; joints in chlorine service shall be socket-welded except as required to mate with threaded or flanged equipment
Flanges	All	Two-piece, van stone type PVC flat face flange in accordance with the fittings above, 150 lb ASME B16.5 drilling
Bolting	All	Type 304 SST hex head bolts in accordance with ASTM A 193, Grade B8, Class 1, and hex head nuts in accordance with ASTM A 194, Grade 8 Type 316 SST hex head bolts in accordance with ASTM A 193 Grade B8M, Class 1, and hex head nuts in accordance with ASTM A 194 Grade 8M Alloy steel quenched and tempered stud bolts and cap screws in accordance with ASTM A 193, Grade B7, with carbon steel heavy hex nuts in accordance with ASTM A 194, Grade 2H Galvanized alloy steel cap screws and heavy hex nuts in accordance with ASTM A 153 Refer to the Pipe Schedule for material
Gaskets	All	Flat face mating flange: Full faced 1/8 inch thick Refer to the Pipe Schedule for material
Solvent Cement	All	Socket type joints shall be made by employing solvent cement that meets or exceeds the requirements of ASTM D 2564 and primer that meets or exceeds requirements of ASTM F 656 and as recommended by the Pipe and Fitting Manufacturer; solvent cement and primer shall be listed by NSF for use with potable water; use in strict accordance with the Solvent Cement Manufacturer’s installation instructions Chemical service: Socket type joints shall be made by employing primer and solvent cements that meet or exceed the requirements of ASTM F 493 and primers that meet or exceed the requirements of ASTM F 656 and as recommended by the Pipe and Fitting Manufacturer; solvent cement and primer shall be listed by NSF for use with potable water; use in strict accordance with the Solvent Cement Manufacturer’s installation instructions. Primer and solvent cement used for chemical lines shall be compatible with chemical service in accordance with Manufacturer provided data
Thread Lubricant	All	Teflon tape

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SUPPLEMENT G CPVC PIPE AND FITTINGS		
Item	**Size**	**Description**
Pipe	All	Schedule 80 CPVC: Type IV, Grade I or Class 23447-B in accordance with ASTM D 1784 and ASTM F 441; pipe shall be manufactured with titanium dioxide for UV protection Floor-mounted/trip-hazard pipe: Schedule 120 Threaded nipples shall be Schedule 80
Fittings	All	Schedule to match pipe above: In accordance with ASTM F 439 for socket weld type and in accordance with ASTM F 437 for threaded type; fittings shall be manufactured with titanium dioxide for UV protection; provide metal reinforcement for threaded female fittings; fittings above 3 inch shall not be threaded
Joints	All	Solvent socket weld except where connection to threaded valves and equipment may require future disassembly
Flanges	All	Two-piece, van stone type CPVC flat face flange in accordance with the fittings above, 150 lb ASME B16.5 drilling
Bolting	All	Type 304 SST hex head bolts in accordance with ASTM A 193, Grade B8, Class 1, and hex head nuts in accordance with ASTM A 194, Grade 8 Type 316 SST hex head bolts in accordance with ASTM A 193, Grade B8M, Class 1, and hex head nuts in accordance with ASTM A 194, Grade 8M Alloy steel quenched and tempered stud bolts and cap screws in accordance with ASTM A 193, Grade B7, with carbon steel heavy hex nuts in accordance with ASTM A 194, Grade 2H Galvanized alloy steel cap screws and heavy hex nuts in accordance with ASTM A 153 Refer to the Pipe Schedule for material
Gaskets	All	Flat face mating flange: Full faced 1/8 inch thick Raised face mating flange: Flat ring 1/8 inch, with filler gasket between OD of raised face and flange OD to protect the flange from bolting moment Refer to the Pipe Schedule for material
Solvent Cement	All	Socket type joints shall be made by employing primer and solvent cements that meet or exceed the requirements of ASTM F 493 and primers that meet or exceed the requirements of ASTM F 656 and as recommended by the Pipe and Fitting Manufacturer; solvent cement and primer shall be listed by NSF for use with potable water; use in strict accordance with the Solvent Cement Manufacturer’s installation instructions. Chemical service: Primer and solvent cement used for chemical lines shall be compatible with chemical service in accordance with Manufacturer provided data
Thread Lubricant	All	Teflon tape

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SUPPLEMENT H LLDPE TUBING INSIDE HDPE CONTAINMENT PIPE	
Item	**Description**
General	Materials in contact with potable water shall be in accordance with NSF/ANSI 61
Tubing	Size and wall thickness as shown on the Drawings Minimum tensile elongation at break shall be at least 700%, in accordance with ASTM D 638 Environmental-stress-cracking resistance F50 in accordance with ASTM D 1693: 1,000 hours. White or clear LLDPE tubing, minimum working pressure 100 psi; tubing buried in containment pipe with tube connection to exposed pipe as shown on the Drawings
Carrier/Containment Pipe	HDPE, as specified in SECTION 33 41 18
Joints	Barblock coupling inserts inside expandable tubing with outside closure collar, coupling, and collar constructed of PP or equal material compatible with listed chemical service

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SUPPLEMENT I PP PIPE, TUBING, AND FITTINGS	
Item	**Description**
Pipe	Exposed: PP, in accordance with ASTM F 2389, SDR 11, NSF 61; water system components certified; pipe joints shall be butt fusion weld or threaded type Buried: Not for buried use
Fittings	Exposed: Conform to same requirements as pipe; fitting shall be injection molded and butt fusion joined or threaded Buried: Not for buried use
Joints	Exposed: Butt fusion weld or threaded except where connection to flanged valves and equipment that may require future disassembly Buried: Not for buried use
Flanges	Exposed: Two-piece, stub end and backing ring arrangement; 125 lb in accordance with ASME B16.1 drilling; do not mate with raised face flange Buried: Not for buried use
Bolting	Exposed: Type 316 SST Grade B8M hex head bolts in accordance with ASTM A 193, and hex head nuts in accordance with ASTM A 194 Grade 8M Buried: Not for buried use
Gaskets	Flat face mating flange: Full faced 1/8 inch thick ethylene propylene rubber

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SUPPLEMENT J
FLEXIBLE REINFORCED PVC TUBING

Item	Description
PVC Tubing	Reinforced PVC tubing with a nylon or steel braid reinforcement embedded in a wall of tubing and a nominal Shore A durometer of 675; minimum working pressure shall be 150 psi; minimum working vacuum rating shall be 28 in Hg vacuum; shall meet FDA regulations for food use or NSF regulations for potable water.
Fittings	Tubing shall be joined to pipe with a male adapter fitting and externally secured to the fitting with a SST worm drive hose clamp Tubing run joints shall be made by connecting the tubing ends with a coupling as recommended by the Hose and Tubing Manufacturer and as approved by the ENGINEER

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SUPPLEMENT K DOUBLE WALL CONTAINMENT PIPING		
Item	**Size**	**Description**
Carrier Pipe	All	PVC: Schedule 80; shall be manufactured from a Class 12454 B PVC resin, in accordance with ASTM D 1784; joints shall be solvent-welded socket type; supply straight sections in 20 foot random lengths CPVC: Schedule 80, Class 23447 A, in accordance with ASTM D 1784; joints shall be solvent-welded socket type; supply straight sections in 20 foot random lengths
Containment Pipe	All	PVC: Schedule 80, in accordance with ASTM D 1784 CPVC: Schedule 80, in accordance with ASTM D 1784
Joints	All	Solvent socket weld except where connection to threaded valves and equipment may require future disassembly
Leak Detection	All	No electronic leak detection system; process piping configuration is designed to consolidate leaks to predetermined fittings for manual inspection

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SECTION 40 05 06
COUPLINGS, ADAPTORS, AND SPECIALS FOR PROCESS PIPE

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for couplings, adaptors, and specials for process pipe.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 09 90 00 – PAINTING AND COATING
4. SECTION 33 05 19 – DUCTILE-IRON PIPE AND FITTINGS FOR WATER TRANSMISSION AND DISTRIBUTION
5. SECTION 33 14 11 – WATER UTILITY TRANSMISSION AND DISTRIBUTION PIPING – GENERAL
6. SECTION 33 14 17 – WATER SERVICE LINES
7. SECTION 40 05 00 – PROCESS PIPING – GENERAL
8. SECTION 40 05 07 – HANGERS AND SUPPORTS

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):

1. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250
2. B16.5 – Pipe Flanges and Flanged Fittings: NPS 1/2 through NPS 24 Metric/Inch Standard

B. American Water Works Association (AWWA):

1. C153 – Ductile-Iron Compact Fittings
2. C213 – Fusion-Bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines
3. C219 – Bolted, Sleeve-Type Couplings for Plain-End Pipe
4. Manual M11 – Steel Pipe – A Guide for Design and Installation

C. ASTM International (ASTM):

1. A 153 – Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware
2. A 240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
3. A 276 – Standard Specification for Stainless Steel Bars and Shapes
4. A 536 – Specification for Ductile Iron Castings
5. C 1173 – Standard Specification for Flexible Transition Couplings for Underground Piping Systems
6. D 2000 – Standard Classification System for Rubber Products in Automotive Applications
7. F 3125 – Standard Specification for High Strength Structural Bolts and Assemblies, Steel and Alloy Steel, Heat Treated, Inch Dimensions 120 ksi and 150 ksi Minimum Tensile Strength, and Metric Dimensions 830 MPa and 1040 MPa Minimum Tensile Strength

D. NSF International/American National Standards Institute (NSF/ANSI):

1. 61 – Drinking Water System Components – Health Effects
2. 61, Annex G – Weighted Average Lead Evaluation Procedure to a 0.25% Lead Requirement
3. 372 – Drinking Water System Components – Lead Content

1.3 SUBMITTALS

A. Action Submittals: Provide the Manufacturer's data on materials, construction, end connections, ratings, overall lengths, and live lengths as applicable.

B. Informational Submittals:

1. Coupling harness:
   a. Details, ratings, calculations, and test reports for thrust restraints relying on welded bars or rings.
   b. Weld procedure qualifications.
   c. Load proof-testing report of prototype restraint for any size coupling.
2. Basket strainer:
   a. The Manufacturer's installation instructions.
   b. The Manufacturer's certificate of proper installation as specified in SECTION 01 44 33.
3. O&M data as specified in SECTION 01 78 23.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Connectors:

1. Teflon bellows connector:
   a. Garlock, Style 214
   b. Proco Products, Inc., Style 442
   c. Resistoflex, No. R6904
   d. Unisource Manufacturing, Inc., Style 112A
2. Metal bellows connector:
   a. Hyspan Precision Products, Inc., Series 1500
   b. Pathway Bellows, Inc., Style CT
3. Flexible metal hose connector:
   a. Proco Products, Inc.
   b. Senior Flexonics
   c. Unisource Manufacturing, Inc.
   d. Universal Metal Hose

4. Quick-connect couplings for chemical services:
    a. OPW, Kamlock
    b. Ryan Herco, 1300 Series
5. Dry quick-connect couplings for chemical services:
    a. Banjo, Dry-Mate
    b. OPW, Kamvaloc

B. Couplings:
1. Flexible sleeve type:
    a. Steel pipe:
        1) Dresser Piping Specialties, Style 38
        2) Smith-Blair, Inc., Style 411
    b. DI pipe:
        1) Dresser Piping Specialties, Style 253
        2) Smith-Blair, Inc., Style 411
2. Flexible coupling:
    a. Fernco Joint Sealer Co.
    b. Pipeline Products Corp.
3. Bolted sleeve-type coupling:
    a. 12 inches and smaller:
        1) As specified in SECTION 33 14 11
    b. Larger than 12 inches:
        1) Steel pipe:
            a) Victaulic, VBSP
            b) Dresser Piping Specialties, Style 38, 138
            c) Smith-Blair, Style 411
        2) DI pipe:
            a) Victaulic, VBSP
            b) Dresser Piping Specialties, Style 162
            c) Smith-Blair, Style 441
4. Transition coupling for steel pipe:
    a. Dresser Piping Specialties, Style 162
    b. Smith-Blair, Inc., Style 413
5. Flanged coupling adapter:
    a. Steel pipe:
        1) Dresser Piping Specialties, Style 128
        2) Smith-Blair, Inc., Style 913
    b. DI pipe:
        1) Dresser Piping Specialties, Style 127
        2) Smith-Blair, Inc., Style 912
6. Thrust restraint:
    a. EBAA Iron Sales Co., Mega-Flange
7. Exposed metallic piping plain end couplings:
    a. Straub Couplings, Grip-L or Metal Grip

C. Expansion Joints:
1. Elastomer bellows:
    a. General Rubber Corp., Style 1015 Maxi-Joint
    b. Mercer, Flexmore Style 450
    c. Proco Products, Inc., Series 251
    d. Unisource Manufacturing, Inc., Series 1500
2. Teflon bellows:
    a. Garlock, Style 215
    b. Proco Products, Inc., Series 443 Resistoflex, No. R6905
    c. Unisource Manufacturing, Inc., Style 113
3. Metal bellows:
    a. Hyspan Precision Products, Inc., Series 1500
    b. Pathway Bellows, Inc., Style CT
4. Copper pipe expansion compensator:
    a. Hyspan Precision Products, Inc., Model 8510
    b. Senior Flexonics, Model HB
    c. Unisource Manufacturing, Inc., Series 416
5. Flexible metal hose:
    a. Anamet Industrial, Inc., BWC21-1
    b. Senior Flexonics, Series 401M

D. Flexible Expansion Joints:
1. EBAA Iron Sales Co., Flex-Tend

E. Service Saddles:
   1. Steel pipe:
      a. Dresser Piping Specialties, Style 91
      b. Smith-Blair, Series 313 or 366
   2. DI pipe:
      a. As specified in SECTION 33 05 19
F. Pipe Sleeves:
   1. Molded PE pipe sleeve:
      a. PSI-Thunderline/Link-Seal, Century-Line, Model CS
   2. Insulated and encased pipe sleeve:
      a. Pipe Shields, Inc.; C Series
   3. Modular mechanical seal:
      a. Thunderline Corp., Link-Seal Division
G. Slab, Floor, Wall, and Roof Penetrations:
   1. American Cast Iron Pipe Co.
   2. U.S. Pipe and Foundry Co.
H. Miscellaneous Specialties:
   1. Strainers, water service, 2 inches and smaller:
      a. Armstrong International, Inc.; F Series
      b. Mueller Steam Specialty, Model 351M
   2. Strainers, water service, 2 1/2 inches and larger:
      a. Armstrong International, Inc., Model A7FL 125
      b. Mueller Steam Specialty, Model 752
   3. Strainers, Y-pattern, chemical services, 4 inches and smaller:
      a. Hayward: Spears Manufacturing
   4. Strainers, basket, chemical services, 4 inches and smaller:
      a. Hayward: Spears Manufacturing
   5. Calibration columns:
      a. Griffco Valve Inc.
      b. Koflo Corporation

2.2 MATERIALS

A. Provide required piping specialty items, whether or not shown on the Drawings, and as required by applicable codes and standard industry practice.
B. Rubber ring joints, mechanical joints, flexible couplings, and proprietary restrained DI pipe joints shall be considered flexible joints; welded, screwed, and flanged pipe joints are not considered flexible joints.
C. Brass and bronze valve components and accessories that have surfaces in contact with potable water shall be alloys containing less than 16% zinc and 2% aluminum and shall be certified in accordance with NSF/ANSI 61, NSF/ANSI 61, Annex G, and NSF/ANSI 372.
D. Connectors:
   1. Teflon bellows connector:
      a. Type: Two convolutions, unless otherwise shown on the Drawings, with metal reinforcing bands.
      b. Flanges: DI, drilled Class 150 in accordance with ASME B16.5.
      c. Working pressure rating: 140 psi, minimum, at 120°F.
      d. Thrust restraint: Limit bolts to restrain the force developed by the specified test pressure.
   2. Metal bellows connector:
      a. Type: Single-ply, annular corrugated metal bellows with limit rods. Circumferential convolution welds are not permitted.
      b. Material: Type 316 SST.
      c. End connections: 150 lb carbon steel flanges in accordance with ASME B16.5.
      d. Minimum design working pressure: 150 psi at 750°F.
      e. Length: Minimum of four convolutions and the minimum Manufacturer’s recommendation for vibration isolation.
   3. Flexible metal hose connector:
      a. Type: Close pitch, annular corrugated with single braided jacket.
      b. Material: Bronze.
      c. End connections: Female copper solder joint.
      d. Minimum burst pressure: 500 psig at 70°F.
      e. Length: The minimum Manufacturer’s recommendation for vibration isolation.
   4. Quick-connect couplings for chemical services:
      a. Type: Twin cam arm actuated, male and female, locking, for chemical loading and transfer.
      b. Materials: Glass-filled PP, PVDF with EPDM, Type 316 SST, EPDM, Viton-A or Teflon gaskets as recommended for the service by the Manufacturer.
      c. End connections: NPT threaded or flanged to match piping connections; hose shank for chemical installations.
      d. Plugs and caps: Female dust cap for each male end; male dust plug for each female end.
      e. Pressure rating: 125 psi, minimum, at 70°F.

5. Dry quick-connect couplings for chemical services:
   a. Type: Twin cam arm actuated, male and female, locking, for chemical loading and transfer. Locking isolation valve and handle for dry disconnection of the coupling.
   b. Materials: Glass-filled PP or Type 316 SST, EPDM, Viton-A or Teflon gaskets as recommended for the service by the Manufacturer.
   c. End connections: NPT threaded or flanged to match piping connections; hose shank for chemical installations.
   d. Plugs and caps: Female dust cap for each male end; male dust plug for each female end.
   e. Pressure rating: 125 psi, minimum, at 70°F.

E. Couplings:
1. General:
   a. Coupling linings for use in potable water systems shall be in accordance with NSF/ANSI 61.
   b. Couplings shall be rated for a working pressure no less than that shown on the piping schedule in SECTION 40 05 00 for the service and no less than 150 psi.
   c. Couplings shall be lined and coated with fusion-bonded epoxy in accordance with AWWA C213.
   d. Unless thrust restraint is provided by other means, couplings shall be harnessed in accordance with AWWA Manual M11 and restrained with a retainer bar or ring welded to the pipe end or as shown on the Drawings.
   e. Sleeve type couplings shall be in accordance with AWWA C219 and shall be hydraulically expanded beyond the minimum yield for accurate sizing and proofing of tensile strength.
2. Bolted sleeve-type and transition couplings, flanged coupling adapter:
   a. In accordance with AWWA C 219.
   b. Center sleeve shall match service pipe material and pressure rating.
   c. Rubber gaskets shall be in accordance with ASTM D 2000.
3. Flexible coupling:
   a. Drain and CP applications:
      1) Flexible, slip-on elastomer in accordance with ASTM C 1173.
      2) SST clamps in accordance with ASTM A 276, Type 301 bands.
   b. Pressure applications:
      1) DI in accordance with ASTM A 536 and AWWA C219.
      2) Working pressure rated to 150 psi minimum.
      3) Rubber gasket.
      4) Low alloy steel bolts and nuts in accordance with ASTM F 3125.
      5) Epoxy finish.
4. Restrained flange adapter:
   a. Pressure rating:
      1) Minimum working pressure rating: 150 psi.
      2) Safety factor: No less than two times the working pressure; supported by the Manufacturer's proof testing.
   b. Thrust restraint:
      1) Provide hardened steel wedges that bear against and engage the outer pipe surface and allow articulation of the pipe joint after assembly while wedges remain in their original setting position on the pipe surface.
      2) Products employing set screws that bear directly on the pipe are not acceptable.
5. Exposed metallic piping plain end couplings:
   a. Plain end pipe couplings shall be self-restrained against hydrostatic thrust forces equal to no less than two times the working pressure rating of the coupling. Couplings shall accommodate 4 degrees of angular deflection at the time of installation and subsequent to pressurization.
   b. Casing, bolts, and nuts shall be ASTM A 240, Type 304 or Type 316 SST. The sealing sleeve shall be EPDM or NBR elastomer as best suited for the fluid service.

F. Expansion Joints:
1. Elastomer bellows:
   a. Type: Reinforced molded wide arch.
   b. End connections: Flanged, Class 125 in accordance with ASME B16.1, split galvanized steel retaining rings.
   c. Washers: Over-retaining rings to help provide a leak-proof joint under the test pressure.
   d. Thrust protection: Control rods to protect the bellows from over-extension.
   e. Bellows arch lining: Buna-N, nitrile, or butyl.
   f. Rated temperature: 250°F.
   g. Rated deflection and pressure:
      1) Lateral deflection: 3/4 inch, minimum.
      2) Burst pressure: Four times the working pressure.
      3) Compression deflection and minimum working pressure:

Size (Inches)	Deflection (Inches)	Pressure (PSI)
2 1/2 to 12	1.06	150
14	1.65	130
16 to 20	1.65	110

2. Teflon bellows:
   a. Type: Three convolutions with metal reinforcing bands.

b. Flanges: DI, drilled, Class 150 in accordance with ASME B16.5.
c. Working pressure rating: 100 psi, minimum, at 120°F.
d. Thrust restraint: Limit bolts to restrain force developed by the specified test pressure.

3. Metal bellows:
   a. Type: Single-ply, annular corrugated metal bellows with limit rods; circumferential convolution welds shall not be permitted.
   b. Material: ASTM A 240, Type 316 SST.
   c. End connections: Class 150 carbon steel flanges in accordance with ASME B 16.5.
   d. Minimum design working pressure: 150 psi at 750°F.
   e. Length: Minimum of four convolutions and the minimum Manufacturer's recommendation for vibration isolation.
4. Copper pipe expansion compensator:
   a. Material: SST bellows with female copper solder joint ends.
   b. Working pressure rating: 175 psi, minimum.
   c. Accessories: Anti-torque device to protect bellows.
5. Flexible metal hose:
   a. Type: Close pitch, annular corrugated with single braided jacket.
   b. Material: ASTM A 276 Type 321 SST.
   c. End connections:
      1) For 3 inch and larger connections: Shop-fabricated flanged ends to match mating flanges.
      2) For 2 1/2 inch and smaller connections: Screwed ends with one union end.
   d. Minimum burst pressure: 600 psi at 70°F for 12 inches and smaller.
   e. Length: Provide hose live-length equal to the lengths shown on the Drawings.

G. Flexible Expansion Joints:
   1. Design:
      a. Ball-and-socket type for earth settlement compensation.
      b. Joints shall be double ball assemblies rated for 15 degree minimum deflection and no less than 4 inches offset from the centerline of connecting piping.
      c. Assembly shall accommodate up to 4 inches of expansion in length.
      d. DI in accordance with AWWA C153.
      e. Rated for 350 psi.
      f. Components lined and coated by the Manufacturer with fusion-bonded epoxy on surfaces not bearing gaskets.
      g. End connections: Flanged or mechanical joint shall be as shown on the Drawings and as required by connecting pipe and fittings.
      h. The joint connecting to the mechanical joint shall be thrust restrained.
      i. Bonding:
         1) The Manufacturer shall factory install exothermic welded joint bonds for the assembled expansion joint.
         2) Provide 24-inch bond wires for field bonds to adjacent metallic piping.
         3) Bond wires shall be #2 AWG with 2, 12 inch long THHN insulated #12 AWG wire pigtails.

H. Service Saddles:
   1. As specified in SECTION 33 14 17.
   2. DI: As specified in SECTION 33 05 19.

I. Pipe Sleeves:
   1. Steel:
      a. Minimum thickness: 3/16 inch.
      b. Seep ring:
         1) Center steel flange for water stoppage on sleeves in exterior or water-bearing walls, 3/16 inch minimum thickness.
         2) The outside diameter shall be 3 inches greater than the outside diameter of the pipe sleeve unless otherwise shown on the Drawings.
         3) Continuously fillet weld on each side all around.
      c. Factory finish:
         1) Galvanizing:
            a) Hot-dip applied in accordance with ASTM A 153.
            b) Electroplated zinc or cadmium plating is not acceptable.
         2) Shop lining and coating: Factory prepare, prime, and finish coat as specified in SECTION 09 90 00.
   2. Molded PE:
      a. Molded HDPE with integral water stop ring no less than 3 inches larger than the sleeve.
      b. Provided with end caps for support during concrete placement.
   3. Modular mechanical seal:
      a. Type: Interconnected synthetic rubber links shaped and sized to continuously fill the annular space between the pipe and the wall sleeve opening.
      b. Fabrication:
         1) Assemble interconnected rubber links with Type 18-8 SST bolts and nuts in accordance with ASTM A 276.
         2) Pressure plates shall be reinforced nylon polymer.
      c. Size: In accordance with the Manufacturer's instructions for the size of pipes shown on the Drawings to provide a watertight seal between the pipe and the wall sleeve opening; withstand a hydrostatic head of 40 feet of water.

J. Slab, Floor, Wall, and Roof Penetrations:
   1. DI wall pipe:
      a. Diameter and ends: Same as connecting DI pipe.
      b. Thickness: Equal to or greater than the remainder of the pipe in line.
      c. Fittings: As specified in the applicable pipe data sheet in SECTION 40 05 00.
      d. Thrust collars:
         1) Rated for thrust load developed at 250 psi.
         2) Safety factor: Two, at a minimum.
         3) Material and construction: DI or CI, cast integral with wall pipe wherever possible, or thrust rated, welded attachment to wall pipe.
   2. Steel or SST wall pipe:
      a. Same material and thickness as connecting pipe, except 1/4 inch minimum thickness.
      b. Lining: Same as connecting pipe.
      c. Thrust collar:
         1) The outside diameter shall be 3 inches greater than the outside diameter of the wall pipe unless otherwise shown on the Drawings.
         2) Continuously fillet welded on each side all around.

K. Miscellaneous Specialties:
   1. Strainers, water service, 2 inches and smaller:
      a. Type: Bronze body, Y-pattern, 200 psi non-shock rated, with screwed gasketed bronze cap.
      b. Screen: Heavy-gauge Type 304 SST or monel, 20-mesh.
   2. Strainers, water service, 2 1/2 inches and larger:
      a. Type: CI or DI body, Y-pattern, 175 psi non-shock rated, with flanged gasketed iron cap.
      b. Screen: Heavy-gauge Type 316 SST, 0.045 inch perforations.
   3. Strainers, Y-pattern, chemical services, 4 inches and smaller:
      a. Type: Y-pattern PVC or CPVC body to match piping, 150 psi non-shock rated, with screwed cap and seals to match piping service.
      b. End connections: Screwed or solvent weld, 2 inches and smaller. Class 150 ANSI flanges, 2 1/2 inches and larger.
      c. Screen: Heavy-gauge PVC or CPVC, 1/32 inch mesh, minimum 2 to 1 screen area to pipe size ratio.
   4. Strainers, basket, chemical services, 4 inches and smaller:
      a. Type: Duplex basket strainer, PVC or CPVC to match piping, 150 psi non-shock rated, with screwed cap and seals to match piping service or release clamp cap.
      b. End connections: Screwed or solvent weld, 2 inches and smaller. Class 150 ANSI flanges, 2 1/2 inches and larger.
      c. Screen: Heavy-gauge PVC or CPVC, 3/32-inch mesh, minimum 6 to 1 screen area to pipe size ratio.
      d. Include pressure gauge for pressure drop across the strainer.
      e. Strainer shall operate so there is no system shutdown for basket cleaning.
   5. Calibration columns:
      a. Materials: Schedule 80 clear PVC or CPVC to match piping, 150 psi rated, volume indication range as shown on the Drawings.
      b. End connections: Screwed, 2 inches and smaller. Class 150 ANSI flanges, 2 1/2 inches and larger.

PART 3 EXECUTION

3.1 GENERAL

A. Provide accessibility to piping specialties for control and maintenance.

3.2 INSTALLATION

A. Piping Flexibility Provisions:
   1. General:
      a. Thrust restraint shall be provided as specified in SECTION 40 05 00.
      b. Install flexible couplings to facilitate piping installation in accordance with approved Shop Drawings.
   2. Flexible joints at concrete backfill or encasement: Install within 18 inches or 1/2 pipe diameter, whichever is less, from the termination of any concrete backfill or concrete encasement.
   3. Flexible expansion joints shall be provided to compensate for earth settlement at buried piping connections to structure wall pipes.

B. Piping Transition:
   1. Applications:
      a. Provide complete closure assembly where pipes meet other pipes or structures.
      b. Pressure pipeline closures: Plain end pieces with double flexible couplings.
      c. Restrained joint pipe closures: Install with thrust tie-rod assemblies as shown on the Drawings.
      d. Gravity pipe closures: As specified for pressure pipelines or concrete closures.
      e. Concrete closures: Use to make connections between dissimilar pipes where standard rubber gasketed joints or flexible couplings are impractical.
      f. Elastomer sleeves bonded to pipe ends are not acceptable.
   2. Installation:
      a. Flexible transition couplings: Install in accordance with the Coupling Manufacturer’s instructions to connect dissimilar pipe and pipes with a small difference in outside diameter.

b. Concrete closures:
    1) Locate away from structures so there are at least two flexible joints between the closure and pipe entering the structure.
    2) Clean pipe surface before placing closure collars.
    3) Wet nonmetallic pipe thoroughly prior to placing collars.
    4) Prevent concrete from entering pipe.
    5) Extend the collar a minimum of 12 inches on each side of joint with a minimum thickness of 6 inches around the outside diameter of pipe.
    6) Make entire collar in one placement.
    7) After concrete has reached initial set, cure by covering with well-moistened earth.

C. Piping Expansion:
1. Piping installation: Allow for thermal expansion due to differences between installation and operating temperatures.
2. Expansion joints:
    a. Grooved joint and flanged piping systems: Elastomer bellows expansion joint.
    b. Nonmetallic pipe: Teflon bellows expansion joint.
    c. Screwed and soldered piping systems: Copper or galvanized and black steel pipe expansion compensator, as applicable.
    d. Air and water service above 120°F: Metal bellows expansion joint.
    e. Pipe run offset: Flexible metal hose.
3. Anchors and anchor walls: Install as specified in SECTION 40 05 07 to withstand expansion joint thrust loads and to direct and control thermal expansion.

D. Service Saddles:
1. Ferrous metal piping, except SST: Double-strap iron.
2. Plastic piping: Nylon-coated iron.

E. Couplings:
1. General:
    a. Install in accordance with the Manufacturer's instructions.
    b. Before coupling, clean the pipe holdback area of oil, scale, rust, and dirt.
    c. Do not remove pipe coating. If damaged, repair before the joint is made.
    d. Application:
        1) Metallic piping systems: Flexible couplings, transition couplings, and flanged coupling adapters.
        2) Concrete encased couplings: Flexible coupling.

F. Flexible Pipe Connections to Equipment:
1. Install to prevent piping from being supported by equipment, for vibration isolation, and where shown on the Drawings.
2. Product applications:
    a. Nonmetallic piping: Teflon bellows connector.
    b. Copper piping: Flexible metal hose connector.
    c. Compressor and blower discharge: Metal bellows connector.
    d. All other piping: Elastomer bellows connector.
3. Limit bolts and control rods: Tighten snug prior to applying pressure to system.

G. Pipe Sleeves:
1. Application:
    a. As specified in SECTION 40 05 00.
    b. Above grade in non-submerged areas: Hot-dip galvanized after fabrication.
    c. Below grade or in submerged or damp environments: Shop-lined and coated.
    d. Alternatively, molded PE pipe sleeve as specified may be applied.
2. Installation:
    a. Support non-insulating type securely in formwork to prevent contact with reinforcing steel and tie-wires.
    b. Caulk joint with specified sealant in non-submerged applications and seal below grade and submerged applications with wall penetration seal.

H. Slab, Floor, Wall, and Roof Penetrations:
1. Applications:
    a. Watertight and below ground penetrations:
        1) Wall pipes with thrust collars.
        2) Provide taps for stud bolts in flanges to be set flush with wall face.
    b. Non-watertight penetrations: Pipe sleeves with seep ring.
    c. Existing walls: Rotary drilled holes.
    d. Fire rated or smoke rated walls, floors or ceilings: Insulated and encased pipe sleeves.
2. Wall pipe installation:
    a. Isolate embedded metallic piping from concrete reinforcement using coated pipe penetrations as specified in SECTION 09 90 00.
    b. Support wall pipes securely by formwork to prevent contact with reinforcing steel and tie-wires.

END OF SECTION

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PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for hangers and supports for process piping.

B. Related Sections:

1. SECTION 05 50 00 – METAL FABRICATIONS

1.2 REFERENCES

A. ASTM International (ASTM):

1. A 123 – Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products
2. A 240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
3. A 653 – Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process
4. E 84 – Standard Test Method for Surface Burning Characteristics of Building Materials

B. Manufacturers Standardization Society (MSS):

1. SP 58 – Pipe Hangers and Supports – Materials, Design, Manufacture, Selection, Application, and Installation

1.3 DEFINITIONS

A. Exposed: Piping support system which is not submerged.

B. Submerged: Piping support system installed below the top of a structure intended to contain liquids.

1.4 SUBMITTALS

A. Action Submittals:

1. Catalog information and Shop Drawings of the piping support system, locating each support, brace, hanger, guide, component, and anchor for piping 4 inches and larger. Identify support, hanger, guide, and anchor type by catalog number and Shop Drawing detail number.
2. For piping smaller than 4 inches, provide catalog information for each type of support. Shop Drawings of the piping system are not required.
3. Calculations for each type of pipe support, attachment, and anchor for piping systems with a nominal diameter 4 inches and larger.
4. Revisions to piping support systems resulting from changes in the related piping system layout or addition of flexible joints.

B. Informational Submittals: Maintenance information on piping support systems.

C. Supplements listed in this Section.

1.5 QUALITY ASSURANCE

A. Design Requirements:

1. General:
   a. Design, size, and locate piping support systems throughout the facility whether shown or not.
   b. Piping support systems shall be designed, and Shop Drawings prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.
   c. Support pipe at changes in direction, or in elevation, adjacent to flexible joints and couplings, and where shown on the Drawings.
   d. Piping smaller than 30 inches: Supports are shown only where specific types and locations are required; additional pipe supports may be required.
   e. In accordance with MSS SP 58 and as specified in this Section.
   f. Special support systems shall be shown on the Shop Drawings.
2. Pipe support systems:
   a. Pipe support systems shall be designed for:
      1) Gravity loads imposed by the weight of pipes including the weight of fluid in the pipes and insulation.
      2) Seismic, snow, and wind loads as shown on the structural drawings.
      3) Temperature loads as required for the site conditions.
   b. Maximum support spacing and minimum rod size:
      1) Metallic piping:

Pipe Size (Inch)	Maximum Support Spacing for Steel and DI (Feet)	Maximum Support Spacing for Copper (Feet)	Minimum Rod Size for Single Rod Hangers (Inch)
1 1/4 and smaller	6	5	3/8
1 1/2 and 2	8	6	3/8
2 1/2	8	6	1/2
3 and 3 1/2	10	8	1/2
4	10	8	5/8
6 and 8	12	10	3/4
10 and 12	14	12	7/8
14 through 18	16	-	1
20 and 24	18	-	1 1/4

2) PVC and CPVC:

Pipe Size (Inches)	Support Spacing (Feet)		Minimum Rod Size for Single Rod Hangers (Inches)
	Operating Temperature ≤ 100°F		
	PVC	**CPVC**	3/8
1/4	3.5	3.5	3/8
3/8	3.5	4	3/8
1/2	4	4.5	3/8
3/4	4	5	3/8
1	4.5	5.5	3/8
1 1/2	5	6	3/8
2 1/2	5	6	1/2
2	5	6	1/2
3	6	7	1/2
4	6.5	7.5	1/2
6	7.5	8	5/8
8	8	9	3/4
10	8.5	10	3/4
12	9.5	10.5	3/4
14	10	11	-
16	10.5	12	-
18	11	12.5	-
20	11.5	13	-
24	12.5	14	-

c. All other non-metallic pipe: Maximum support spacing and minimum hanger rod size for single rod hangers as recommended by the Manufacturer for designed flow temperature in the pipe.

B. Framing Support System:
1. Beams: Size such that beam stress does not exceed 25,000 psi and maximum deflection does not exceed 1/240 of span.
2. Column members: Size in accordance with the Manufacturer's recommended method.
3. Support loads: Calculate using the weight of the pipes filled with water.
4. Maximum spans – other pipelines and special situations: May require supplementary hangers and supports.
5. Electrical conduit support: Include in the design of the framing support system.

C. Anchoring Devices: Design, size, and space support anchoring devices, including anchor bolts, inserts, and other devices used to anchor support, to withstand shear and pullout loads imposed by loading and spacing on each particular support.

D. Vertical Sway Bracing: 10 foot maximum centers or as shown on the Drawings.

E. Existing Support Systems: Use existing supports systems to support new piping only if the CONTRACTOR can show they are adequate for additional load, or if they are strengthened to support additional load.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Hangers, Clevis Type:
1. Anvil, Figure 104 or 260, sizes 1/2 inch through 30 inches
2. B-Line, Figure B3198H or Figure B3100, sizes 3/8 inch through 30 inches
3. Unistrut, fiberglass fabricated clevis hanger (FFCH)

B. Hangers, Hinged Split-Ring Pipe Clamp:
1. Anvil, Figure 104, sizes 3/4 inch through 8 inches
2. B-Line, Figure B3171, sizes 3/4 inch through 8 inches
3. Unistrut, fiberglass two-hole pipe straps (FPS)

C. Hanger Welded Beam Attachments:
1. Anvil, Figure 66
2. B-Line, Figure B3083

D. Hangers, CI Hanging Rolls:
1. Anvil, Figure 171, sizes 1 inch through 30 inches
2. Anvil, Figure 181, sizes 2 1/2 inches through 24 inches
3. B-Line, Figure B3114, sizes 2 inches through 30 inches
4. B-Line, Figure B3110, sizes 2 inches through 24 inches

E. Pedestal Type Saddle Supports:
1. Nonadjustable saddle:
   a. Anvil, Figure 259, sizes 4 inches through 36 inches
   b. B-Line, Figure B3090, sizes 2 1/2 inches through 36 inches

2. Adjustable saddle:
    a. Anvil, Figure 264, sizes 2 1/2 inches through 36 inches
    b. B-Line, Figure B3093, sizes 2 1/2 inches through 36 inches

F. Welded Steel Wall Bracket:
1. Anvil, Figure 199, 3,000 lb rating
2. B-Line, Figure B3067, 3,000 lb rating

G. One-Hole Clamp Wall Bracket:
1. Anvil, Figure 126, sizes 3/8 inch through 4 inches

H. Channel Type Wall Bracket:
1. Aickinstrut (FRP)
2. Anvil, Anvil-Strut
3. B-Line, Strut System
4. Unistrut

I. Riser Pipe Clamps:
1. Anvil, Figure 261, sizes 3/4 inch through 24 inches
2. B-Line, Figure B3373, sizes 1/2 inch through 30 inches

J. Channel Type Support Systems:
1. Aickinstrut, FRP System
2. Anvil, Anvil-Strut
3. B-Line, Strut System
4. Unistrut

K. Insulation Shields:
1. Anvil, Figure 167, sizes 1/2 inch through 24 inches
2. B-Line; Figure B3151, sizes 1/2 inch through 24 inches

L. Welding Insulation Saddles:
1. Anvil, Figure Series 160, sizes 1 inch through 36 inches
2. B-Line, Figure Series B3160, sizes 1/2 inch through 24 inches

M. Vibration Isolation Pads:
1. Korfund, Korpad 40
2. Mason Industries, Type W

N. Intermediate Pipe Guides:
1. Anvil, Figure 103
2. B-Line, B3148 or B3180

O. Pipe Alignment Guides:
1. Anvil
2. B-Line
3. Flexonics

P. Pipe Anchors:
1. B-Line, Figure B3147A or Figure B3147B

2.2 MATERIALS

A. General
1. For general service:
    a. Submerged: SST in accordance with ASTM A 240, Grade 316L, unless otherwise shown on the Drawings.
    b. Exposed: Galvanized steel in accordance with ASTM A 653, Class G90, or hot-dip galvanized after fabrication in accordance with ASTM A 123, unless otherwise shown on the Drawings.
2. For chemical service: FRP, except where otherwise shown on the Drawings.

B. Hangers:
1. Clevis type shall be in accordance with MSS SP 58, Type 1.
2. Hinged split-ring pipe clamp shall be in accordance with MSS SP 58, Type 6 or Type 12.
3. Hanger rods, clevises, nuts, sockets, and turnbuckles shall be in accordance with MSS SP 58.
4. Attachments:
    a. I-beam clamp shall be concentric loading type, in accordance with MSS SP 58, Type 21, 28, 29, or 30 which engage both sides of the flange.
    b. Concrete insert shall be in accordance with MSS SP 58, Type 18, continuous channel insert with load rating not less than that of the hanger rod it supports.
    c. Welded beam attachment shall be in accordance with MSS SP 58, Type 22.
5. CI hanging rolls shall be in accordance with MSS SP 58, Type 41 or Type 43.

C. Saddle Supports:
1. Pedestal type: Schedule 40 pipe stanchion, saddle, and anchoring flange.
    a. Nonadjustable saddle shall be in accordance with MSS SP 58, Type 37 with U-bolt.
    b. Adjustable saddle shall be in accordance with MSS SP 58, Type 38 without clamp.

D. Wall Brackets: Welded steel bracket shall be in accordance with MSS SP 58, Type 33 (heavy duty).

E. Pipe Clamps: Riser clamp shall be in accordance with MSS SP 58, Type 8.

F. Channel Type Support Systems:
1. Channel size and material:
    a. Galvanized steel: 12 gauge, 1 5/8 inch wide minimum.
    b. SST: 12 gauge, 1 5/8 inch wide minimum.

c. FRP: Heavy duty, 1 5/8 inch wide minimum.
2. Members and connections: Design for loads with a safety factor of 5.
3. Fasteners: Vinyl ester fiber, polyurethane base composite nuts and bolts or encapsulated steel fasteners.
4. Furnish zinc-rich primer; paint cut ends prior to installation. Provide caps on the ends from the floor, the walkway, or the pad to 7 feet above. Provide caps on bolts and all-thread on the bottom of the channel.

G. FRP Piping Support Systems:
1. FRP with UV additive, protective veil, and vinyl ester resin resistance to the chemical services shown on the Drawings.
2. For indoor use only.
3. Fire retardant: In accordance with ASTM E 84.
4. Include hangers, rods, attachments, and fasteners.
5. Design pipe support spacing and hanger rod sizing in accordance with the Manufacturer's recommendations.

H. Accessories:
1. Insulation shields: Galvanized steel or SST, in accordance with MSS SP 58, Type 40.
2. Welding insulation saddles: In accordance with MSS SP 58, Type 39.
3. Vibration isolation pads: Neoprene waffle.
4. Flush type channel inserts: As specified in SECTION 05 50 00.

I. Intermediate Pipe Guides:
1. Piping with a nominal diameter 6 inches and smaller: Pipe clamp with oversized pipe sleeve to provide minimum 1/8 inch clearance.

J. Pipe Alignment Guides:
1. Piping with a nominal diameter 8 inches and smaller: Spider or sleeve type.

K. Pipe Anchors: Anchor chair with U-bolt strap.

L. Anchoring Systems: Sized by the Equipment Manufacturer, 1/2 inch minimum diameter, and as specified in SECTION 05 50 00.

PART 3 EXECUTION

3.1 GENERAL

A. When specified items are not available, fabricate pipe supports of the correct material and to the general configuration indicated by catalogs.

B. Special support and hanger details are shown for cases where standard catalog supports are inapplicable.

3.2 INSTALLATION

A. General:
1. Install support systems in accordance with MSS SP 58 unless otherwise shown on the Drawings.
2. Install pipe hanger rods plumb, within 4 degrees of vertical during shutdown, startup, or operations.
3. Support piping connections to equipment by the pipe support and not by the equipment.
4. Support large or heavy valves, fittings, and appurtenances independently of connected piping.
5. Pipe shall not be supported from the pipe above it.
6. Support pipe at changes in direction or in elevation, adjacent to flexible joints and couplings, and where shown.
7. Do not install pipe supports and hangers in equipment access areas or bridge crane runs.
8. Brace hanging pipes against horizontal movement by both longitudinal and lateral sway bracing and to reduce movement after startup.
9. Install lateral supports for seismic loads at changes in direction.
10. Install pipe anchors where required to withstand expansion thrust loads and to direct and control thermal expansion.
11. Repair mounting surfaces to original condition after attachments are made.

B. Standard Pipe Supports:
1. Horizontal suspended piping:
   a. Single pipes: Adjustable swivel-ring, split-ring, or clevis hangers.
   b. Grouped pipes: Trapeze hanger systems.
   c. Furnish galvanized steel protection shield and oversized hangers for insulated pipe.
   d. Furnish pre-cut sections of rigid insulation with vapor barrier at hangers for insulated pipe.
2. Horizontal piping supported from walls:
   a. Single pipes: Wall brackets or wall clips attached to wall with anchors. Clips attached to wall-mounted framing shall also be acceptable.
   b. Stacked piping: Wall-mounted framing system and clips are acceptable for piping with a nominal diameter less than 3 inches.
   c. Piping clamps that resist axial movement of pipe through support are not acceptable. Provide a 3-inch sleeve of the next larger pipe diameter at each support location. Use CI hanging rolls supported from the wall bracket. Wall-mounted piping clips are not acceptable for insulated piping.
3. Horizontal piping supported from floors:
   a. Stanchion type:
      1) Pedestal type; adjustable with stanchion, saddle, and anchoring flange.
      2) Use yoked saddles for piping whose centerline elevation is 18 inches or greater above floor and for exterior installations.
      3) Provide a neoprene waffle isolation pad under anchoring flanges, adjacent to equipment, or where otherwise required to provide vibration isolation.
      4) Provide minimum 1 inch grout beneath the base plate.

b. Floor-mounted channel supports:
   1) Use for piping with a nominal diameter less than 3 inches running along floors and in trenches at piping elevations lower than can be accommodated using pedestal pipe supports.
   2) Attach channel framing to floors with base plate on minimum 1 inch grout and with anchor bolts.
   3) Attach pipe to channel with clips or pipe clamps.
c. Concrete cradles: Use for piping with a nominal diameter greater than 3 inches running along floors and in trenches at piping elevations lower than can be accommodated using stanchion type pipe supports.

4. Vertical pipe: Support with wall brackets and base elbow or riser clamps on floor penetrations.
5. Insulated pipe:
   a. Pipe hanger and support shall be on the outside of insulation. Do not enclose within insulation.
   b. Provide precut 120-degree sections of rigid insulation (minimum length same as shield), shields, and oversized hangers or insulated saddle system.
   c. Wall-mounted pipe clips are not acceptable for insulated piping.
6. Standard attachments:
   a. To concrete ceilings: Concrete inserts or anchor bolts.
   b. To steel beams: I-beam clamp or welded attachments.
   c. To wooden beams: Lag screws and angle clips to members not less than 2 1/2 inches thick.
   d. To concrete walls: Concrete inserts or brackets or clip angles with anchor bolts.
   e. Submerged concrete: Epoxy anchors.
7. Existing walls and ceilings: Install as specified for new construction unless otherwise shown on the Drawings.

C. Intermediate and Pipe Alignment Guides:
   1. Provide pipe alignment guides, or pipe supports that provide same function, at expansion joints and loops.
   2. Guide piping on each side of expansion joint or loop at 4-pipe and 14-pipe diameters from each joint or loop.
   3. Install intermediate guides on metal framing support systems not carrying a pipe anchor or alignment guide.

D. Accessories:
   1. Insulation shield: Install on insulated non-steel piping. Oversize rollers and supports.
   2. Welding insulation saddle: Install on insulated steel pipe. Oversize rollers and supports.
   3. Vibration isolation pad: Install under base flange of pedestal type pipe supports adjacent to equipment, and where required to isolate vibration.
   4. Dielectric barrier:
      a. Install between carbon steel members and copper or SST pipe.
      b. Install between SST supports and non-SST ferrous metal piping.
   5. Electrical isolation: Install 1/4 inch by 3-inch neoprene rubber wrap between submerged metal pipe and oversized clamps.

END OF SECTION

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SECTION 40 05 51
COMMON REQUIREMENTS FOR PROCESS VALVES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for common requirements for process valves.

B. Related Sections:
1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
3. SECTION 09 90 00 – PAINTING AND COATING
4. SECTION 22 00 00 – PLUMBING
5. SECTION 33 14 19 – VALVES FOR WATER UTILITY PIPING
6. SECTION 33 15 00 – AWWA RUBBER-SEATED BUTTERFLY VALVES

1.2 REFERENCES

A. American Society of Mechanical Engineers (ASME):
1. B16.1 – Gray Iron Pipe Flanges and Flanged Fittings: Classes 25, 125, and 250

B. American Water Works Association (AWWA):
1. C504 – Rubber-Seated Butterfly Valves
2. C511 – Reduced-Pressure Principle Backflow Prevention Assembly
3. C542 – Electric Motor Actuators for Valves and Slide Gates
4. C550 – Protective Interior Coatings for Valves and Hydrants
5. C800 – Underground Service Line Valves and Fittings

C. ASTM International (ASTM):
1. A 351 – Standard Specification for Castings, Austenitic, for Pressure-Containing Parts
2. B 61 – Standard Specification for Steam or Valve Bronze Castings
3. B 62 – Standard Specification for Composition Bronze or Ounce Metal Castings
4. B 98 – Standard Specification for Copper-Silicon Alloy Rod, Bar, and Shapes
5. B 127 – Standard Specification for Nickel-Copper Alloy Plate, Sheet, and Strip
6. B 139 – Standard Specification for Phosphor Bronze Rod, Bar and Shapes
7. B 164 – Standard Specification for Nickel-Copper Alloy Rod, Bar, and Wire
8. B 194 – Standard Specification for Copper-Beryllium Alloy Plate, Sheet, Strip, and Rolled Bar
9. B 584 – Standard Specification for Copper Alloy Sand Castings for General Applications
10. B 763 – Standard Specification for Copper Alloy Sand Castings for Valve Applications
11. D 429 – Standard Test Methods for Rubber Property-Adhesion to Rigid Substrates
12. D 1784 – Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Compounds and Chlorinated Poly(Vinyl Chloride) (CPVC) Compounds
13. D 2513 – Standard Specification for Polyethylene (PE) Gas Pressure Pipe, Tubing, and Fittings
14. D 4101 – Standard Classification System and Basis for Specification for Polypropylene Injection and Extrusion Materials

D. Manufacturers Standardization Society (MSS):
1. SP-81 – Stainless-Steel or Stainless-Steel-Lined, Bonnetless, Knife Gate Valves with Flanged Ends
2. SP-88 – Diaphragm Valves

E. National Electrical Manufacturers Association (NEMA):
1. 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)

F. NSF International/American National Standards Institute (NSF/ANSI):
1. 61 – Drinking Water System Components – Health Effects
2. 61, Annex G – Weighted Average Lead Evaluation Procedure to a 0.25% Lead Requirement
3. 372 – Drinking Water System Components – Lead Content

1.3 SUBMITTALS

A. Product Data: Sheets for each make and model; indicate valve type number, applicable tag number, and facility name/number or service where used.

B. Shop Drawings:
1. Complete catalog information, descriptive literature, specifications, and identification of materials of construction.
2. Power and control wiring diagrams, including terminals and numbers.
3. For each power actuator provided, the Manufacturer's standard data sheet with application specific features and options clearly identified.
4. Sizing calculations for open-close/throttle and modulating valves.

C. Certificates:
1. Manufacturer's certificate of compliance, as specified in SECTION 01 44 33.
    a. Electric actuators: In accordance with AWWA C542.
    b. Butterfly valves: In accordance with AWWA C504.
2. Manufacturer's certificate of proper installation as specified in SECTION 01 44 33.

D. Quality Control Submittals: Tests and inspection data.

E. O&M Data: As specified in SECTION 01 78 23.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Gate Valves:
   1. Type V104 bronze gate valve:
      a. As specified in SECTION 33 14 19
   2. Type V125 resilient-seated gate valve – Class 150:
      a. As specified in SECTION 33 14 19
   3. Type V130 PVC gate valve:
      a. ASAHI/America, Type P
      b. Spears
   4. Type V140 knife gate:
      a. Dezurik, Series KGC-BD
      b. ITT Fabri-Valve, Figure C67R

B. Globe Valves:
   1. Type V200 bronze globe valve:
      a. As specified in SECTION 33 14 19
   2. Type V210 PVC globe valve:
      a. ASAHI/America
      b. Spears

C. Ball Valves:
   1. Type V300 bronze three-piece ball valve:
      a. As specified in SECTION 33 14 19
   2. Type V301 SST ball valve:
      a. As specified in SECTION 22 00 00
   3. Type V307 SST three-piece ball valve:
      a. Apollo, 86A-100 Series
      b. Neles-Jamesbury, Value-Line Series 3
   4. Type V330 PVC ball valve:
      a. ASAHI/America, Type 21
      b. Hayward, TB Series
      c. Nibco, Chemtrol Tru-Bloc
      d. Spears, True Union 2000 Industrial
   5. Type V335 CPVC ball valve:
      a. ASAHI/America, Type 21
      b. Nibco, Chemtrol Tru-Bloc
      c. Spears, True Union 2000 Industrial
   6. Type V340 PP ball valve:
      a. ASAHI/America, Type 21
      b. Nibco, Chemtrol Tru-Bloc
   7. Type V350 PE ball valve:
      a. AVK Plastics
      b. R.W. Lyall
   8. Type V361 three-way ball valve:
      a. Flow-Tek, Multiport Ball Valve
      b. Valworx, Model 552916

D. Plug Valves:
   1. Type V402 eccentric plug valve:
      a. As specified in SECTION 33 14 19
   2. Type V420 non-lubricated plug valve:
      a. Duriron Co., Figure No. G432
      b. Tufline, Figure 066
   3. Type V462 gauge cock:
      a. As specified in SECTION 33 14 19 Type V464 corporation stop:
      b. As specified in SECTION 33 14 19

E. Butterfly Valves:
   1. Type V504 AWWA butterfly valve:
      a. As specified in SECTION 33 15 00
   2. Type V515 high performance butterfly valve:
      a. DeZurik, BHP Series
      b. Tyco/Keystone, K Lok Series
   3. Type V520 PVC butterfly valve:
      a. ASAHI/America, Type 56
      b. Nibco, Chemtrol Model B

F. Check and Flap Valves:
   1. Type V605 bronze swing type check valve:
      a. As specified in SECTION 33 14 19

2. Type V606 CI swing type check valve:
    a. As specified in SECTION 33 14 19
3. Type V608 DI swing type check valve:
    a. As specified in SECTION 33 14 19
4. Type V609 bronze spring check valve:
    a. As specified in SECTION 33 14 19
5. Type V610 duck billed check valve:
    a. As specified in SECTION 33 14 19
6. Type V612 double disk check valve:
    a. APCO, Series 9000
    b. Crane/Stockham, WG-970
    c. Tyco, Gulf MB Series
    d. Valmatic, Dual Disk
7. Type V615 PVC swing type check valve:
    a. ASAHI/America
    b. Spears
8. Type V616 CPVC swing type check valve:
    a. Spears
9. Type V630 PVC ball check valve:
    a. ASAHI/America, Tru Union Ball Valve
    b. Nibco, Chemtrol Tru Union
    c. Spears, True Union 2000
10. Type V631 CPVC ball check valve:
    a. ASAHI/America, Tru Union Ball Valve
    b. Nibco, Chemtrol Tru Union
    c. Spears, True Union 2000
11. Type V632 PP ball check valve:
    a. ASAHI/America
    b. Nibco
    c. Spears
12. Type V633 CI ball check valve, 3 inch and larger:
    a. Flomatic, Model 408
    b. Flygt, Model 5087
13. Type V642 RP BFPA:
    a. FEBCO, Model 860
    b. Watts, Series 009/909
14. Type V690 flap gate valve:
    a. As specified in SECTION 33 14 19

G. Self-Regulated Automatic Valves:
1. Type V710 bronze PRV:
    a. Fisher, Type 75A
    b. Watts, Series 223
2. Type V711 CI PRV:
    a. Fisher, 95 Series
3. Type V712 PVC PRV:
    a. Hayward, Pressure Regulator
    b. Plast-O-Matic, Series PR
4. Type V713 CPVC PRV:
    a. Hayward, Pressure Regulator
    b. Plast-O-Matic, Series PR
5. Type V714 PP PRV:
    a. Plast-O-Matic
6. Type V722 PVC pressure relief, bypass relief, back-pressure regulator, anti-siphon valve:
    a. Griffco, Series BPV
    b. Plast-O-Matic, Series RVDT
    c. Primary Fluid Systems, TOP Valve
    d. Pulsafeeder, Series BPV
7. Type V723 CPVC pressure relief, bypass relief, back-pressure regulator, anti-siphon valve:
    a. Griffco, Series BPV
    b. Plast-O-Matic, Series RVDT
    c. Primary Fluid Systems, TOP Valve
    d. Pulsafeeder, Series BPV
8. Type V732 DI pressure relief, bypass relief:
    a. Cla-Val, 50-01, 650-01
    b. Singer, Model 106 RPS, 206 RPS

9. Type V733 DI PRV:
    a. Cla-Val, 90-01 KO Series
    b. Singer, Model 106-AC
10. Type V747 air release and air vacuum combination valve:
    a. As specified in SECTION 33 14 19

H. Specialty Valves:
1. Type V901 CI diaphragm valve:
    a. ITT Engineered Valves
    b. Saunders Valve, Inc.
2. Type V903 PVC diaphragm valve:
    a. ASAHI/America, Diaphragm Valve Type 14/15
    b. ITT Engineered Valves, Dia-Flo
    c. Saunders Valve, Diaphragm Valve
3. Type V904 CPVC diaphragm valve:
    a. ASAHI/America, Valve Type 14/15
    b. Spears
4. Type V910 pinch valve:
    a. Red Valve Co., Series 75 and 5400E
    b. RF Technologies, Inc., RF Valve
5. Type V920 CPVC needle valve:
    a. Hayward NVA Series
6. Type V921 PVC needle valve:
    a. Hayward NVA Series
7. Type V922 PP needle valve:
    a. Hayward NVA Series
8. Type V925 sampling valve:
    a. Fetterolf Corporation, Rod-Seal Sampling Valve
    b. Strahman Valves, Inc., Piston Type Sampling Valve
9. Type V940 solenoid valve:
    a. As specified in SECTION 33 14 19

I. Electric motor actuators:
1. Open-close or modulating service (1E):
    a. ASAHI/America, Series 94
    b. Bettis, Model EM
    c. El-O-Matic, EL Series

J. Accessories:
1. T-handled operating wrench:
    a. Clow, F-2520
    b. Mueller Co., No. A-24610
2. Extension bonnet for valve operator complete with enclosed stem, extension, support brackets, and accessories for valve and operator:
    a. DeZurik
    b. Pratt
3. Floor stand and extension stem:
    a. Clow, F-5515
    b. Mueller Co.,
4. Floor box and stem:
    a. Clow, F-5695
    b. Neenah Foundry, R 7506
5. Chain wheel and guide:
    a. Clow, F-5680
    b. DeZurik Corp., Series W or LWG
    c. Walworth Co., Figure 804

2.2 MATERIALS

A. General:
1. Valves shall include operator, actuator, handwheel, chain wheel, extension stem, floor stand, operating nut, chain, wrench, and accessories to allow a complete operation from the intended operating level.
2. The valve shall be suitable for its intended service. Renewable parts shall not be of a lower quality than specified.
3. The valve shall be the same size as adjoining pipe unless otherwise called out on the Drawings.
4. Valve ends shall suit adjacent piping.
5. Resilient-seated valves shall have no leakage (drop-tight) in either direction at the valve rated design pressure. Other valves shall have no leakage (drop-tight) in either direction at the valve rated design pressure unless otherwise specified in this Section or in the stated valve standard.
6. Size operators and actuators to operate valve for the full range of pressures and velocities.
7. Buried valves shall open by turning clockwise. Non-buried, in-plant service valves shall open by turning counter-clockwise.

8. Valve construction shall be compatible with the electric actuator if an electric actuator is required; as specified in the electric operator schedule.
9. Factory-mount operator, actuator, and accessories.
10. Potable water applications:
    a. Brass and bronze valve components and accessories that have surfaces in contact with potable water shall be alloys containing less than 16% zinc and 2% aluminum and shall be certified in accordance with NSF/ANSI 61, NSF/ANSI 61, Annex G, and NSF/ANSI 372.
        1) Approved alloys: ASTM B 61, ASTM B 62, ASTM B 98 (Alloy UNS No. C65100, C65500, or C66100), ASTM B 139 (Alloy UNS No. C51000), ASTM B 584 (Alloy UNS No. B89520, B89833, C90300 or C94700), ASTM B 164, ASTM B 194, ASTM B 127 and ASTM B 763 (Alloy UNS No. C9950).
        2) SST alloy 18-8 may be substituted for bronze.
11. Recycled water applications: Brass and bronze goods that have surfaces not in contact with potable water shall be manufactured in accordance with AWWA C800 using copper alloy UNS No. C83600, commercially known as 85-5-5, in accordance with ASTM B 62.

B. Gate Valves: Type V130 PVC gate valve 1 1/2 inches to 4 inches: Solid PVC body in accordance with ASTM D 1784, removable bonnet, flanged ends, Class 150, rated 150 psi at 70°F, PP gate in accordance with ASTM D 4101, non-rising stem with sealed position indicator, clean-out plug and EPDM seals.

C. Type V140 knife gate valve 24 inches and smaller: Bonnetless wafer body type, outside stem and yoke, rated for 150 psi cold water, ASME B16.1 flanged ends, non-clogging, with round port, resilient EPDM seat, bi-directional drip-tight shutoff. Wetted parts ASTM A 351 CF8M Type 316 SST, stem ASTM A 351 CF8 SST with stem extension kit, yoke sleeve bronze, gate finish ground both sides with a sharp knife edge. Packing system leak-tight seal around gate, valve superstructure and yoke designed for full peripheral access to gland bolds when valve is equipped with manual or power actuator. In accordance with MSS SP-81.

D. Globe Valves: Type V210 PVC globe valve 4 inches and smaller: Solid PVC body in accordance with ASTM D 1784, removable bonnet, flanged ends, Class 150, rated 150 psi at 70°F, PP disc in accordance with ASTM D 4101 and EPDM seals.

E. Ball Valves:
1. Type V307 SST three-piece ball valve 3 inches and smaller: three-piece, standard port, NPT threaded ends, Type 316 SST body, ball and stem, PTFE seats and seals, adjustable packing nut, blow-out proof stem, rated 1,000 psi CWP.
2. Type V330 PVC ball valve 2 inches and smaller: Rated 150 psi at 73°F, Type I, Grade 1 PVC body, ball, and stem, end entry, double union design, solvent weld socket ends, elastomer seat, EPDM O-ring stem seals, to block flow in both directions in accordance with ASTM D 1784.
    a. For sodium hypochlorite service, provide a pressure relief hole drilled on the low-pressure side of the ball.
3. Type V335 CPVC ball valve 4 inches and smaller: Rated 150 psi at 73°F, Type I, Grade 1 CPVC full port body, ball, and stem, end entry, double union design, solvent-weld socket ends, PTFE seat, Viton (FKM)O-ring stem, face, and carrier seals, to block flow in both directions in accordance with ASTM D 1784.
    a. For sodium hypochlorite service, provide a pressure relief hole drilled on the low-pressure side of the ball.
4. Type V340 PP ball valve 2 inches and smaller: Rated 150 psi at 73°F, PP body, ball, and stem, end entry, double union design, solvent-weld socket ends, elastomer seat, EPDM O-ring stem seals, to block flow in both directions in accordance with ASTM D 4101.
5. Type V350 PE ball valve 2 inches and smaller: Solid PE body in accordance with ASTM D 2513, socket weld ends, EPDM seat and seals, rated 150 psi at 73°F.
6. Type V361 three-way ball valve: Rated for a minimum of 150 psi, T-port flow path, Type 316 SST body and ball, full port, NPT threaded ends, live-loaded stem with primary and secondary sealing, PTFE seat, Type 316 SST hardware.

F. Plug Valves: Type V420 non-lubricated plug valve 2 inches and smaller: DI or carbon steel body, Type 316 SST plug with straight-way rectangular ports, Teflon sleeves, screwed ends, wrench operator, Class 150, rated 275 psi WOG.

G. Butterfly Valves:
1. General:
    a. Valves shall be in accordance with AWWA C504 and the following requirements:
        1) Suitable for throttling operations and infrequent operation after periods of inactivity.
        2) Elastomer seats which are bonded or vulcanized to the body shall have adhesive integrity of bond between the seat and the body assured by testing, with minimum 75 lb pull in accordance with ASTM D 429, Method B.
        3) Bubble-tight with rated pressure applied from either side; test valves with pressure applied in both directions.
        4) No travel stops for the disc on the interior of the body.
        5) Self-adjusting V-type or O-ring shaft seals.
        6) Isolate metal-to-metal thrust bearing surfaces from flowstream.
        7) Provided traveling nut or worm gear actuator with handwheel; valve actuators shall be in accordance with AWWA C504.
        8) Provide linings and coatings in accordance with AWWA unless otherwise shown on the Drawings or specified herein.
        9) Valves shall be in accordance with NSF/ANSI 61; provide a NSF/ANSI 61 certificate for each valve.

b. Non-AWWA butterfly valves shall meet the following actuator requirements: For above ground installations, provide a handle and notch plate for valves 6 inches and smaller and heavy duty, totally-enclosed gearbox type operators with handwheel, position indicator and travel stops for valves 8 inches and larger unless otherwise shown on the Drawings or specified herein.

2. Type V515 high performance butterfly valve, 2 inches to 20 inches: Wafer style, CI body, Type 316 SST disc, Type 316 SST one-piece stem, EPDM replaceable resilient seat suitable for operating temperatures up to 250°F, 150 psi working pressure, rating, bubble-tight at 50 psi differential pressure, externally adjustable bronze packing gland with Buna N packing, valve body to fit between ASME B16.1 Class 125/150 flanges.
3. Type V520 PVC butterfly valve 1 1/2 inches to 8 inches: Wafer body type, pressure rated 150 psi at 70°F CWP, solid ASTM D 1784, Type I, Grade 1, PVC body and contoured PVC or PP valve disc, SST valve stem, Viton (FKM) seat, lever operator.

H. Check and Flap Valves:

1. Type V612 double disc swing check valve 2 inches to 48 inches: Wafer style, spring loaded, CI body, aluminum-bronze or DI discs, EPDM resilient seats, and Type 316 SST spring, hinge pin, and stop pin, rated for minimum 150 psi nonshock working pressure.
2. Type V615 PVC swing type check valve 4 inches and smaller: In accordance with ASTM D 1784, Type I, Grade 1 PVC body, flanged ends, rated 150 psi at 73°F, EPDM seat and seal, external counter balance measure and top entry access.
3. Type V616 CPVC swing type check valve 4 inches and smaller: In accordance with ASTM D 1784, Type IV, CPVC body, flanged ends, rated 150 psi at 73°F, EPDM seat and seal, external counter balance measure and top entry access.
4. Type V630 PVC ball check valve 3 inches and smaller: In accordance with ASTM D 1784, Type I, Grade 1 PVC body, dual union socket weld ends, rated 150 psi at 73°F, and EPDM seat and seal.
5. Type V631 CPVC ball check valve 4 inches and smaller: In accordance with ASTM D 1784, Cell Class 23477-B CPVC body, dual union socket weld ends, rated 150 psi at 73°F, 110 psi at 140°F, Viton seat and seal.
6. Type V632 PP ball check valve 3 inches and smaller: In accordance with ASTM D 4101, PP body, dual union socket weld ends, rated 150 psi at 73°F, and EPDM seat and seal, minimum shut-off of 5 psi.
7. Type V633 ball check valve 3 inches and larger: Flanged end, iron body valve with cleanout and sinking type hollow steel ball, vulcanized nitrile rubber exterior, flanges ASME B16.1, Class 125, rated 150-lb working pressure, suitable for horizontal flow. Valve shall be equipped with a limit switch with dry contacts, capable of communication with the plant control system, to provide indication when ball is in the closed position.
8. Type V642 RP BFPA 3/4 inch to 10 inches: Two resilient-seated check valves with an independent relief valve between the valves, two non-rising stem resilient-seated isolation valves, test cocks, in accordance with AWWA C511, rated 175 psi maximum working pressure.

I. Self-Regulated Automatic Valves:

1. Type V710 bronze PRV 2 1/2 inches and smaller: Direct diaphragm operated, spring controlled, bronze body, adjustable pressure setting, rated 300 psi.
2. Type V711 CI PRV 2 inches and smaller: Direct diaphragm, spring controlled, CI body, spring case, composition seat and diaphragm, SST valve stem, adjustable pressure setting, rated 300 psi.
3. Type V712 PVC PRV 1 1/2 inches and smaller: Diaphragm operated assembly, spring controlled, in-line pattern, NPT threaded inlet and outlet, rated 150 psi, PVC body, EPDM seals and diaphragm, coated SST spring, SST adjusting bolt, locknut, and fasteners, designed to regulate downstream pressure closing when pressure reaches SP, set pressure adjustable from 5 psi to 50 psi.
4. Type V713 CPVC PRV 1 1/2 inches and smaller: Diaphragm operated assembly, spring controlled, in-line pattern, NPT threaded inlet and outlet, rated 150 psi, CPVC body, EPDM seals and diaphragm, coated SST spring, SST adjusting bolt, locknut, and fasteners, designed to regulate downstream pressure closing when pressure reaches SP, set pressure adjustable from 5 psi to 50 psi.
5. Type V714 PP PRV 1 1/2 inches and smaller: Diaphragm operated assembly, spring controlled, in-line pattern, NPT threaded inlet and outlet, rated 150 psi, PP body, EPDM seals and diaphragm, coated SST spring, SST adjusting bolt, locknut, and fasteners, designed to regulate downstream pressure closing when pressure reaches SP, set pressure adjustable from 5 psi to 50 psi.
6. Type V722 PVC pressure relief, bypass relief, back-pressure regulator, back-pressure, anti-siphon valve 2 inches and smaller: Direct acting diaphragm, spring controlled, in-line pattern, NPT threaded inlet and outlet, rated 150 psi, PVC body, Teflon diaphragm, PVC or Teflon piston, high-density PE or SST adjusting bolt and locknut, SST or coated steel spring, SST fasteners, designed to open when upstream pressure reaches SP, set pressure adjustable from 10 psi to 100 psi, minimum.
7. Type V723 CPVC pressure relief, bypass relief, back-pressure regulator, back-pressure, anti-siphon valve 2 inches and smaller: Direct acting diaphragm, spring controlled, in-line pattern, NPT threaded inlet and outlet, rated 150 psi, CPVC body, Teflon diaphragm, CPVC or Teflon piston, high-density PE or SST adjusting bolt and locknut, SST or coated steel spring, SST fasteners, designed to open when upstream pressure reaches SP, set pressure adjustable from 10 psi to 100 psi, minimum.
8. Type V732 DI pressure relief, bypass relief, 3 inches and larger: Hydraulically operated, diaphragm actuated, pilot-controlled globe valve, in-line pattern, ASME B16.1 Class 150 flanged ends rated 250 psi, SST trim and stem, FDA approved fusion-bonded epoxy lining and coating installed in accordance with AWWA C550, externally mounted strainers with cocks, to open when upstream pressure reaches a maximum SP, set pressure as shown on the Drawings.

9. Type V733 PRV 3 inches and larger: Hydraulically operated, diaphragm actuated, pilot controlled globe valve, pilot on the left side looking in the direction of flow, anti-cavitation option, DI body, ASME B16.1 Class 150 flanged ends, rated 250 psi, SST trim, SST stem, externally mounted wye strainers with cocks, maintains a constant downstream pressure regardless of fluctuations in flow or upstream pressure. Fusion bonded epoxy lining (and coating) installed in accordance with AWWA C550. The size/rating shall be as shown on the Drawings.

J. Specialty Valves:
  1. Type V901 CI diaphragm valve 1/2 inch to 12 inches: Straight-through type, soft rubber lined CI body, ASME B16.1 flanged ends, manual operator indicating, rising stem type with handwheel, diaphragm natural rubber, in accordance with MSS SP-88, Category B.
  2. Type V903 PVC diaphragm valve 1/2 inch to 4 inches: Weir type with PVC Type 1, Grade 1 body, PTFE diaphragm, double union design, solvent weld socket ends, handwheel operator, position indicator, adjustable travel stop, clear molded acrylic stem cap. For sodium hypochlorite service, diaphragm shall be three-layer type, designed with PVDF gas barrier between wetted PTFE layer and EPDM top cushion.
  3. Type V904 CPVC diaphragm valve 1/2 inch to 4 inches: Weir type with CPVC body, PTFE diaphragm, double union design, solvent weld socket ends, handwheel operator, position indicator, adjustable travel stop, clear molded acrylic stem cap. For sodium hypochlorite service, diaphragm shall be three-layer type, designed with PVDF gas barrier between wetted PTFE layer and EPDM top cushion.
  4. Type V910 pinch valve 1 inch to 12 inches: CI fully enclosed body, ASME B16.1 Class 125 flanged ends, one-piece molded Buna-N elastomer tube, 90 psi minimum working pressure, double-acting upper and lower pinch bars that close on centerline, SST stem, electrically actuated or handwheel operator, position indicator, geared operator for valves 6 inches and larger. Cone sleeve configuration to eliminate cavitation at design flow. Select cone size to minimize flow restriction when the valve is fully opened.
  5. Type V920 CPVC needle valve 1/2 inch and smaller: CPVC body, in-line style, integrated stem with PTFE seat, threaded connections, fine pitch stem thread for precise adjustment, body shall be rated for 150 psig at 70°F.
  6. Type V921 PVC needle valve 1/2 inch and smaller: PVC body, in-line style, integrated stem with PTFE seat, threaded connections, fine pitch stem thread for precise adjustment, body shall be rated for 150 psig at 70°F.
  7. Type V921 PP needle valve 1/2 inch and smaller: PP body, in-line style, integrated stem with PTFE seat, threaded connections, fine pitch stem thread for precise adjustment, body shall be rated for 150 psig at 70°F.
  8. Type V925 sampling valve: Type 316 SST wetted parts, hand-operated iron crank, piston to extend to inner surface of pipe, sealed by two compressible replaceable PTFE rings, one above discharge port and other below discharge port, 3/4 inch NPT inlet and 3/4 inch NPT outlet.

K. Operators and Actuators:
  1. Manual operators:
    a. General:
      1) For AWWA valves, the operator force shall not exceed the requirements of the applicable valve standard. For non-AWWA valves, the operator force shall not exceed the applicable industry standard or 80 lbs, whichever is less, under any operating condition, including initial breakaway. Provide a gear reduction operator when force exceeds requirements.
      2) The operator shall be the self-locking type or equipped with a self-locking device.
      3) Position indicator on quarter-turn valves.
      4) Worm and gear operators shall be one-piece design worm-gears of gear bronze material. Worm hardened alloy steel with thread ground and polished. Traveling nut type operators threader steel reach rods with internally threaded bronze or DI nut.
    b. Exposed operator:
      1) Galvanized and painted unless otherwise specified.
      2) Cranks on gear type operators.
      3) Chain wheel operator with tiebacks, extension stem, floor stands, and other accessories to permit operation from normal operation level.
      4) Valve handles shall take a padlock; wheels shall take a chain and padlock.
    c. Buried operator:
      1) Buried service operators on valves larger than 2 1/2 inches shall have a 2-inch AWWA operating nut. Buried operators on valves 2 inches and smaller shall have a cross handle for operation by forked key. Enclose moving parts of the valve and the operator in housing to prevent contact with the soil.
      2) Design buried service operators for quarter-turn valves to withstand 450 ft-lbs of input torque at the fully open or fully closed positions, grease-packed and gasketed to withstand a submersion in water to 10 psi.
      3) Buried valves shall have extension stems, bonnets, and valve boxes.
  2. Electric motor actuators:
    a. General:
      1) In accordance with AWWA C542.
      2) Size to 1 1/2 times the required operating torque; motor stall torque shall not exceed the torque capacity of the valve.
      3) Controls integral with the actuator and fully equipped in accordance with AWWA C542.
      4) Stem protection for rising stem valves.
    b. Actuator operation – general:
      1) Suitable for full 90 degree rotation of quarter-turn valves or for use on multi-turn valves, as applicable.
      2) Manual override handwheel.
      3) Valve position indication.

4) Operate from full closed to full open positions or the reverse in the number of seconds specified in the electric operator schedule.
5) Valve shall remain in the last position upon loss of signal (fail last position) unless otherwise shown on the Drawings.

c. Open-close or modulating service (1E):
1) Size motors for unrestricted continuous duty.
2) Feedback potentiometer and integral electronic positioner/comparator circuit to maintain valve position.
3) Hand-off-auto (local-off-remote) selector switch:
a) Open-stop-close push button to control valve in hand position.
b) 4 mA to 20 mA DC input signal to control valve in auto position.
c) Auxiliary contact which closes when the hand-off-auto or local-off-remote switch is in the auto or remote position.
4) Open and closed indicating lights.
5) Reversing motor starter with built-in overload protection.
6) Actuator power supply:
a) 120 V, single-phase unless otherwise shown on the Drawings.
b) Externally operable power disconnect switch.
7) Enclosure:
a) In accordance with NEMA 250, Type 4X.
b) Contain 120 V space heaters.
8) Limit switch:
a) SPDT type, field adjustable cam-operated, with contacts rated for 5 A, 120 VAC.
b) Each valve actuator shall have a minimum of two transfer contacts at end position, one for valve full open and one for valve full closed; limit switches shall be for customer use only.
c) Housed in actuator control enclosure.
9) Control features: Furnish electric actuators with features as specified in the electric operator schedule.

2.3 ACCESSORIES

A. Tagging: 1 1/2 inch diameter heavy brass or SST tag attached with No. 16 solid brass or SST jack chain for each valve bearing the valve tag number affixed to the valve at the factory prior to shipment.

B. T-Handled Operating Wrench:
1. Galvanized operating wrenches, 4 feet long: Two each.
2. Galvanized operating keys for cross handled valves: One each.

C. Floor Stand:
1. Non-rising, heavy pattern, indicating type.
2. Complete with solid extension stem, coupling, handwheel, stem guide brackets, and yoke attachment; stem length as required to connect valve operating nut and floor stand.
3. Stem guide: Space such that stem L/R ratio does not exceed 200.
4. Anchor bolts: Type 304 SST.

D. Floor Box:
1. Plain type, for support of non-rising type stem.
2. Complete with solid extension stem, operating nut, and stem guide brackets; stem length as required to extend valve operating nut to within 3 inches of finish floor.
3. Stem guide: Space such that stem L/R ratio does not exceed 200.
4. Anchor bolts: Type 304 SST.

E. Chain Wheel and Guide:
1. Handwheel direct-mount type.
2. Complete with chain.
3. Galvanized or cadmium-plated.

F. Indicator Post Assembly:
1. Cast or DI post head, bell, and wrench with cast, DI, or steel barrel.
2. Plexiglas protected window to indicate open and closed position.
3. Padlockable eye bolt for wrench.
4. Adjustable bury depth; bury depth as required for valve installation.
5. UL listed, FMG approved.

2.4 FINISHES

A. Factory Finishing:
1. Epoxy lining and coating:
a. Use where specified for individual valves described herein.
b. In accordance with AWWA C550.
c. Either two-part liquid material or heat-activated (fusion) material except only heat-activated material if specified as fusion or fusion-bonded epoxy.
d. MDFT 7 mil, except where limited by valve operating tolerances.
2. Exposed valves:
a. Coating shall match the Pipe Schedule and shall be as specified in SECTION 09 90 00.
b. Safety isolation valves and lockout valves with handles, handwheels, or chain wheels shall be safety yellow.

PART 3 EXECUTION

3.1 INSTALLATION

A. Flange Ends:
   1. Flanged valve bolt holes shall straddle vertical centerline of pipe.
   2. Clean flanged faces, insert gasket and bolts, and tighten nuts progressively and uniformly.

B. Screwed Ends:
   1. Clean threads by wire brushing or swabbing.
   2. Apply joint compound.

C. Valve Installation and Orientation:
   1. General:
      a. Install valves so handles operate from fully open to fully closed without encountering obstructions.
      b. Install valves in a location that allows for easy access for routine O&M.
      c. Install valves in accordance with the Manufacturer's recommendations.
      d. Install a line size ball valve and union upstream of each solenoid valve, in-line flow switch, or other in-line electrical device, excluding magnetic flowmeters, for isolation during maintenance.
      e. Locate the valve to provide accessibility for control and maintenance. Install access doors in finished walls and plaster ceilings for valve access.
   2. Gate, globe, and ball valves:
      a. Install the operating stem vertical when the valve is installed in horizontal runs of pipe having centerline elevations 4 feet 6 inches or less above the finished floor.
      b. Install the operating stem horizontal in horizontal runs of pipe having centerline elevations greater than 4 feet 6 inches above the finished floor.
   3. Plug valves:
      a. Unless otherwise restricted or shown on the Drawings, install the valve as follows:
         1) Liquids with suspended solids service with horizontal flow: Install the valve with the stem in the horizontal position with the plug up when the valve is open; install the valve with the seat end upstream, the flow shall produce unseating pressure.
         2) Liquids with suspended solids service with vertical flow: Install the valve with the seat in the highest portion of the valve, seat up.
         3) Clean liquids and gas service: Install the valve with the seat end downstream of higher pressure when the valve is closed; higher pressure forces the plug into the seat.
   4. Butterfly valves:
      a. Unless otherwise restricted or shown on the Drawings, install the valve a minimum of eight diameters downstream of an elbow or branch tee and with the shaft in horizontal position.
      b. For a vertical elbow or branch tee immediately upstream of the valve, install the valve with the shaft in the vertical position.
      c. For a horizontal elbow or branch tee immediately upstream of the valve, install the valve with the shaft in the horizontal position.
      d. When installed immediately downstream of a swing check, install the valve with the shaft perpendicular to the swing check shaft.
      e. For free inlet or discharge into basins and tanks, install the valve with the shaft in the vertical position.
   5. Check valves:
      a. Install the valve in horizontal or vertical flow (up) flow piping only for liquid services.
      b. Install the valve in vertical flow (up) piping only for gas services.
      c. Install the swing check valve with the shaft in horizontal position.
   6. Extension stem for operator: Where the depth of the valve operating nut is 3 feet or greater below finish grade, furnish an operating extension stem with a 2-inch operating nut to bring the operating nut to a point within 6 inches of finish grade.
   7. Torque tube: Where the operator for the quarter-turn valve is located on a floor stand, furnish an extension stem torque tube of a type properly sized for the maximum torque capacity of the valve.
   8. Floor box and stem: Steel extension stem length shall locate the operating nut in the floor box.
   9. Chain wheel and guide: Install chain wheel and guide assemblies or chain lever assemblies on manually operated valves over 6 feet 9 inches above the finished floor. Install chain to within 3 feet of finished floor. Where chains hang in normally traveled areas, use appropriate L-type, tie-back anchors. Install chains to within operator horizontal reach of 2 feet 6 inches, maximum, measured from the normal operator standing location or station.

3.2 QUALITY CONTROL

A. Tests and Inspection:
   1. Valves may be tested while testing pipelines or as a separate step.
   2. Test that valves open and close smoothly under operating pressure conditions. Test that two-way valves open and close smoothly under operating pressure conditions from both directions.
   3. Inspect air and vacuum valves as the pipe is being filled to verify the venting and seating is fully functional.
   4. Count and record the number of turns to open and close each valve; account for any discrepancies with the Manufacturer's data.
   5. Set, verify, and record set pressures for relief and regulating valves.
   6. Automatic valves shall be tested in conjunction with control system testing. Set opening and closing speeds and limit switches as required or recommended by the ENGINEER.

7. Test hydrostatic relief valve seating; record leakage. Adjust and retest to a maximum leakage of 0.1 gpm/ft of seat periphery.

END OF SECTION

SECTION 40 05 59.23
FABRICATED STAINLESS STEEL SLIDE GATES

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for fabricated stainless steel slide gates.

B. Related Sections:
1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 01 91 00 (.01 or .02) – COMMISSIONING

1.2 REFERENCES

A. American Society of Testing and Materials (ASTM):
1. A 240 – Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
2. A 276 – Standard Specification for Stainless Steel Bars and Shapes
3. B 584 – Standard Specification for Copper Alloy Sand Castings for General Applications
4. D 2000 – Standard Classification System for Rubber Products in Automotive Applications
5. D 4020 – Standard Specification for Ultra-High-Molecular-Weight Polyethylene Molding and Extrusion Materials
6. F 593 – Standard Specification for Stainless Steel Bolts, Hex Cap Screws, and Studs
7. F 594 – Standard Specification for Stainless Steel Nuts

B. American Water Works Association (AWWA):
1. C541 – Hydraulic and Pneumatic Cylinder and Vane-Type Actuators for Valves and Slide Gates
2. C542 – Electric Motor Actuators for Valves and Slide Gates
3. C561 – Fabricated Stainless-Steel Slide Gates

C. The Society for Protective Coatings/NACE International (SSPC/NACE):
1. SSPC SP 10/NACE No. 2 – Near-White Blast Cleaning

1.3 SUBMITTALS

A. Shop Drawings:
1. Make and model of each equipment assembly: Weights of equipment assemblies and components to include stem and slide weight.
2. The Manufacturer's catalog information, descriptive literature, specifications, and identification of materials of construction.
3. Detailed structural and mechanical drawings showing the equipment fabrications and interface with other items. Include dimensions, size, and locations of connections to other work, and weights of equipment associated therewith.
4. Installation drawings showing the details of construction, details required for installation, dimensions, and anchor bolt locations.
5. The material thickness of structural components of the frame and slide.
   a. Submit the following calculations for each gate and service condition:
      1) Maximum bending stress and deflection of the slide under maximum design head.
      2) Gate opening and closing thrust forces.
      3) Gate actuator and stem sizing calculations.
      4) Stem guide spacing calculations.

B. Quality Control Submittals:
1. Manufacturer’s certificate of compliance in accordance with AWWA C561.
2. Shop test report prior to gate shipment.
3. Certificate of proper installation as specified in SECTION 01 91 00.

C. O&M Manual:
1. Submit one electronic or hardcopy preliminary manual for review within 4 weeks after final approval of submittals as specified in SECTION 01 78 23 and with reference to the Drawings.
2. Any deficiencies found by the ENGINEER to exist in the manuals shall be corrected by the CONTRACTOR and resubmitted for review.
3. Final manuals shall be submitted in two hardcopies and one electronic copy at least 15 days prior to the scheduled delivery of equipment. Hardcopy manuals shall be fixed in three-ring binders which are clearly labeled to designate the equipment for which it is intended. Submit the PDF electronically by using the DW approved dropbox.

D. Extra Materials: Furnish, tag, and box for shipment and storage any special tools required to maintain or dismantle the gate.

E. Supplements included in this Section.

1.4 QUALITY ASSURANCE

A. Design:
1. Leakage not to exceed 0.10 gpm/ft of wetted seal perimeter at the specified seating and unseating heads.
2. Gates designed for the design heads as specified in Supplement A.
3. Additional information as specified in Supplement A.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS:

A. Gate:
1. Fresno Valves
2. Hydro Gate
3. Waterman
4. Whipps, Inc.

B. Gear Actuator:
   1. Rotork
   2. Auma (manual only)

2.2 MATERIALS

A. Components:

Components	Material
Thimble, frame, guides, slide, yoke and stem guides	SST, Type 304 or 316 ASTM A 240
Actuator pedestal	SST ASTM A 240
Actuator gear housing	Cast aluminum, DI, or SST, Type 304
Seat/seals	UHMW PE ASTM D 4020
Invert seal (upward opening gates)	Neoprene or EPDM ASTM D 2000
Thrust nut, lift nut and stem couplings	Bronze ASTM B 584
Stem	SST, Type 304 or 316 ASTM A 276
Fasteners and anchor bolts	SST, Type 304 or 316 ASTM F 593 and ASTM F 594

B. Slide Gates:
   1. Frame and guides:
      a. Frame: Rigid, welded unit with a clear opening the same size as the waterway, unless otherwise specified. The minimum thickness of members except seal retainers shall be 1/4 inch.
      b. Vertical guides:
         1) Extend in one continuous piece from the gate invert to the top rail to fully support the slide.
         2) Incorporate replaceable UHMW PE seats-seals in a retainer slot on both the downstream side and the upstream side of the gate frame.
      c. Join vertical guide frames, top rail, and invert with factory welded corners.
      d. Size guided slot to provide a minimum disc engagement of 3/4 inch on each side.

C. Slide:
   1. Slide plate (sliding member): One-piece, reinforced as required so the disc will not deflect more than 1/360 of the gate width or 1/16 inch, whichever is smaller, at maximum design head. The minimum thickness of members except seal retainers shall be 1/4 inch.
   2. Reinforce gate slide with one-piece angles or channels welded to the disc plate. Bolted reinforcements will not be permitted.

D. Flush Bottom Closure:
   1. On upward opening gates.
   2. A resilient neoprene or EPDM seal shall be mounted on the bottom of the disc or installed into the frame invert member to provide flush-bottom closure.
   3. Invert seal shall be held in place by a SST retainer bar and SST fasteners.

E. Side and Top Seats-Seals:
   1. Gates equipped with self-adjusting UHMW PE seat-seals to restrict leakage and to prevent metal to metal contact between the frame and slide.
   2. The side seat-seals shall extend to support 1/2 of the height of the slide when the slide is in the fully opened position.
   3. Downward opening weir gates shall be provided with UHMW PE seat-seals across the invert member.
   4. Durable seal system designed to accommodate high velocities and frequent cycling without loosening or suffering damage.
   5. Seals shall be bolted or otherwise mechanically fastened to the frame or slide. Seals that are force fit or held in place with adhesives are not acceptable.
   6. Seat-seals mounted so as not to obstruct the water way opening.
   7. Gates that utilize rubber J seals or P seals are not acceptable.

F. Operator Support Yoke: For self-contained gates, welded to the vertical extensions of the guide frames.

G. Stems:
   1. Solid SST.
   2. Threads which generate gate motion shall be machine cut or rolled Acme type with a surface finish of 16 micro-inches or better.
   3. Extend threaded portion of stem 2 inches above operator when gate is in closed position.
   4. On rising stem gates with manual actuators, provide an adjustable stop collar for the closed position.
   5. On downward opening gates, a bronze stop collar or other positive means shall be provided to prevent the loss of the slide from the guides.
   6. On downward opening gates, provide a field adjustable stop collar to prevent the slide from rising above the invert seal.
   7. The stop collar shall be set with a set screw.
   8. The stem shall be connected to the slide by a thrust nut or by a minimum of two bolts.

H. Couplings:
   1. If stems are furnished in more than one piece, connect with solid couplings.
   2. Connections shall be threaded and keyed or threaded and bolted and of greater strength than the stems.

I. Stem Guides:
1. Provided as required to meet the stem design requirements.
2. Mounted on the gate guides or yoke or wall-mounted.
3. Spaced in accordance with the Manufacturer's recommendations so the L/R ratio does not exceed 200.
4. Wall mounted stem guides shall be two-piece, with a bronze bushing, adjustable in two directions.
5. Bushings shall have a maximum diametral clearance of 1/8 inch.

J. Stem Covers:
1. Provide on rising stem gates.
2. Transparent plastic, waterproof, sun fade resistant, and vented pipe stem cover and cap.
3. Provide with open/closed designators with 1 inch graduations on clear mylar pressure sensitive, adhesive tape, suitable for outdoor application.

K. Gate Actuator:
1. Provide manual, electric, or hydraulic actuators as specified in the Schedule on the Drawing. On gates that are not self-contained, provide operating pedestals as shown on the Drawings.
2. Manual actuators shall be provided with a crank or handwheel. The gate shall open with a counter-clockwise rotation of the crank or handwheel.
3. Electric actuators shall be in accordance with the operating speed requirements of AWWA C561 and AWWA C542.
4. Hydraulic actuators shall be in accordance with AWWA C541.

L. Appurtenances:
1. Lifting lugs: Furnish suitably attached for equipment assemblies and components weighing over 100 lbs.
2. Anchor and mounting bolts: Sized and furnished by the Gate Manufacturer.
3. Pedestals: The pedestal height shall be such that the handwheel or pinion shaft on the crank-operated gearbox is located approximately 36 inches above the operating floor.
4. Wall mounting bracket: As shown on the Drawings, provide for actuator and support pedestal. The bracket shall be fabricated SST, designed to support the maximum operating force of the gate with a minimum safety factor of 4 with regard to ultimate tensile, compressive, and shear strength, and a minimum safety factor of 2 with regard to tensile, compressive, and shear yield strength. Furnish SST anchor bolts.

2.3 FINISHES

A. Shop/Factory Finishing:
1. Cast and carbon steel surfaces, except seating surfaces and machined surfaces in an unsubmerged location shall be prepared for coating by sandblasting to a near white metal finish in accordance with SSPC/NACE SSPC SP 10/NACE No. 2. These surfaces shall then be coated with a two-part thermosetting polyamide epoxy in two or more uniform coats to a minimum DFT of 10 mils.
2. SST surfaces shall not be coated.

PART 3 EXECUTION

3.1 SLIDE GATE SCHEDULE

A. As shown on the Drawings.

3.2 QUALITY CONTROL

A. Factory Quality Control:
1. The completely assembled gate will be shop-inspected for proper seating.
2. Adjust seals to exclude a 0.004 inch thickness gauge between the seating surfaces.
3. Shop performance testing shall be performed in accordance with AWWA C561.
4. Shop-operate the assembled slide gate for three cycles from the fully open to the fully closed position to verify the assembly is smoothly functioning with no binding of the gates, guides, stems, and gears.
5. A shop leakage test is not required.

B. Field Quality Control:
1. Leakage test:
   a. Conduct on each slide gate.
   b. Perform under design head conditions.
   c. Leakage shall not exceed 0.10 gpm/ft of the seating perimeter.
   d. The Manufacturer shall adjust, realign, or modify and repair units and retest if necessary to meet proper operation.

C. Manufacturer's Services: Furnish a Manufacturer's Representative for a minimum of 1 person-days for inspection, functional and leakage testing, final adjustments, and completion of the Manufacturer's certificate of proper installation.

3.3 SUPPLEMENTS

A. Supplement A – Fabricated SST Slide Gate Schedule.

END OF SECTION

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SUPPLEMENT A – FABRICATED SST SLIDE GATE SCHEDULE

Gate ID No.	Gate Size (clear opening width by height inches)	Design and Operating Head (feet) Seating/Unseating Condition	Mounting Configuration (flange or channel)	Frame Type (self-contained or conventional)	Upward or Downward Opening (weir gate)	Rising or Non-rising stem	Actuators

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SECTION 40 27 95
ELECTRIC VALVE AND GATE ACTUATORS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for electric valve and gate actuators.

B. Related Sections:

1. SECTION 01 44 33 – MANUFACTURER'S SERVICES

1.2 REFERENCES

A. American Water Works Association (AWWA):

1. C542 – Electric Motor Actuators for Valves and Slide Gates

1.3 SUBMITTALS

A. Shop Drawings:

1. Product data sheets for make and model.
2. Complete actuator information, descriptive literature, Specifications, and identification of materials of construction.
3. Factory mechanical drawings of the complete actuator assembly including the electric motor, pedestal and rod extensions.
4. Open/close and throttling sizing calculations.
5. Maximum torque capabilities of operator mechanism and operating torque requirement for each valve under the specified operation condition.
6. Motor and actuator characteristic data and nameplate data.
7. Actuator mechanical contactor or solid state starter Manufacturer, model number and cut-sheet.
8. Factory electrical drawings showing schematic representation of the complete power and control circuitry and wiring diagrams showing interconnections, wire designations and terminal numbers for remote operation and position indication by the OWNER. Each actuator drawing shall be identified with the respective valve number or tag number indicated in the Bill of Materials, Electric Actuator Schedule, or on the P&IDs in the I&C Drawings.
9. Factory installation and services information giving full installation and adjustment instructions, and part listings for field replaceable parts.
10. Listings of normal starting and running currents, and full nameplate data from the motor.
11. Provide drawings in DWG or DXF electronic format.

B. Quality Control Submittals: For electric actuators, certified copies of reports covering proof-of-design testing of the actuators in accordance with AWWA C542, Section 5, together with an affidavit of compliance in accordance with AWWA C542, Section 6.3, shall be submitted to the ENGINEER before the actuators are shipped.

C. O&M Manuals:

1. Shop Drawing Submittals.
2. Quality Control Submittals.
3. Submit installation and O&M instructions in a manual presenting full details for installation, care, and maintenance of equipment furnished under the Contract.
4. Manual:
   a. O&M manuals shall be provided by the Equipment Manufacturer at least 2 weeks prior to shipment of major equipment components.
   b. Each manual shall be a bound, indexed binder prepared specifically for this Project rather than general equipment instructions.
   c. Installation and maintenance instructions for the specific equipment, including the installation and startup sequences, maintenance items, and trouble-shooting checkpoints.
   d. Provide printed, tabbed, and bound instructions covering the details pertaining to installation, care, and maintenance of equipment and data. Identify parts with a number and a description.
   e. Provide two hardcopies and one electronic copy (PDF with sections tabbed/linked) to the OWNER.

D. Extra Materials: Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer's name, description, and part number for shipment and long-term storage, and deliver the following extra materials prior to 75% of the Substantial Completion date:

1. Provide five handheld programmers, three IR communication setups (including sensors, sensor mounting bracket, cables, etc.) for laptop computer, and three licensed copies of actuator software, for every four actuators.
2. Provide two fuses, for every actuator, of every size and type of fuse internal to the actuator. Provide one spare battery for every applicable actuator.
3. Provide one extra lockable clasp for lock out, tag out use.

E. Warranty Documentation:

1. Sample warranty.
2. Warranty.

F. Supplements listed in this Section.

1.4 QUALITY ASSURANCE

A. Equipment Manufacturer Qualifications: A minimum of 10 years of documented experience in the Work of this Section.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Performance and Design Requirements:

1. General:
   a. Actuators and appurtenances shall be designed for the conditions and requirements.

b. Liberal factors of safety shall be used throughout the design, especially in the design of parts subject to intermittent or alternating stresses. In general, working stresses shall not exceed 1/3 of the yield point or 1/5 of the ultimate strength of each material.

2. Valve actuators:
   a. Each actuator shall be designed to open or close the valve under the operating conditions.
   b. The actuators and gear train shall be designed for the full design head rating of the valve or gate and a maximum fluid velocity of 25 fps.
   c. Valve actuators shall be provided and adjusted by the Valve Manufacturer. Actuator mounting arrangements and positions shall facilitate O&M and shall be determined by the Valve Manufacturer unless shown otherwise on the Drawings or directed by the ENGINEER.
3. Limit switches: A minimum of eight programmable limit switches shall be provided for each actuator. Limit switches shall be programmed for the status functions.

D. Manufacturer's Training:
1. The Actuator Manufacturer shall supply a factory-trained field service representative to provide O&M training for the actuators. The representative shall be a full-time employee of the Manufacturer qualified to do field training presentations.
2. Minimum of 4 hours and include both a classroom presentation and a field presentation. The training shall be specific to the products installed and the application and shall be recorded for future reference.

1.5 DELIVERY, STORAGE, AND HANDLING

A. Delivery and handling of the valves shall be in accordance with the Manufacturer’s recommendations in their O&M manual.

1.6 SITE CONDITIONS

A. Environmental Requirements: Materials and equipment shall be designed and constructed for continuous operation, at rated current and voltage, at 5,800 feet above mean sea level, 104°F ambient temperature and 95% relative humidity. The Equipment Manufacturer shall submit a certified letter stating the equipment provided meets the requirement.

1.7 WARRANTY

A. Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the equipment system and associated appurtenances. Acceptance will occur after the completion of startup as described in this Section.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Actuator:
1. Rotork, IQ

B. Actuator Gearing:
1. Rotork, Exeeco

2.2 MATERIALS

A. Except as modified or supplemented herein, materials used in the manufacture of actuators shall be in accordance with AWWA C542.

2.3 COMPONENTS

A. Electric Actuators:
1. General:
   a. Electric motor-operated actuator shall be designed to develop sufficient operating torque to unseat, open, and close the valve under the operating conditions specified herein. Except as modified or supplemented herein, the actuator shall be in accordance with AWWA C542.
   b. Electric motor-operated actuator shall be designed to move the valve from fully open to fully closed position within the time specified in the Electric Actuator Schedule, under the maximum differential pressure across the valve and maximum flow conditions.
   c. Electric actuator shall be a completely integrated, electrically powered unit with isolated manual handwheel operation in case of power failure. Provide motor actuator with rated output torque at least 1.5 times the maximum torque required to open or close the valve at any position including seating and unseating conditions.
   d. Electric actuator shall include the motor, actuator unit gearing, motorized adaptor, limit switches, torque switches, declutch mechanism, manual operating handwheel, local valve position indicator, position transducer, and push button control station to allow local electric control of valve position.
   e. Electric actuator shall be suitable for modulating service and shall be suitable for Class I duty cycle. The actuator shall be suitable for operation over a temperature range of -20°F to 150°F and shall be of totally enclosed, non-ventilated construction, meeting NEMA Type 4 enclosure requirements.
   f. The complete actuator shall be furnished fully factory wired, tested, and ready for interconnection with the electric power source and external remote control dry-contact interposing relays furnished by others.
   g. Gearing shall be grease or oil-bath lubricated. Lubricating oil shall be food grade. Ball or tapered roller bearings shall be used throughout.
   h. A handwheel shall be provided for manual operation with an arrow to indicate the open or close rotation. The handwheel shall not rotate during electric motor operation and operation of the handwheel shall not cause the motor to rotate. When in manual operation, the operator shall remain in this mode until the electric motor is energized, at which time the actuator shall automatically return to electric motor operation and shall remain in motor operation until manual operation is again re-engaged. The change from electric motor to manual operation shall be accomplished by a positive action declutching mechanism, which mechanically disengages the motor and motor gearing. The declutching mechanism shall be lockable with a standard

padlock. A blocked or fused motor shall not prevent manual operation. It shall be impossible to place the operator directly into manual operation while the motor is running. The handwheel shall rotate in a clockwise direction to close the valve. The handwheel diameter shall be selected to result in a maximum required force of 40 lbs to close or open the valve under any operating conditions.

i. The valve actuator shall have an electro-mechanical reversing contactor mounted in the control enclosure, with a control power transformer furnishing control power voltage. The control power transformer shall utilize a fuse in each primary lead and one fuse in the secondary lead. The other secondary lead shall be grounded. The contactor shall be either a standard full size NEMA type horsepower rated device, or shall be a definite purpose contactor sized to provide a minimum of 50,000 full load current interruption cycles using IEC utilization Category AC-4 curves. Contactors designated as IEC type devices, which do not meet these requirements, will not be acceptable.

2. Features:
   a. Modulating with open/close controls.
   b. Programmable, non-intrusive set up and calibration.
      1) Externally programmable.
      2) Programming performed with:
         a) Handheld infrared linked device.
         b) Local control switches and LCD.
   c. Self-contained unit with CI or aluminum alloy housing.
   d. Shall be integrally assembled on the applicable valve by the Valve Manufacturer.
   e. Protected from the ingress of moisture and dust when the terminal cover is removed. Provide the same rating as the actuator when the terminal cover is removed.
   f. Enclosure shall allow for temporary site storage without the need for electrical supply connection.
   g. Mount the actuator above the reduction gearing.
   h. Electronic torque sensing circuitry with independently programmed motor shutoff torque SPs in either direction of travel.
   i. Valve travel limit switch function provided by electronic Hall Effect magnetic pulse counting circuitry.
   j. Rotary selector or integral pushbutton control station to provide full valve operation, using the electric motor, while operating isolated from the remote control equipment.
      1) Three-position rotary selector switch local–off–remote and padlockable in any position.
      2) Switch leads brought to the terminal strip:
         a) To allow for remote indication of switch position.
         b) To provide remote open and close contact power.
         c) To provide a means of disabling local control power.
      3) Valve function rotary selector switch for open–close–stop operation:
         a) Operate when selector switch is in the local position.
         b) Field configurable for push and hold control.
      4) Provide LED indicating lights:
         a) Red: Full open.
         b) Green: Full closed.
         c) Red and green: Modulating.
   k. Position transducer:
      1) Internally mounted, programmable.
      2) 4 mA to 20 mA, scaled to 0% to 100% valve position. Uses Hall Effect measurement or absolute encoder.
      3) Suitable for use with an external load impedance of up to 500 ohms.
      4) Output signal at a terminal strip for connection.
      5) External 24 VDC power supply input to keep current transmitter, status contacts, and LCD operational and indicating valve position when the main operator motor power source has been de-energized.
      6) Actuator position shall be internally updated while the main power source is removed, including manual operation, and reflect actual position when the power is restored.
   l. Electric actuator control power wired out to terminals for the customer's use. Each actuator shall be furnished with a sealed compartment containing a reversing controller, multi-tap transformer, electronic controls, and monitoring and protection modules. Reversing controllers shall be both mechanically and electrically interlocked and provided with the necessary direct-operated auxiliary contacts for required interlocking and control. The multi-tap transformer shall provide power for the internal circuits, and shall provide 120 VAC or 24 VDC power supply power wired out to terminals for remote controls.
   m. Electromechanical reversing contactor:
      1) Mounted in the control enclosure.
      2) Control power transformer furnishing control power voltage.
      3) Standard full-size NEMA type horsepower rated device, or a definite purpose contactor.
      4) Sized to provide a minimum of 50,000 full load current interruption cycles using IEC utilization Category AC-4 curves.
      5) Contactors designed as IEC type devices, which do not meet these requirements, will not be accepted.
   n. Remote controls: Valve position and actuator status indication shall be provided by eight contacts which can be selected to indicate any position of the valve. Contacts shall be NO or NC selectable. Contacts shall maintain and update position indication during handwheel operation. Contacts shall be rated 5 A, 250 VAC or 30 VDC.

o. Electric actuators for modulating service, when indicated as modulating service, shall include:
    1) Control module for position modulating type service. The control module shall be mounted within the controls compartment. The module shall accept a standard 4 mA to 20 mA DC analog input signal with a load impedance of not greater than 400 ohms. The control module shall contain adjustments for span, zero, gain, and deadband.
    2) Solid state starter to achieve an increased design life. A minimum of four pairs of 1,600 V thyristors switch two phases of the incoming power supply. Thyristors are considered to be more suitable than triacs for reversing applications and have a higher resistance to transients in the power supply. The design also includes snubbing and transient protection circuits.
    3) Provide with a suitably rated low inertia motor with the hammerblow backlash omitted from the output gear train.
    4) Actuators shall be suitable for up to sixty starts per hour with a duty in accordance with IEC 60034-1 to S4 50%.
    5) Modulating actuators shall be protected with suitably rated high speed semiconductor fuses.

p. Vandal resistant, lockable cover protecting standard rotary selectors and window display.

3. Electric Motor:
    a. Rated for an operating voltage in accordance with the Contract Documents or Electric Actuator Schedule, 60 Hz, 1.0 SF, reversing, totally enclosed non-ventilated.
    b. Produce actuator output of 1.5 times the required valve operating torque.
    c. Normal operating temperature rise that does not exceed NEMA Class B standards at 5,800 feet above mean sea level.
    d. Ratings are for 5,800 feet above mean sea level without reducing the SF.
    e. NEMA Class H insulation.
    f. Anti-friction bearings, lubricated and sealed against contamination.
    g. Motor overload protection via thermal switches.

4. Terminal facilities:
    a. Terminal facilities for connection to motor leads, switches, and control and indication signals shall be provided in a readily accessible terminal compartment. The terminal compartment shall have at least three openings for external electrical conduits, sized for at least 3/4 inch RGS conduit. Each terminal compartment shall be large enough to allow easy routing and termination of fifteen #14 AWG conductors.
    b. The terminals shall be embedded in a terminal block of high tracking resistance compound.
    c. The terminal compartment shall be separated from the inner electrical components of the actuator by means of a watertight seal and shall be provided with a minimum of two threaded cable entries with provision for a maximum of four. Wiring supplied as part of the actuator to be contained within the main enclosure for physical and environmental protection. External conduit connections between components are not acceptable. A durable terminal identification card showing plan of terminals shall be provided attached to the inside of the terminal box cover indicating:
        1) Serial number.
        2) External voltage values.
        3) Wiring diagram number.
        4) Terminal layout.

2.4 FINISHES

A. Shop Painting:
    1. Ferrous metal surfaces, except bearing and finished surfaces and SST components of valve actuators and accessories, shall be shop-painted for corrosion protection. The Valve Manufacturer's standard coating will be acceptable, provided it is functionally equivalent to the specified coating and is compatible with the specified field painting.
    2. The following surfaces shall be painted:
        a. Polished or machined surfaces: Rust-preventive compound.
        b. Other surfaces: Epoxy enamel.
        c. Actuators and accessories: Universal primer.

PART 3 EXECUTION

3.1 GENERAL

A. Electric Actuator Schedule: As shown on the Drawings.

B. Equipment provided under this Section shall be fabricated and assembled in accordance with the Specifications, and recommendations of the Equipment Manufacturer, unless exceptions are noted by the ENGINEER.

C. Actuators shall be furnished with the necessary parts and accessories in accordance with the Contract Documents or otherwise required for a complete, properly operating installation and shall be the latest standard products of a Manufacturer regularly engaged in the production of actuators.

D. Governing Standards: Except as modified or supplemented herein, powered actuators shall be in accordance with AWWA C542.

E. Power Supply: Power supply to electric actuators shall be in accordance with the Electric Actuator Schedule.

F. Marking:
    1. Each actuator shall be marked with the Manufacturer's name, model number, and the country of origin. An identifying serial number shall be stamped on a corrosion-resistant plate attached to the actuator.
    2. Each actuator shall be factory tagged or marked to identify the actuator and the applicable valve or gate by number or service as indicated in the Electric Actuator Schedule.

G. Temporary Number Plates: Each actuator shall be factory tagged or marked to identify the actuator and the applicable valve or gate by number or service in accordance with the Electric Actuator Schedule.

3.2 QUALITY CONTROL

A. Manufacturer's Field Services:

1. The Actuator Manufacturer shall supply a factory-trained field service representative to inspect the installation of the actuators. The representative shall be a full-time employee of the Manufacturer qualified to do field service work, and as specified in SECTION 01 44 33.
2. Present at site for minimum 2 person-days for inspection, functional and performance testing, and completion of the Manufacturer's certificate of proper installation.

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SECTION 40 41 00
HEAT TAPE SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for heat tape systems.

B. Related Sections:
   1. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   2. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   3. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   4. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS

1.2 REFERENCES

A. National Electrical Manufacturers Association (NEMA):
   1. 250 – Enclosures for Electrical Equipment (1000 Volts Maximum)

1.3 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Shop Drawings:
   1. Itemized Bill of Material including the Manufacturer, complete model number, and options included.
   2. Catalog, descriptive and specification information for equipment, components, and devices.
   3. Calculations for actual wattage required. Provide complete and actual loads for heat tape systems.
   4. Method and equipment for installing heat tracing, heat tape systems, and heating mats.
   5. Dimensioned layout drawings, including depths. Provide actual length for each heat tape system.
   6. Schematic, wiring, and connection diagrams.
   7. Certified factory test reports.
   8. Field test reports.
   9. Installation manuals.
   10. The Equipment Manufacturer shall submit a certified letter stating that materials and equipment provided shall be designed and constructed for continuous submergence in water.

D. Quality Control Submittals:
   1. Testing related Submittals.
   2. O&M manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing information.
      d. Testing related Submittals.
      e. Legend abbreviation lists.
      f. Device O&M manuals for components, electrical devices, and mechanical devices shall include:
         1) Operations procedures.
         2) Installation requirements and procedures.
         3) Maintenance requirements and procedures.
         4) Troubleshooting procedures.
         5) Internal schematic and wiring diagrams.
      g. A list of spares and expendables is required.
      h. Final As-Built Drawings:
         1) Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
            a) Drawings shall be on a standard DW title block and border provided by DW.
            b) As-Builts and Manufacturer's Drawings shall be provided:
               (1) On a standard DW provided title block and border.
               (2) With the drawing graphics and text, assigned to a pen 2 color (yellow).
               (3) Text: Minimum 0.1 inches, maximum 0.2 inches.
               (4) Titles: 0.2 inches.
      i. Warranty documentation.

1.4 QUALITY ASSURANCE

A. The equipment furnished under this Section shall be the product of a Manufacturer who has produced the same type of equipment for a period of at least 5 consecutive years.

B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.

C. Manufacturer's Services:
   1. Furnish a Manufacturer's Representative, as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
      a. Installation assistance, inspection of installation and training of the OWNER's personnel: 1.

1.5 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions as specified in SECTION 26 05 00.

1.6 WARRANTY

A. Manufacturer: Warranty for 18 months from the Substantial Completion date for the satisfactory performance and installation of the heat tape system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Piping Heat Tracing System:
  1. Raychem, Chemelex BTV Connection System

B. Power Connection Kit:
  1. Raychem, Chemelex AM-BC
  2. Thermon, ECA-1

C. Splice Kit:
  1. Raychem, Chemelex AM-BS
  2. Thermon, ECS-1

D. Tee Kit:
  1. Raychem, Chemelex AM-B4
  2. Thermon, ECT-2

E. End Seal Kit:
  1. Thermon, ET-8C

F. Pilot Light:
  1. Raychem, Chemelex AM-L
  2. Thermon, VIL-4C

G. Pipe Adapter Kit:
  1. Thermon, XP-1

H. Securing Tape for Plastic Piping Systems:
  1. Raychem, Chemelex AT-180
  2. Thermon, AL-20P

I. Securing Tape for Metallic Piping Systems:
  1. Raychem, Chemelex GS54 or GT66
  2. Thermon, PF-1

J. Pipe-Mounted Thermostat:
  1. Raychem, Chemelex AMC-F5
  2. Raychem, Chemelex E507S for hazardous areas

K. Ambient Thermostat:
  1. Raychem, Chemelex AMC-1A
  2. Raychem, Chemelex AMC-1H for hazardous areas
  3. Thermon, B4X-15140

L. Heat Tape Systems:
  1. Self-regulating heating cable:
     a. Raychem, Electro Melt EM2XR
  2. Heat tracer cable:
     a. Raychem, 8XL2CR
  3. Power connection and end seal kit:
     a. Raychem, EMK-XP
  4. Junction box:
     a. Raychem, EMK-XJB
  5. Cable ties:
     a. Raychem, EMK-XCT
  6. LCP-HTS controls:
     a. Tyco ETI APS-4C
     b. Snow ice sensor:
        1) Raychem, CIT-1
        2) Raychem, GIT-1
        3) Raychem, SIT-6E
     c. Thermostat:
        1) Envirotech, SST-2

2.2 MATERIALS

A. Piping Heat Tracing System:
  1. Design heating load:

Nominal Pipe Size (Inches)	50°C Column Heat Trace Minimum Capacity (Watts/Foot)
1/4	1.9
1/2	2.5
3/4	2.9

Nominal Pipe Size (Inches)	50°C Column Heat Trace Minimum Capacity (Watts/Foot)
1	2.2
1 1/4	2.5
1 1/2	2.8
2	3.2
2 1/2	3.8
3	4.4
3 1/2	3.6
4	3.9
6	5.3

B. General:
1. Cable: Self-limiting, parallel circuit construction consisting of a continuous inner core of variable resistance conductive heating material between two parallel copper bus wires. Provide tinned copper braid for PVC, FRP, and SST pipe applications.
2. UL listing: Listed as self-limiting pipe tracing material for pipe freeze protection application in ordinary conditions.
3. Maximum maintenance temperature: 150°F.
4. Maximum intermittent temperature: 185°F.
5. Service voltage: As shown by branch circuits provided for heat tracing on the Drawings.

C. Connection System:
1. Rating: NEMA 250, Type 4 and FMG approved.
2. Operating monitor light: Furnish with each circuit power connection kit to indicate when heat tracing is energized.
3. Securing tape:
   a. Plastic piping systems: Aluminum foil coated adhesive tape.
   b. Metallic piping systems: Glass or polyester cloth pressure sensitive tape.

D. Pipe-Mounted Thermostat:
1. Type: Fixed, non-adjustable, set at 40°F.
2. Sensor: Fluid-filled with 3-foot capillary.
3. Enclosure: Glass-filled nylon, NEMA 250, Type 4X weatherproof with gasketed lid.
4. Switch:
   a. SP-ST, UL listed, rated 22 A, 120 VAC to 240 VAC.
   b. SP-ST, UL listed, rated 50 A, 480 VAC.

2.3 COMPONENTS

A. Ambient Thermostat:
1. Type: Adjustable setting, 15°F to 140°F.
2. Sensor: Fluid-filled probe.
3. Enclosure: Epoxy-coated NEMA 250, Type 4X aluminum enclosure with exposed hardware of SST.
4. Switch: SP-DT, UL or FM listed, rated 22 A, 125 VAC to 250 VAC.

B. Heat Tape Systems:
1. Function: To prevent ice forming in the switchyard drainage area.
2. Embed the heat tape system in concrete and around drainage pipe as recommended by the Manufacturer and as shown on the Drawings.
3. Provide controls to operate the heat tape system: Energize the heat tape system when the Manufacturer recommended sensor determines and when the outside air temperature is below freezing.
4. Voltage: 208 VAC or 277 VAC.
5. Provide embedded snow melt caution sign.

PART 3 EXECUTION

3.1 INSTALLATION

A. General:
1. Install in accordance with the Manufacturer's instructions and recommended practices.
2. Ground and bond metallic structures or materials used for the support of heating cable.
3. Wiring between power connection points of heat tracing cable branch lines shall be provided by the heat tracing system Supplier.
4. Provide end of circuit pilot lights on heat tracing circuits for buried piping.
5. Heat tape system equipment, materials and support systems shall be rated for continuous submergence in water.

B. Electrical Heating Tape:
1. Determine the required length of electrical heating tape by considering length of circuit and number and type of fittings and fixtures, design heating load, and heating tape output.
2. Where design heating load exceeds heating tape capacity, install by spiraling.
3. Derate heating tape capacity when installed on plastic piping.
4. Install on services as follows:

Service	Piping Material	Placement	Location
1 1/2 inch SW/HP (Water)	Metallic	Partially Exposed and Buried	Chemical Neutralization Vault

Service	Piping Material	Placement	Location
1 inch AC (Acid)	FRP	Partially Exposed and Buried	
2 inch and 3 inch CD	PP	Exposed and Partially Buried	Chemical Neutralization Vault
HS, LS, BWS, and XE (Air Release Valves and Piping)	Steel	Exposed; provide insulation	Distribution Pump Station
6 inch TSL	CLDI	Exposed	Metro Site
Sample, chemical piping	PVC	Exposed; provide insulation	Outdoors at Distribution Pump Station (roof of storage tank)

5. Install additional heating tape at bolted flanges, valves, pipe supports, and other fittings and fixtures as recommended by the Supplier, but not less than the following:

Item	Heating Tape Length (Min. Feet)
Bolted flanges (per pair)	Two times pipe diameter
Valves	Four times valve length
Pipe hanger or support penetrating insulation	Three times pipe diameter

C. Heat Tracing Circuits: Limit individual lengths of heat tracing circuits such that maximum single circuit capacity is 20 A when starting the circuit at 40°F. Provide 20 A circuits at individual heat tracing locations circuits as shown on the Drawings. Combine multiple heat trace services on single 20 A circuits where shown on the Drawings. Notify the ENGINEER if additional circuits are required.

D. Thermostats:
1. Install in accordance with the Manufacturer's instructions and as approved by the ENGINEER.
2. For each heat trace service, install one pipe-mounted thermostat.

3.2 QUALITY CONTROL

A. Test each circuit with a 500 V insulation tester between circuit and ground with neutrals isolated from ground. Insulation resistance shall be a minimum 1,000 megohms per 1,000 feet.

B. Additional testing as specified in SECTION 26 08 00.

C. The Heat Tape System Manufacturer’s factory service technician shall set, calibrate, and test equipment and controls in accordance with the Manufacturer’s recommendations and as specified.

END OF SECTION

SECTION 40 42 13
PIPING INSULATION

PART 1 GENERAL

1.1 SUMMARY

- A. Section includes general information, products, and execution for piping insulation.
- B. Related Sections:
  1. SECTION 09 90 00 – PAINTING AND COATING
  2. SECTION 40 05 00 – PROCESS PIPING – GENERAL

1.2 REFERENCES

- A. American Society of Heating, Refrigerating, and Air Conditioning Engineers Inc. (ASHRAE):
  1. 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings
- B. ASTM International (ASTM):
  1. B 209 – Standard Specification for Aluminum and Aluminum-Alloy Sheet and Plate
  2. C 177 – Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmission Properties by Means of the Guarded-Hot-Plate Apparatus
  3. C 518 – Standard Test Method for Steady-State Thermal Transmission Properties by Means of the Heat Flow Meter Apparatus
  4. C 534 – Standard Specification for Preformed Flexible Elastomeric Cellular Thermal Insulation in Sheet and Tubular Form
  5. E 84 – Standard Test Method for Surface Burning Characteristics of Building Materials
  6. E 96 – Standard Test Methods for Water Vapor Transmission of Materials

1.3 SUBMITTALS

- A. Product Data: The Manufacturer's descriptive literature.
- B. Informational Submittals: Maintenance information.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

- A. Pipe Insulation:
  1. Type 1:
     - a. Armacell, AP Armaflex
     - b. K-Flex, LS
  2. Type 2:
     - a. Johns Manville, Micro-Loc with AP-T Jacket
     - b. Owens-Corning Fiberglass, ASJ/SSL-II
  3. Type 3:
     - a. Pittsburgh Corning, FOAMGLAS
  4. Type 4:
     - a. Urecon
- B. Fitting Insulation:
  1. Type 1:
     - a. Armacell, AP Armaflex
     - b. K-Flex, Elastomeric fitting with WT clad
  2. Type 2:
     - a. Johns Manville, Ceel-Co
     - b. Johns Manville, Zeston
     - c. Proto Corporation
     - d. Speedline Corporation
  3. Type 3:
     - a. Pittsburgh Corning, FOAMGLAS
  4. Type 4:
     - a. Urecon
- C. Insulation Finish Systems:
  1. Type F1 – PVC:
     - a. Johns Manville, Zeston
     - b. Proto Corporation
  2. Type F2 – paint:
     - a. Armstrong, WB Armaflex finish
     - b. Rubatex, 374, white finish
  3. Type F3 – aluminum:
     - a. Childers
     - b. Pabco
     - c. RPR Products, Insul-Mate
  4. Type F4 – foam glass jacketing (for use with Type 3 insulation and fitting insulation):
     - a. Pittsburgh Corning, PITTWRAP
  5. Type F5 – (for use with Type 4 insulation and fitting insulation):
     - a. Urecon

2.2 MATERIALS

A. Pipe Insulation:
1. Type 1:
a. Material: Flexible elastomeric pipe insulation, closed-cell structure in accordance with ASTM C 534.
b. Temperature rating: -40°F to 180°F.
c. Nominal density: 6 pcf.
d. Conductivity in accordance with ASHRAE 90.1 and minimum of 0.27 (Btu*in)/(h*ft^2*degF) at 75°F in accordance with ASTM C 177 or ASTM C 518.
e. Minimum water vapor transmission of 0.08 perm-inch in accordance with ASTM E 96, Procedure A.
f. Joints: The Manufacturer's adhesive.
g. Flame spread rating: Less than 25 in accordance with ASTM E 84.
h. Smoke developed index: Less than 50 in accordance with ASTM E 84.
2. Type 2:
a. Material: UL rated, preformed, sectional rigid fiberglass with factory-applied, kraft paper with aluminum foil vapor barrier jacket with pressure-sensitive, self-sealing lap.
b. Temperature rating: 0°F to 850°F.
c. Conductivity in accordance with ASHRAE 90.1 and minimum of 0.27 (Btu*in)/(h*ft^2*degF).
d. Minimum water vapor transmission for jacket of 0.02 perm-inch in accordance with ASTM E 96.
e. Joints: Matching pressure-sensitive butt strips for sealing circumferential joints.
3. Type 3:
a. Material: Cellular glass.
b. Temperature rating: -290°F to 900°F.
c. Follow the Manufacturer's recommendation based upon the temperature of the piping to be insulated.
d. Insulation shall be fabricated and distributed in the Denver Metro area.
e. 12 inches and greater: Insulation shall include factory-applied exterior mortar coating with glass reinforcing mesh to maintain integrity until installation. System shall be approved by the Manufacturer for use with the insulation system and does not take the place of the insulation finish system.
4. Type 4:
a. Material: Rigid polyisocyanurate foam.
b. Temperature rating: -200°F to 200°F.
Follow the Manufacturer's recommendation based upon the temperature of the piping to be insulated.

B. Fitting Insulation:
1. Type 1:
a. Material: Flexible elastomeric pipe insulation, closed-cell structure in accordance with ASTM C 534.
b. Temperature rating: -40°F to 180°F.
c. Nominal density: 6 pcf.
d. Conductivity in accordance with ASHRAE 90.1 and minimum of 0.27 (Btu*in)/(h*ft^2*degF) at 75°F in accordance with ASTM C 177 or ASTM C 518.
e. Minimum water vapor transmission of 0.08 perm-inch in accordance with ASTM E 96, Procedure A.
f. Joints: The Manufacturer's adhesive.
g. Flame spread rating: Less than 25 in accordance with ASTM E 84.
h. Smoke developed index: Less than 50 in accordance with ASTM E 84.
2. Type 2: Wired in-place premolded insulation or mitered segments, or soft fiberglass insulation inserts.
3. Type 3:
a. Material: Cellular glass.
b. Temperature rating: -290°F to 900°F.
c. Follow the Manufacturer's recommendation based upon the temperature of the piping to be insulated.
d. Fitting insulation shall be fabricated and distributed in the Denver Metro area.
e. 12 inches and greater: Fitting insulation shall include factory-applied exterior mortar coating with glass reinforcing mesh to maintain integrity until installation. System shall be approved by the Manufacturer for use with the insulation system and does not take the place of the insulation finish system.
4. Type 4:
a. Material: Rigid polyisocyanurate foam.
b. Temperature rating: -200°F to 200°F.
c. Follow the Manufacturer's recommendation based upon the temperature of the piping to be insulated.

C. Roof Drain and Overflow Drain Sump Insulation: 1 inch thick.

D. Insulation at Pipe Hangers and Supports:
1. Type 1:
a. Copper and nonmetallic pipe, 2 inches and smaller: Use insulation shields.
b. Steel pipe, 1 1/2 inches and smaller: Use insulation shields.
c. Larger sizes: Use insulation saddles or Type 3 rigid insulation insert, 10 inches long.
2. Type 2: UL rated, preformed rigid pipe insulation inserts of thickness equal to adjoining insulation, 10 inches in length, with factory-applied, vinyl-coated and embossed vapor barrier jacket with self-sealing lap.

E. Insulation Finish Systems:
1. Type F1 – PVC: PVC jacketing, white, for straight run piping and fitting locations; temperatures to 159°F.
2. Type F2 – paint: Acrylic latex paint, white, and suitable for outdoor use.

3. Type F3 – aluminum:
    a. Aluminum roll jacketing: For straight run piping, wrought aluminum ASTM B 209 Alloy 3003, 5005, 1100, or 3105 with H-14 temper, minimum 0.016 inch thickness, with smooth mill finish.
    b. Vapor barrier: Provide factory-applied vapor barrier, consisting of 40 lb kraft paper with 1 mil thick low density PE film, heat and pressure bonded to the inner surface of the aluminum jacketing.
    c. Fitting covers: Material as for aluminum roll jacketing, premolded, one-piece or two-piece covers, which includes elbows, tee and valves, end caps, mechanical line couplings, specialty fittings, etc.
4. Type F4 – foamglass jacketing with aluminum metal jacket: For use with Type 3 insulation.
    a. Buried: Bituminous resin with woven, glass fabric, aluminum foil layer, and plastic film coating; heat-sealed at overlap.
    b. Exposed: Bituminous resin with woven, glass fabric, aluminum foil layer, and plastic film coating; heat-sealed at overlap. Outer aluminum metal jacket.
    c. Transition from exposed to buried: Install outer aluminum metal jacket to 1 foot below grade.
5. Type F5 – polymer coating with aluminum jacketing: For use with Type 4 insulation.
    a. Buried: High density polyurethane coating.
    b. Exposed: High density polyurethane coating with aluminum jacket.
    c. Transition from exposed to buried: Install aluminum jacket to 1 foot below grade.

PART 3 EXECUTION

3.1 INSTALLATION

A. Application:
1. General:
    a. Insulate valve bodies, flanges, and pipe couplings.
    b. Insulate and vapor seal hangers, supports, anchors, and other piping appurtenances secured directly to cold surfaces.
    c. Do not insulate flexible pipe couplings and expansion joints.
    d. Service and insulation thickness: Refer to the piping schedule in SECTION 40 05 00.

B. General:
1. Install in accordance with the Manufacturer's instructions and as specified herein.
2. Install insulation after the piping system has been pressure tested and the leaks corrected.
3. Apply insulation over clean, dry surfaces.
4. Do not allow insulation to cover nameplates or code inspection stamps.
5. Run insulation continuously through pipe hangers and supports, wall openings, ceiling openings, and pipe sleeves.
6. Install removable insulation sections on devices that require access for maintenance of equipment or removal such as unions and strainer end plates.
7. Use insulating cements, lagging adhesives, and weatherproof mastics recommended by the Insulation Manufacturer.

C. Connection to Existing Piping: Cut back existing insulation to remove the portion damaged by piping revisions; install new insulation.

D. Cold Surfaces: Provide a continuous vapor seal on insulation on cold surfaces where vapor barrier jackets are used.

E. Placement:
1. Slip insulation on pipe or tubing before assembly, when practicable, to avoid longitudinal seams.
2. Insulate valves and fittings with sleeved or cut pieces of the same material.
3. Seal and tape joints.

F. Insulation at Hangers and Supports: Install under piping, centered at each hanger or support.

G. Heat-Traced Piping: Apply insulation after heat-tracing work is completed and approved.

H. Roof Drains: Insulate vertical drops from the roof drain to horizontal pipe, exposed and concealed horizontal piping, and 2 feet down on vertical risers from horizontal pipe.

I. Roof and Overflow Drain Sumps: Insulate underside.

J. Vapor Barrier:
1. Provide a continuous vapor barrier at joints between rigid insulation and pipe insulation.
2. Install vapor barrier jackets with pipe hangers and supports outside the jacket.
3. Do not use staples and screws to secure vapor sealed system components.

K. Aluminum Jacket:
1. Use a continuous friction type joint to hold the jacket in place, providing positive weatherproof seal over the entire length of the jacket.
2. Secure circumferential joints with preformed snap straps containing weatherproof sealant.
3. On exterior piping, apply coating over insulation and vapor barrier to prevent damage when aluminum fitting covers are installed.
4. Do not use screws or rivets to fasten the fitting covers.
5. Install removable pre-fabricated aluminum covers on exterior flanges and unions.
6. Caulk and seal exterior joints to make watertight.

L. Field Finishing:
1. Apply a coating of insulating cement where needed to obtain a smooth and continuous appearance.
2. Where pipe labels or banding are specified for a piping system, they shall be applied to the finished insulation and not to the pipe.

3. Painting piping insulation exposed to view:
   a. Metal or PVC jacketing shall not require painting.
   b. If an insulated piping system is specified to be painted in SECTION 40 05 00, the piping shall receive a prime coat as specified in SECTION 09 90 00. Finished insulation, and not the piping, shall be painted as specified in SECTION 09 90 00.

END OF SECTION

SECTION 40 50 00
INSTRUMENTATION AND CONTROL SYSTEMS

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for instrumentation and control systems.

B. Related Sections:
   1. SECTION 01 31 00 – PROJECT MANAGEMENT AND COORDINATION
   2. SECTION 01 44 33 – MANUFACTURER'S SERVICES
   3. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
   4. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
   5. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   6. SECTION 26 05 19 – LOW-VOLTAGE CONDUCTORS
   7. SECTION 26 05 33 – RACEWAYS
   8. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
   9. SECTION 27 00 00 – COMMUNICATIONS SYSTEMS

1.2 REFERENCES

A. American National Standards Institute (ANSI):
   1. C84.1 – Electric Power Systems and Equipment – Voltage Ratings (60 Hertz)

B. CSA Group (CSA):
   1. C22.2 NO. 107.1 – Power Conversion Equipment

C. Institute of Electrical and Electronics Engineers (IEEE):
   1. 802.3 – Standard for Ethernet
   2. C37.90.1 – Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus
   3. C62.41.2 – Recommended Practice on Characterization of Surges in Low-Voltage (1,000 V and less) AC Power Circuits
   4. C62.45 – Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1,000 V and less) AC Power Circuits

D. National Electrical Manufacturers Association (NEMA):
   1. ICS 2 – Controllers, Contactors and Overload Relays Rated 600 Volts
   2. PE 1 – Uninterruptible Power Systems (UPS) – Specification and Performance Verification

E. National Fire Protection Association (NFPA):
   1. 70 – National Electrical Code (NEC)

F. NSF International/American National Standards Institute (NSF/ANSI):
   1. 61 – Drinking Water System Components – Health Effects

G. Occupational Safety and Health Administration (OSHA):
   1. 29 CFR 1910 – Occupational Safety and Health Standards

H. Underwriters Laboratories (UL):
   1. 1449 – Standard for Surge Protective Devices
   2. 1778 – Uninterruptible Power Systems

1.3 COORDINATION

A. The I&C Systems Subcontractor shall be a Subcontractor to the Electrical Contractor.

B. Work Includes: Engineering, design, providing, installing, calibrating, adjusting, testing, documenting, starting up, and OWNER training for a complete I&C system.

C. Detailed Design: The I&C design, as indicated in the Contract Documents, includes functional, performance, and component requirements. Complete the detailed I&C design.

D. I&C Work Scope:
   1. At a minimum, provide LCPs, ECPs, controls, and instruments shown on the Drawings, etc.
   2. For equipment and ancillaries required for the I&C system:
      a. Furnish and install the equipment specified in the Contract Documents required for the I&C.
      b. Completing detail design.
      c. Required Submittals.
      d. Instructions, details, recommendations, and coordination for the certificate of proper installation.
      e. Verify readiness for operation.
      f. Verify the correctness of final interface.
      g. Adjusting and calibrating.
      h. Starting up and commissioning.
      i. Testing and coordination of testing.
      j. Training.
   3. Verify the following Work is provided: Correct size, type, materials, connections, and interface of field equipment and devices.
   4. For equipment not provided under I&C systems but directly connected to equipment required by I&C systems:
      a. Obtain the Manufacturer's information on installation, interface, function, and adjustment.
      b. Coordinate with the CONTRACTOR to allow required interface and operation with I&C.
      c. For operation and control, verify that installations, interfacing signal terminations, and adjustments have been completed in accordance with the Manufacturer's recommendations.
      d. Test to demonstrate required interface and operation with I&C.

e. Examples of items that may be in this category shall not be limited to:
1) Electrical equipment indicated in Division 26.
2) Valve operators.
3) Switchgear.
4) RVSS motor controllers.
5) Transformers.
6) Pumps and motors.

E. Wiring External to I&C Equipment:
1. Special control and communications cable: Provided by the I&C Contractor.
2. Other wiring and cable: As specified in SECTION 26 05 19.

1.4 SEQUENCING AND SCHEDULING

A. I&C Progress Schedule:
1. Coordinate activities and interactions between the CONTRACTOR, the ENGINEER, and the OWNER for coordination meetings, testing, programming, Submittal reviews, test witnessing, and training. Clarify required Work sequences and major milestone prerequisites.
2. Format: As specified in SECTION 01 31 00.
3. Include:
a. Design activities.
b. Submittals.
c. Purchasing, fabricating, and assembly activities.
d. Shipment and delivery.
e. Installation.
f. Testing.
g. Startup.
h. Training.
i. Coordination meetings.
j. Substantial Completion date.
k. Acceptance.

B. Prerequisite Activities and Lead Times: Do not begin the following key Project activities until the prerequisite activities and lead times listed herein have been completed and satisfied:
1. Submittals to the ENGINEER:
a. Prerequisite: ENGINEER acceptance of the I&C progress schedule.
2. Shop Drawing Submittals complete and approved.
3. Hardware purchasing, fabrication, and assembly.
4. Tests: Associated test plan Submittal completed. For FDT and PAT, a notice of the test schedule is required 4 weeks prior to the start of the test.
5. Training: Associated training plan Submittal, reviewed, and accepted by the ENGINEER.
6. PLC applications software configuring by the ENGINEER.
7. UFT completed.
8. FDT completed.
9. PLC applications software configuring and testing by the ENGINEER.
10. Equipment delivered to the site.
11. Submit preliminary O&M manuals.
12. SDT completed.
13. ORT1 and ORT2: The allowance for interruptions to the CONTRACTOR's Work due to applications software testing shall be 10 days total.
14. PAT:
a. Prerequisite: ORTs completed and facility started up.
b. Allowance for interruptions to the CONTRACTOR's Work due to applications software testing shall be 10 days total.

C. I&C Substantial Completion Date: In accordance with the General Conditions and the Supplementary Conditions, unless otherwise noted herein for I&C. Additional prerequisites for Substantial Completion include:
1. I&C Submittals accepted or approved.
2. PAT successfully completed.
3. OWNER training plan on schedule.
4. Spares, expendables, and test equipment delivered to the OWNER.
5. Service and maintenance agreements submitted for the Work required in this Section.

D. I&C Acceptance: In accordance with the General Conditions, unless otherwise specified herein for I&C.
1. When the ENGINEER issues a written notice of acceptance, the following prerequisites shall have been met:
a. I&C Substantial Completion.
b. Punchlist items completed.
c. Final O&M manuals and As-Built Drawings accepted.
d. After the I&C has been completely installed and made operational, the entire system shall be subject to an operational test run before being accepted. To complete the requirement, the I&C and PLC/RTU communications shall operate properly, without significant system malfunction, as deemed by the ENGINEER, for a continuous uninterrupted time period of 20 days. If the PLC/RTU system fails to meet the requirement,

make the necessary repairs or adjustments required to correct the problem. The acceptance test shall completely restart from the beginning for a complete retest.

e. Maintenance service agreements for I&C have been accepted by the OWNER.

1.5 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Administrative Submittals:

1. Statements of qualification:
   a. Submit within 10 days after the Pre-Construction Meeting.
   b. I&C Subcontractor's site Representative:
      1) Minimum of 5 years of documented experience in industrial systems and projects of a similar scope and size as the project.
   c. Organization chart: Showing the organizational structure of the company and this project. Identify key personnel.
   d. Resumes of project personnel, including but not limited to, the Project Manager, site Representative, and startup and testing team.
2. I&C progress schedule:
   a. Submit within 30 days after the Pre-Construction Meeting.
   b. Upon acceptance by the ENGINEER, it shall form the basis and schedule for Submittal reviews, test witnessing, and partial payments relating to I&C Work.
3. OWNER training plan: As specified in SECTION 01 44 33.

D. Shop Drawings:

1. Itemized Bill of Material including the Manufacturer, complete model number, and options included.
2. Catalog, descriptive and specification information for equipment, components, and devices.
3. Use Contract Drawing equipment and device tags and abbreviations.
4. External power and signal connections.
5. Scaled drawings showing exterior dimensions and locations of electrical interfaces, mechanical interfaces, and mounting arrangements.
6. Specific features and configuration data:
   a. Location or service.
   b. Manufacturer and complete model number.
   c. SPs and scale range.
   d. Engineering specifications.
   e. Equipment weights.
   f. Power and grounding requirements.
   g. Materials of construction.
7. Name, address, and telephone number of the Manufacturer's local office, representative, distributor, or service facility.
8. Construction drawings:
   a. Show to scale enclosure, internal equipment layout, and external device nameplates and layout.
   b. Show dimensions and locations of panel-mounted devices, doors, louvers, and subpanels (internal and external).
   c. Panel legend: List front of panel devices by tag numbers, nameplate inscriptions, service legends, and annunciator inscriptions.
   d. Construction details: NEMA rating, materials, material thickness, structural stiffeners and brackets, lifting lugs, louvers, mounting brackets and tabs, door hinges and latches, and welding.
   e. Samples of LCPs mimic bus graphic materials, colors, and adhesive.
   f. Cable access areas and cable routing.
   g. Anchor bolt size and location.
   h. Installation and mounting detail drawings.
   i. P&IDs.
   j. Hydraulic and electrical schematics.
   k. Equipment weights.
9. Wiring diagrams:
   a. Ladder diagrams in a format similar to those shown on the Drawings.
   b. Diagrams shall be coordinated and show field interfaces.
   c. Interconnection from power sources and panelboards.
   d. Electrical connections between equipment, consoles, panels, terminal junction boxes, and field-mounted components.
   e. Component and panel terminal board identification numbers, and external wire and cable numbers.
   f. Circuit names, identify terminals, cable ID tags, actual cable lengths, and conduit tags.
   g. Grounding diagram, philosophy, implementation, terminations, type, and connections.
   h. Show each circuit individually.
   i. Identify each item with attributes listed:
      1) Wires, conductors, cables: Type, number, size and color.
      2) Terminals: Location, terminal strip number, and terminal block number.

3) Discrete components:
   a) Tag number, terminal numbers, and location.
   b) Switching action, open or close on rising or falling variable, SP value and units, and variable description.
4) I/O point list for I/O points, include:
   a) Point names and descriptions.
   b) Point addresses, tag numbers, functions, ranges, and engineering units.
   c) Wire and cable assignments.
   d) I/O card layout, module, and block number.
   e) Field wiring termination assignments.
5) Relay coils:
   a) Tag number and its function.
   b) On the right side of the run where the coil is located, list the contact location by ladder number and sheet number.
6) Relay contacts: Coil tag number, function, and coil location.

10. LCP cabinet power consumption and heat dissipation, tabulate and summarize:
    a. Required voltages, currents, and phases.
    b. Maximum heat dissipations Btu/hr.
    c. Include calculations.
11. Communications with LCP devices, PLC equipment: Describe configuration, operation, limitations, and diagnostics for LANs, data highway, serial links, and other communication paths.
12. Applications software documentation:
    a. Complete configuration documentation for microprocessor based configurable devices.
    b. For each device, include a program configuration listing showing:
       1) Functional blocks or modules used.
       2) Configuration, calibration, and tuning parameters.
       3) Descriptive annotations.

E. Shop Drawings for changes impacting software configuration:
   1. Schedule:
      a. Submit first changes as part of the Shop Drawings.
      b. Submit updated changes at 30-day intervals.
   2. Changes to I/O list reflecting actual equipment and instrumentation.
   3. Changes required to software configuration resulting from installation of alternative, upgraded, and modified equipment.

F. Quality Control Submittals:
   1. Testing Related Submittals:
      a. Unwitnessed factory test: No Submittals required.
      b. FDT, operational readiness, and PAT:
         1) Preliminary test procedures: Outlines of proposed tests, forms, and checklists.
         2) Final test procedures: Proposed test procedures, forms, and checklists.
         3) Test documentation: A copy of the signed off test procedures when tests are completed. Completed component calibration sheets with O&M manuals.
   2. O&M Manuals:
      a. Provide preliminary and final manuals.
      b. As specified in SECTION 01 78 23.
      c. Shop Drawing Submittal information.
      d. Manufacturer's O&M manuals: Certificate of proper installation, instructions for installation, operation, maintenance, troubleshooting, and calibration. Include internal schematics and wiring diagrams.
      e. Software documentation: Updated version of software.
      f. Hardcopy and electronic version of installed programs in controllers.
      g. Calibration, startup, and commissioning reports.
      h. Complete lists of equipment furnished, including Manufacturer model numbers, correct settings, alarm points, and operating ranges.
      i. Detailed instructions for periodic maintenance schedules, equipment inspection, and adjustment.
      j. Final As-Built Drawings: Provide Drawings electronically via the DW approved dropbox and in quality hardcopy media. AutoCAD Drawings shall be in accordance with DW's current CAD Standards and shall include, but not be limited to, the Standards located online in DW's CPPM: http://www.denverwater.org/contractors/construction-information/design-standards/cad-standards.
         1) Drawings shall be on a standard DW title block and border provided by DW.
         2) As-Builts and Manufacturer's Drawings shall be provided:
            a) On a standard DW provided title block and border.
            b) With the drawing graphics and text, assigned to a pen 2 color (yellow).
            c) Text: Minimum 0.1 inch, maximum 0.2 inch.
            d) Titles: 0.2 inch.
   3. Warranty documentation.

G. Contract Closeout Submittals: Prior to the Substantial Completion date, submit service agreements signed by the OWNER and the maintenance provider for Work required in this Section.

H. Extra Materials:
   1. Furnish, box, tag, and clearly mark on exterior, identify each item with the Manufacturer’s name, description, and part number for shipment and long-term storage, and deliver prior to 75% of the Substantial Completion date the following extra materials for the LCPs and associated components:
      a. Fuses: A minimum of three of each type and size.
      b. Indicating light bulbs and LEDs: A minimum of two of each type and size.
I. Supplements listed in this Section.

1.6 QUALITY ASSURANCE

A. Provide OWNER contact information to the Equipment Manufacturers as owner of record for warranties, recalls, updates (including software and firmware), notices, etc.
B. UL Compliance: Materials manufactured within the scope of UL shall conform to UL standards and have an applied UL listing mark.
C. Coordination Meetings:
   1. As specified in SECTION 01 31 00.
   2. At the site or the ENGINEER’s office, as approved by the ENGINEER.
   3. Attended by the ENGINEER, CONTRACTOR, Subcontractor, Manufacturer, and OWNER, as requested by the ENGINEER.
   4. Meeting frequency: When requested by the ENGINEER. Estimated monthly in the first half of the Project and weekly in the second half of the Project.
D. Training:
   1. General:
      a. Provide an integrated training program for the OWNER's personnel.
      b. Perform training to meet the specific needs of the OWNER's personnel.
      c. Include training sessions, classroom and field, for managers, ENGINEERs, operators, and maintenance personnel.
      d. Accommodate the OWNER's personnel schedule.
      e. The OWNER reserves the right to make and reuse videos of the training sessions.
   2. O&M training:
      a. Coordinate specific requirements specified in the I&C subsystems.
      b. Include a review of O&M manuals and a survey of spares, expendables, and test equipment.
      c. Use equipment similar to that provided or currently owned by the OWNER.
      d. Provide training suitable for instrument technicians with at least a 2-year associate engineering or technical degree, or equivalent education and experience in electronics, instrumentation, or digital systems.
   3. Operation training:
      a. Training session duration: One instructor day.
      b. Number of training sessions: One.
      c. Location: Project site.
      d. Content:
         1) Loop/circuit functions: Understanding of loop/circuit functions, including interlocks for each loop/circuit.
         2) Operation: For example, adjusting variable SPs, manual/remote control, protective relay trips and resets, annunciator acknowledgment and resetting.
         3) Interfaces with field equipment, governor equipment, electrical equipment, existing equipment, etc.
   4. Maintenance training:
      a. Training session duration: One instructor day.
      b. Number of training sessions: One.
      c. Location: Project site.
      d. Content: Provide training for each type of component and function provided.
         1) Functions: Understanding details of each loop/circuit and how they function.
         2) Component calibration.
         3) Adjustments: For example, controller tuning constants, current switch trip points, and similar items.
         4) Troubleshooting and diagnosis for components.
         5) Replacing lamps, fuses, reset breakers, reset protective relays.
         6) Component removal and replacement.
         7) Periodic maintenance.
E. Instrument Tag Numbers: The tag number notation corresponds to the Drawings and is used in the loop specifications.

1.7 DELIVERY, STORAGE, AND HANDLING

A. Provide field and warehouse secure, environmentally controlled storage facilities for equipment.
B. Prior to shipment, include corrosive-inhibitive vapor capsules in shipping containers, and related equipment as recommended by the Capsule Manufacturer.
C. Prior to installation, store items in dry indoor locations. Provide heating in storage areas.
D. Cover panels and other elements exposed to dusty construction environments.

1.8 SITE CONDITIONS

A. Materials and equipment shall be designed and manufactured for continuous operation, site conditions shall be as specified in SECTION 26 05 00.

1.9 WARRANTY

A. Manufacturer: Warranty for 1 year from the Substantial Completion date for the satisfactory performance and installation of the I&C system and associated appurtenances.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURES

A. Terminal Blocks, 0 V to 600 V:
   1. General purpose, #8 AWG to #4 AWG:
      a. General Electric, EB series
   2. Terminal block, general purpose:
      a. General Electric, CR 151A2
      b. Terminal block, fuse/disconnect plug:
         1) Phoenix Contact, V10K 1,5-D/TG/D/PE with Type ST, UK 6,3-HESI 600V/25A, UK 5-HESI 600V/6.3A
      c. Terminal block, general purpose:
         1) Phoenix Contact, Type UK5N and UK6N
      d. Terminal block, ground:
         1) Phoenix Contact, Type USLKG
      e. Terminal block, blade disconnect switch:
         1) Phoenix Contact, Type UDK4-MTK
      f. Terminal block, fuse/disconnect plug:
         1) Phoenix Contact, VIOK 1,5-D/TG/D/PE with Type ST
      g. Terminal block, fused, 24 VDC:
         1) Phoenix Contact, Type UK6, 3-HESI
      h. Terminal block, fused, 120 VAC:
         1) Phoenix Contact, UK6, 3-HESI
      i. Terminal block, fused, 120 VAC, high current:
         1) Phoenix Contact
   3. Enclosure/cabinet, freestanding two door:
      a. Exhaust grill:
         1) nVent Hoffman TEP10UL12
      b. Cooling fan:
         1) nVent Hoffman TFP101UL12
      c. Data pocket:
         1) nVent Hoffman ADP3
      d. Corrosion-inhibiting vapor capsules:
         1) nVent Hoffman Engineering, Model A-HCI
         2) Northern Instruments, Model Zerust VC
      e. Aluminum air filters:
         1) nVent Hoffman, Series A-FLT
      f. Three-point door latches:
         1) Southco Type 44

B. Panel Electrical:
   1. Relays:
      a. MOV for AC voltage coils:
         1) Littlefuse, Model V240ZA05
      b. MOVs for DC voltage coils:
         1) Littlefuse, Model V180ZA5
      c. Auxiliary industrial control relays:
         1) Potter & Brumfield, KUEP series
      d. Magnetic control, machine tool and industrial relays:
         1) General Electric; Type CR120B
      e. 24 V signal/control relays:
         1) IDEC Corp series RH

C. Corrosion-Inhibiting Vapor Capsules:
   1. nVent Hoffman Model A-HCI
   2. Northern Instruments

2.2 MATERIALS

A. Electrical Requirements:
   1. Wires within enclosures:
      a. Wiring shall be as specified in SECTION 26 05 19.
      b. AC circuits:
         1) CT and PT secondary wiring shall be SIS type conductors.
         2) Type: 600 V, Type THHN/THWN stranded copper.
         3) Size: For current to be carried, but not less than #14 AWG.
      c. Analog signal circuits:
         1) Type: 600 V, Type 3 stranded copper, twisted shielded pairs.
         2) Size: #16 AWG, minimum.
      d. Other DC circuits:
         1) 125 VDC shall be SIS type conductors.
         2) Type: 600 V, Type THHN/THWN stranded copper.
         3) Size: #14 AWG, minimum.

e. Special signal circuits: Use the Manufacturer's standard cables.
f. Wire identification: Numbered and tagged at each termination.
    1) Wire color scheme shall be as follows:
        a) Power, AC: Black.
        b) Control, AC: Red.
        c) Neutral: White.
        d) Ground: Green.
        e) 24 VDC power: Blue (positive), blue with white tracer (negative).
        f) 125 VDC power: Purple (positive), purple with white tracer (negative).
        g) Control: Yellow.
    2) Wire tags: Snap-on or slip-on PVC wire markers with legible machine printed markings and numbers. Adhesive and taped-on tags shall not be acceptable.

2. Terminal blocks, 0 V to 600 V:
    a. General:
        1) Accommodate present and spare needs.
        2) One wire per terminal.
        3) Wire spare and unused panel-mounted elements to their panels' terminal block.
        4) Spare terminals: 20% of the connected terminals, but no less than 10 per terminal block.
    b. General purpose, #8 AWG to #4 AWG:
        1) Connection type: Washer head binding screws into molded one-piece terminal boards, conductors and cables terminated with heavy duty ring terminals.
    c. Terminal block, general purpose:
        1) Use for conductor and cable terminations.
        2) Rated voltage: 600 VAC.
        3) Rated current: 30 A.
        4) Wire size: #18 AWG to #10 AWG.
        5) Connection type: Washer head binding screws, conductors, and cables terminated with heavy duty ring terminals.
        6) Provide the Manufacturer's mounting kit and marking strip. Marking shall be permanent machine produced.
    d. Terminal block, fuse/disconnect plug:
        1) Use: Provide one for each analog I/O field interface cable.
        2) Rate voltage: 300 VAC.
        3) Rated current: 15 A.
        4) Wire size: #30 AWG to #14 AWG.
        5) Terminal block, general purpose:
            a) Rated voltage: 600 VAC.
            b) Rated current: 30 A.
            c) Wire size: #22 AWG to #10 AWG.
            d) Rated wire size: #10 AWG.
            e) Color: Gray body.
            f) Spacing: 0.25 inch, maximum.
            g) Test sockets: One screw test socket 0.079 inch diameter.
        6) Terminal block, ground:
            a) Wire size: #20 AWG to #1/0 AWG.
            b) Rated wire size: As required.
            c) Color: Green and yellow body.
            d) Spacing: 0.25 inch, maximum.
            e) Grounding: Ground terminal blocks electrically grounded to the mounting rail.
        7) Terminal block, blade disconnect switch:
            a) Rated voltage: 600 VAC.
            b) Rated current: 10 A.
            c) Wire size: #22 AWG to #12 AWG.
            d) Rated wire size: #12 AWG.
            e) Color: Gray body, orange switch.
            f) Spacing: 0.25 inch, maximum.
        8) Terminal block, fuse/disconnect plug:
            a) Use: Provide one for each analog I/O field interface wire.
            b) Rated voltage: 300 VAC.
            c) Rated current: 15 A for terminal block, 6.3 A for ST-SI-UK 4 disconnect plug.
            d) Wire size: #30 AWG to #14 AWG.
            e) Fusing shall be approved by the ENGINEER.
        9) Terminal block, fused, 24 VDC:
            a) Rated voltage: 600 VDC.
            b) Rated current: 16 A.
            c) Wire size: #26 AWG to #8 AWG.
            d) Rated wire size: #10 AWG.
            e) Color: Black body.

f) Fuse: Amperage size as required.
g) Indication: LED diode 24 VDC.
h) Spacing: 0.32 inch, maximum.

10) Terminal block, fused, 120 VAC:
a) Rated voltage: 600 VAC.
b) Rated current: 6.3 A.
c) Wire size: #26 AWG to #8 AWG.
d) Rated wire size: #12 AWG.
e) Color: Black body.
f) Fuse: Amperage size as required.
g) Indication: Neon lamp 110 VAC.
h) Leakage current: 1.0 mA, maximum.
i) Spacing: 0.32 inch, maximum.

11) Terminal block, fused, 120 VAC, high current:
a) Rated voltage: 600 VAC.
b) Rated current: 35 A.
c) Wire size: #18 AWG to #8 AWG.
d) Rated wire size: #8 AWG.
e) Fuse: Amperage size as required.

3. Grounding:
a. Enclosures, control panels, and cabinets' signal and shield ground connections shall be made as shown on the Drawings.
b. Each control panel and cabinet shall have a dedicated #6 AWG ground conductor from the ground grid to the grounding terminal, control panel, and cabinet. Control panel grounding:
1) Furnish isolated copper grounding bus for signal and shield ground connections.
2) Ground the ground bus at a common signal ground point in accordance with NFPA 70.
3) Single point ground for each analog loop:
a) Locate at the DC power supply for the loop.
b) Use to ground wire shields for the loop.
4) Ground terminal block rails to the ground bus.

B. Nameplates, Tags, and Mimic Bus:
1. Mimic bus, graphic display.
a. The front of the LCP and ECP shall include a graphic display (mimic bus) showing major flows and functions as shown on the Drawings.
b. Graphic materials, lines, and symbols, shall be formed from 1/8 inch thick fade-resistant colored plastic.
c. The graphic materials shall be cemented to the LCP front with 3M 300 series adhesive or as recommended by the Manufacturer and approved by the ENGINEER, to form the mimic bus.
d. Graphic materials, shapes, adhesive, and colors shall be approved by the ENGINEER.
2. Panel nameplates: Enclosure identification located on the enclosure face.
a. Location and inscription: As shown on the Drawings.
b. Materials: Adhesive backed, laminated plastic.
c. Letters: 1/2 inch white surface engraved to a black core, white with black letters.
3. Component nameplates: Component identification located as shown on the Drawings, or near component.
a. Inscription: Component tag number.
b. Materials: Adhesive backed, laminated plastic.
c. Letters: 3/16 inch white surface engraved to a black core, white with black letters.
4. Nametags: Component identification for field devices.
a. Inscription: Component tag number.
b. Materials: 16 gauge, Type 304 SST.
c. Letters: 3/16 inch imposed.
d. Mounting: Affix to component with 16 gauge or 18 gauge SST wire or SST screws.
5. LCP, ECP, equipment drawings: Include a folder in the enclosure with a complete set of As-Built Drawings. Provide laminated As-Built Drawings of the conduit/conductor schedules.

2.3 COMPONENTS
A. Component Specifications: Located in Supplement A.
B. Nameplates and Tags:
1. Panel nameplates: Enclosure identification located on the enclosure face.
a. Location and inscription: As shown on the Drawings.
b. Materials: Adhesive backed, laminated plastic.
c. Letters: 1/2 inch white surface engraved to a black core, white with black letters.
2. Component nameplates: Component identification located as shown on the Drawings, or near component.
a. Inscription: Component tag number.
b. Materials: Adhesive backed, laminated plastic.
c. Letters: 3/16 inch white surface engraved to a black core, white with black letters.
3. Nametags: Component identification for field devices.
a. Inscription: Component tag number.
b. Materials: 16 gauge, Type 304 SST.

c. Letters: 3/16 inch imposed.
d. Mounting: Affix to component with 16 gauge or 18 gauge SST wire or SST screws.
4. Drawings: Include a folder in the cabinets for a complete set of As-Built Drawings. Coordinate with the Electrical Contractor and the ENGINEER to provide laminated As-Built Drawings of the conduit/conductor schedules in each cabinet.

2.4 FABRICATION

A. General:
1. Panel dimensions, device and instrument arrangements, labels, and wire tags shall be approved by the ENGINEER, before panel fabrication.
2. Factory assembly: Assemble enclosures, install instruments, wire, and devices at factory. No fabrication other than the correction of minor defects or minor transit damage permitted on-site.
3. Electrical work, equipment, and devices: In accordance with the applicable requirements of SECTION 26 05 00.

B. Wiring Within Enclosures:
1. Restrain by plenum rated plastic ties and ducts or metal raceways, unless otherwise shown on the Drawings.
2. Hinge wiring: Secure at each end so that bending or twisting will be around the longitudinal axis of wire. Protect the bend area with sleeve.
3. Arrange wiring neatly, cut to proper length, and remove surplus wire.
4. Provide abrasion protection for wire bundles which pass through holes or across edges of sheet metal.
5. Connections to screw type terminals:
a. Ring-tongue lugs.
b. Use the Manufacturer's recommended tool with the required sized anvil to make crimp lug terminations.
c. Wires terminated in a crimp lug: One, maximum.
d. Lugs installed on a screw terminal: Two, maximum.
6. Connections to compression clamp type terminals:
a. Strip, prepare, and install wires in accordance with the Terminal Manufacturer's recommendations.
b. Wires installed in a compression screw and clamp: One, maximum.
7. Splicing and tapping of wires, allowed only at device terminals or terminal blocks.
8. Terminate 24 VDC and analog signal circuits on a separate terminal block from AC circuit terminal blocks, unless otherwise shown on the Drawings.
9. Separate analog and 50 VDC and less circuits by at least 6 inches from AC power and control wiring, except at unavoidable crossover points and at device terminations. Separation methods and channels in cabinets and control panels, including concrete trough, shall be approved by the ENGINEER.
10. Arrange wiring to allow access for testing, removal, and maintenance of circuits and components.
11. Plastic wire duct fill: Do not exceed the Manufacturer's recommendations.

C. Provide corrosion-inhibiting vapor capsules in enclosures, panels, and cabinets.

D. Temperature Control:
1. Non-ventilated panels: Size to adequately dissipate heat from equipment mounted inside panel or on panel.
2. Ventilated panels:
a. Furnish with louvers and forced ventilation as required to prevent temperature buildup from equipment mounted inside panel or on panel. Size to adequately dissipate heat from equipment mounted inside panel or in panel face. Panel louvers shall have industrial, heavy duty, washable aluminum air filters.
b. Construction: Stamped sheet metal.
c. Ventilation fans:
1) Furnish where required to provide adequate cooling.
2) Create positive internal pressure within panel.
3) Fan motor power: 120 V, 60 Hz AC, thermostatically controlled.
d. Panel louvers shall have industrial, heavy duty, washable aluminum air filters.
3. Provide and install louvers, forced ventilation, and thermostats to control the temperature in control panels and cabinets containing PLCs and equipment requiring ventilation. The forced ventilation in the control panels and cabinets shall keep the control panels and cabinets' internal temperature below 75ºF.
4. Space heaters: Thermostatically controlled to maintain internal panel temperatures above dew point.

E. Freestanding Panel Construction:
1. Materials: Sheet steel unless otherwise shown on Drawings with a minimum thickness of 10 gauge.
2. Panel fronts:
a. Fabricated from a single piece of sheet steel.
b. No seams or bolt heads visible when viewed from front.
c. Panel cutouts: Smoothly finished with rounded edges.
d. Stiffeners: Steel angle or plate stiffeners or both on back of panel face to prevent panel deflection under instrument loading or operation.
3. Internal framework:
a. Structural steel for instrument support and panel bracing.
b. Permit panel lifting without racking or distortion.
4. Lifting rings to allow simple, safe rigging and lifting of panel during installation.
5. Adjacent panels: Securely bolted together so front faces are parallel.
6. Doors:
a. Full height, fully gasketed access doors as shown on the Drawings.
b. Latches: Three-point, Southco Type 44.

c. Handles: D ring, foldable type.
d. Hinges: Full length, continuous, piano type, steel hinges with SST pins.

F. Panel Electrical:
1. Power distribution within panels:
   a. Provide overcurrent protection on each individual branch circuit distributed from panelboards.
      1) Locate to provide a clear view of and access to breakers when the door is open.
      2) Breaker sizes: Coordinate such that a fault in the branch circuit will blow only the branch breaker but not trip the main breaker.
   b. Circuit wiring: P&IDs and control diagrams on the Drawings show function only. Use following rules for actual circuit wiring:
      1) 120 VAC branch circuit loading: 15 A continuous, maximum.
      2) 24 V branch circuit loading: Minimum overcurrent and circuit sizes are shown on the Drawings. Size breakers, fuses, and circuits for actual loads, less than 75% of full load circuit capacity.
      3) Panel lighting and service outlets: Put on separate 20 A 120 VAC branch circuit.
      4) Provide 120 VAC plugmold for panel components with line cords.
2. Signal distribution:
   a. Isolated 4 mA to 20 mA DC signals.
   b. Signal wiring shall be twisted, shielded pairs, as specified in SECTION 26 05 19.
3. Signal switching:
   a. Use dry circuit type relays or switches.
   b. No interruption of 4 mA to 20 mA loops during switching.
   c. Switching transients in associated signal circuit:
      1) 4 mA to 20 mA DC signals: 0.2 mA, maximum.
      2) One VDC to 5 VDC signals: 0.05 V, maximum.
4. Relays:
   a. General:
      1) Relays shall be provided with surge protection across the coils as follows:
         a) Surge suppressers: Magnetic control, machine tool, and industrial relays.
         b) MOVs: AC voltage coils.
         c) Diodes: DC voltage coils.
         d) Surge protection shall be provided and installed as recommended by the Relay Manufacturer and approved by the ENGINEER.
      2) Signal/control circuit switching relays:
         a) Relay mounting: Plug-in type socket.
         b) Relay enclosure: Furnish dust cover.
         c) Socket type: Screw terminal interface with wiring.
         d) Socket mounting: DIN rail.
         e) Provide hold down clips.
   b. Magnetic control, machine tool, and industrial relays:
      1) Use when shown on the Drawings.
      2) NEMA ICS 2, Class A600 (600 V, 10 A continuous, 7,200 VA make, 720 VA break), industrial control with a minimum of four field-convertible contacts.
      3) Time delay attachment: Solid state.
      4) Provided and installed with the Manufacturer recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
   c. 24 V signal/control relays:
      1) Tags: As shown on the Drawings.
      2) Type: Compact general purpose plug-in.
      3) Contact arrangement: As shown on the Drawings, two form C contacts minimum.
      4) Contact rating: 10 A minimum at 24 VDC and 250 VAC.
      5) Contact material: Silver cadmium oxide alloy.
      6) Coil voltage: 24 VDC.
      7) Coil power: 2.2 VA/1.3 W.
      8) Provided and installed with the Manufacturer recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
      9) Expected mechanical life: 10,000,000 operations minimum.
      10) Expected electrical life at rated load: 100,000 operations.
      11) Indication type: LED indicator lamp.
      12) Lockable push-to-test button.
   d. Auxiliary industrial control relays:
      1) 120 VAC and 110 VDC coil relays.
      2) Type: Hinged armature auxiliary, with cover.
      3) Contact arrangement: As shown on the Drawings, two form C contacts minimum.
      4) Contact rating: 5 A at 150 VDC load switching.
      5) Contact material: Silver cadmium oxide alloy.
      6) Coil voltage: 110 VDC or 120 VAC.
      7) Coil power: 1.8 W.

8) Provide with indicator lamps.
9) Expected mechanical life: 100,000 operations minimum.
10) Expected electrical life at rated load: 100,000 operations minimum.
11) Provided and installed with Manufacturer-recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
12) 110 VDC coil relay bases shall include appropriately rated voltage drop resistors and surge suppression diodes professionally soldered onto the base with leads protected by heat shrink tubing. Voltage drop resistor rating is estimated to be 2,000 ohms, with a minimum rating of 2 W, with at least 5% accuracy. Surge suppression diode shall be a minimum rating of 3 A, 1000 V. Device rating calculations and example fabricated base shall be submitted to the ENGINEER for approval.
13) Provide and install relay hold-down springs.

5. Internal panel lights for control panels and cabinets:
   a. Type: Switched enclosed and gasketed, fiberglass, industrial lamp LED fixtures.
   b. Mounting: Inside, centered in the top.
6. Service outlets for control panels and cabinets:
   a. Type: Three-wire, 120 V, 20 A, duplex receptacles.
   b. Two, locations to be approved by the ENGINEER.

G. Factory Finishing:
1. Minimum requirements for steel panels:
   a. Sand panel and remove mill scale, rust, grease, and oil.
   b. Fill imperfections and sand smooth.
   c. Paint panel interior and exterior with one coat of epoxy coating metal primer, two finish coats of two-component type epoxy enamel.
   d. Sand surfaces lightly between coats.
   e. DFT: 3 mils, minimum.
   f. Color: ANSI 61 gray unless otherwise shown on the Drawings.

PART 3 EXECUTION

3.1 GENERAL

A. Provide materials, equipment, and software, except for ENGINEER-provided applications software, whether indicated or not, necessary for complete system integration and performance.
B. Use products of one Manufacturer and of the same series or family of models to achieve standardization for appearance, operation, maintenance, spare parts, and Manufacturer's services.
C. Communications systems as specified in SECTION 27 00 00.
D. Coordinate with SECTION 26 05 33 to verify exterior raceways that enter a below grade structure and terminate in a below grade panel, cabinet, or enclosure shall enter the panel, cabinet, or enclosure in the bottom third of the panel, cabinet, or enclosure.

3.2 PREPARATION

A. Equipment provided by the I&C Contractor and installed by others, requires the I&C Contractor to observe and advise on installation to the extent required to certify with ORT that equipment has been properly installed.
B. For equipment not provided by the I&C Contractor, but that directly interfaces with the I&C, verify the following conditions:
1. Proper installation, calibration, and adjustment.
2. Correct control action.
3. Switch settings and dead bands.
4. Opening and closing speeds and travel stops.
5. I/O signals.

3.3 INSTALLATION

A. Material and Equipment Installation:
1. Follow the Manufacturer’s installation instructions. Provide a signed draft copy of the Manufacturer’s certification of proper installation prior to proceeding with further testing.
2. Wiring connected to I&C components and assemblies, including power wiring as specified in SECTION 26 05 19.

B. Provide, install, and be responsible for a complete fully operational I&C including field I/O connections and terminations, and communications between the PLC, devices, and communications. Provide and install wiring, cables, PLC/RTU ports, and connectors as needed to properly implement the I&C. The OWNER shall provide the computer system and GUI.
C. PLC programming logic shall be provided by and installed by the ENGINEER. Demonstrate to the ENGINEER required communications. Provide assistance to the ENGINEER in testing, configuring, calibrating, and scaling of the PLC I/O points as required during the programming of the PLC and startup of the I&C.
D. The intent of the Contract Documents is to show general locations and the minimum amount of devices and interconnection required to make the I&C functional. The detailed design, layout, and installation of the required control wiring, interconnections, and devices to make the complete system fully functional is the CONTRACTOR’s responsibility.
E. Install and perform in accordance with the Manufacturer’s recommendations including, but not limited to, PLC/RTU communications equipment, I/O cards and terminations, testing, startup, and other necessary appurtenances.
1. The fully operational system shall include:
   a. Communications between PLCs and office servers.
   b. Field I/O connections and terminations in accordance with the Contract Documents.
   c. Field I/O connections include, but are not limited to, primary elements, transmitters, control panels, etc.
2. PLC programming logic shall be provided by and installed by the ENGINEER.

3. Demonstrate to the ENGINEER network communications between the PLCs and office servers.

3.4 PROTECTION

A. Protect enclosures and other equipment containing electrical, I&C devices, including spare parts, from corrosion through the use of corrosion-inhibiting vapor capsules.

B. Periodically replace capsules in accordance with the Capsule Manufacturer's recommendations. Replace capsules just prior to Final Payment and Acceptance.

3.5 QUALITY CONTROL

A. General:
   1. Test I&C elements, both hardware and software.
   2. Factory tests:
      a. UFT.
      b. FDT.
   3. On-site tests:
      a. SDT.
      b. ORT
         1) Phase 1
         2) Phase 2.
      c. PAT.
   4. Test format – cause and effect:
      a. The person conducting the test initiates an input, cause.
      b. The specific test requirement is satisfied and if correct result, effect occurs.
   5. Procedures, forms, and checklists:
      a. Except for UFT, conduct tests in accordance with, and documented on, ENGINEER-approved procedures, forms, and checklists.
      b. Describe each test item to be performed.
      c. Have space after each test item description for signoff by the appropriate party after satisfactory completion.
   6. Required test documentation: Test procedures, forms, and checklists. Signed by the ENGINEER and the CONTRACTOR except for Phase 1 ORT items signed only by the CONTRACTOR.
   7. Conducting tests:
      a. Special testing materials and equipment.
      b. Wherever possible, perform tests using actual PVs, equipment, and data.
      c. If not practical to test with real PVs, equipment, and data, provide suitable means of simulation.
      d. Define simulation techniques in test procedures.
   8. Coordinate I&C testing with the OWNER and the affected Contractors.
   9. The ENGINEER will actively participate in many of the tests and reserves the right to test or retest specified functions whether or not explicitly stated in the test procedures.
   10. The ENGINEER's decision will be final regarding the acceptability and completeness of testing.

B. UFT:
   1. Scope: Inspect and test I&C to ensure it is operational, ready for FDT.
   2. Location: I&C Contractor's factory.
   3. Integrated test:
      a. Interconnect and test I&C.
      b. Exercise and test functions.
      c. Simulate required I/O.

C. FDT:
   1. General: During the initial coordination meetings, the ENGINEER and the I&C Contractor shall evaluate and discuss the requirements for the FDT. To facilitate the coordination of the PLC, software programming, the FDT may be replaced with SDT at the site. The ENGINEER will make the final decision regarding the substitution of SDT for the FDT.
   2. The I&C Contractor shall include a minimum of 1 week in the schedule for factory testing and preliminary PLC checkouts with the ENGINEER.
   3. The I&C Contractor shall include any changes in the I&C progress schedule.
   4. The I&C Contractor shall make allowances for the ENGINEER to load pre-developed PLC software for testing during the FDT.
   5. The software shall assist in demonstrating the correct operation of the PLC and RTU communications and specific functions.
   6. The I&C Contractor shall provide simulated hardwire interfaces as required to test specific loops and functions.
   7. Scope: Test entire I&C, with exception of primary elements and final control elements, to demonstrate it is operational.
   8. Location: I&C Contractor's factory.
   9. Functions:
      a. Demonstrate functions as required for I&C, PLCs, control panels, and cabinets.
      b. Timing: Include tests for timing requirements.
      c. Diagnostics: Demonstrate online and offline diagnostic tests and procedures.
      d. Communications: Demonstrate communications between PLCs, RTUs, control panels, and cabinets.
   10. Correct deficiencies found and complete prior to shipment to the site.

11. Failed tests:
    a. Repeat and witnessed by the ENGINEER.
    b. With approval of the ENGINEER, certain tests may be conducted by the I&C Contractor and witnessed by the ENGINEER as part of ORT.
12. Make the following documentation available to the ENGINEER at the test site both before and during FDT:
    a. Drawings, specifications, addenda, and change orders.
    b. Master copy of FDT procedures.
    c. Shop Drawing Submittals for equipment being tested.
13. Daily schedule for FDT:
    a. Begin each day meeting to review the day's test schedule.
    b. End each day with a meeting to review the day's test results and to review or revise the next day's test schedule.

D. SDT:
1. Replaces the FDT if no FDT is performed.
2. The SDT shall follow the same procedures and tests as the FDT but is performed on the site instead of at the Manufacturer’s factory.

E. On-site Supervision: The I&C site Representative shall be on-site during the total period required to supervise, coordinate, and complete on-site I&C activities.

F. Startup and Testing Team:
1. Thoroughly check installation, terminations, and adjustments.
2. Complete on-site tests.
3. Complete on-site training.
4. Provide startup assistance to the ENGINEER.

G. ORT: Prior to startup test period and PAT, inspect, test, and document that entire I&C is ready for operation.
1. Cleaning and checking and functional testing activities as specified in SECTION 01 91 00.
2. Phase 1 ORT (ORT1): Performed by the I&C Contractor to test and document that I&C, excluding ENGINEER-provided PLC applications software, is ready for operation. For I&C systems for which the ENGINEER provides applications software, provide sufficient temporary software configuring to allow testing of the subsystems.
    a. Inspections and tests:
        1) Check I&C for proper installation, calibration, and adjustment on a loop-by-loop, circuit-by-circuit, and component-by-component basis.
        2) Provide space on forms for signoff by the I&C Contractor and the ENGINEER.
        3) Organize and track inspection, adjustment, and calibration of each loop, circuit, and component, include:
            a) Project name.
            b) Tag number for each component.
            c) Checkoffs/signoffs for each component:
                (1) Tag/identification.
                (2) Installation.
                (3) Termination wiring.
                (4) Calibration/adjustment.
                (5) Interface terminations.
                (6) I/O interface terminations with PLC.
            d) I/O signals for PLC are operational: Received/sent, processed, and adjusted.
            e) Total loop or circuit operational.
            f) Space for comments.
        4) Component calibration sheet for each component, except simple hand switches, lights, gauges, and similar items, and each PLC I/O module and include:
            a) Project name.
            b) Loop or circuit number and description.
            c) Component tag number or I/O module number.
            d) Manufacturer, model number/serial number for component.
            e) Summary of functional requirements, for example:
                (1) Indicators, scale, and ranges.
                (2) Transmitters/converters, input, and output ranges.
                (3) Computing elements' function.
                (4) Controllers, action, and control modes.
                (5) Switching elements, unit range, differential, reset, and auto/manual.
                (6) I/O modules: Input or output.
            f) Calibrations, for example:
                (1) Analog devices: Actual I/O at 0%, 10%, 50%, and 100% of span, rising and falling.
                (2) Discrete devices: Actual trip points and reset points.
                (3) Controllers: Mode settings.
                (4) I/O modules: Actual inputs or outputs of 0%, 10%, 50%, and 100% of span, rising and falling.
            g) Space for comments.
        5) Maintain loop and circuit status reports, valve adjustment sheets, and component calibration sheets at the site and make them available to the ENGINEER for review, at all times.
    b. FDTs, repeat:
        1) Repeat FDT on-site with entire I&C installed.

2) Use FDT test procedures as the basis for the test.
3) In general, the test shall not require witnessing. However, portions of the test, as identified by the ENGINEER during original FDT, shall be witnessed.

c. ORT forms: Shall be approved by the ENGINEER.

3. Phase 2 ORT (ORT2): A combined effort between the I&C Contractor and the ENGINEER to confirm that I&C, including applications software, is ready for operation.
   a. Prerequisite: Completion of Phase 1 ORT.
   b. Joint test with the ENGINEER. Repeat of the ENGINEER's FDT application software tests, except using actual devices. Control and communications with PLC and computer tested on loop-by-loop, circuit-by-circuit and component-by-component basis.
   c. Test procedures approved by the ENGINEER based on Phase 1 ORT and on FDT application software tests.
4. Additional field testing and commissioning as specified in SECTION 26 08 00.

H. PAT:
1. Performance testing activities as specified in SECTION 01 91 00.
2. After ORT has been completed and the facility has been started up, perform jointly with the ENGINEER a PAT on complete I&C to demonstrate it is operating as required by the Contract Documents. Demonstrate each required function on a paragraph-by-paragraph, loop-by-loop, circuit-by-circuit, and component-by-component basis.
3. Tests shall be the same as required for FDT except that the entire installed I&C shall be tested using actual PVs and functions demonstrated.
4. Perform local and manual tests for each loop, circuit, and component before proceeding to remote and automatic modes.
5. Where possible, verify test results using visual confirmation of process equipment and actual PV. Exercise and observe devices supplied by others, as needed to verify correct signals to and from such devices and to confirm overall system functionality. Test verification by means of disconnecting wires or measuring signal levels shall be acceptable only where the direct operation of equipment is not possible.
6. Make updated versions of documentation required for PAT available to the ENGINEER at the site both before and during testing.
7. Make one copy of the O&M manuals available to the ENGINEER at the site both before and during testing.
8. Follow the daily schedule required for FDT.
9. PAT procedures and forms shall be approved by the ENGINEER.

I. I&C Systems Acceptance: Shall meet the requirements defined in Part 1.
1. I&C system PAT complete.
2. I&C, PLC, and SCADA communications operating properly.
3. Entire system operates, without significant system malfunction, as deemed by the ENGINEER, for a continuous uninterrupted time period of 20 days.
4. If any part of the system fails to meet the requirement, make the necessary repairs or adjustments required to correct the problem. Restart the acceptance test from the beginning for a complete retest.

3.6 CLEANING

A. Clean debris, dirt, dust, etc. from equipment.

3.7 SUPPLEMENTS

A. Supplement A – Component Specifications
B. Supplement B – Instrument List
C. Supplement C – Loop Status Reports
D. Supplement D – Instrument Calibration Sheet
E. Supplement E – Performance Acceptance Test Sheet
F. Supplement F – PLC Input and Output Testing Record
G. Supplement G – Control Loop Descriptions

END OF SECTION

SUPPLEMENT A
COMPONENT SPECIFICATIONS

A. Annunciator Panel:
  1. General:
    a. Function: Annunciate.
    b. Type: Integral logic annunciator.
  2. Features:
    a. Sequence: ISA Sequence F3A, first alarm flashing.
    b. Test: Provide test push button to illuminate visual displays, activate flasher, and audible device.
    c. Push buttons: Integral.
    d. Control contact: Provide the capability to accept external dry contact inputs from remote acknowledge, reset, and test push buttons.
    e. Visual displays:
      1) Module dimension: 3 inches high by 3 5/16 inches wide.
      2) Points per module: Two.
      3) Number of points: As shown on the Drawings.
      4) Window type: Various colors to be approved by the ENGINEER during the Submittal process. Laser-engraved black-filled characters.
      5) Inscriptions: As shown on the Drawings.
      6) Spare points: Completely wire to LCP terminals and equip spare points with no inscription on window.
      7) LEDs: Long life reliable LEDs, minimum two per window, four per module.
      8) Bezel color: Black.
  3. Signal interface:
    a. Field contacts: Accept either normally open or normally closed contacts, with optical isolation.
    b. Output: One common alarm output contact to close when any point is in alarm.
      1) Rating: 5 A at 120 VAC.
    c. Auxiliary contact:
      1) Type: One form C for each alarm point.
      2) Rating: 5 A at 120 VAC.
      3) Action: Follows field contact.
    d. Electrical connections: Locking fork terminal lugs to terminal blocks for field connections.
  4. Enclosure:
    a. Materials: Minimum 16 gauge steel with baked enamel coating.
    b. Mounting: Flush.
    c. Rating: NEMA 1.
    d. Door: None.
  5. Power: 125 VDC input, with integral annunciator filtering.
  6. Power supply:
    a. Type: Integral.
    b. Output voltage: 24 VDC.
    c. Location: Lower right module if integral.
    d. Provide integral filter for external sources.
  7. Audible device:
    a. Type: Adjustable volume range of 78 dB to 103 dB.
    b. Remote mounting: As shown on the Drawings.
    c. Voltage: 125 VDC or 120 VAC.
  8. Manufacturer and product:
    a. Ametek Power Instruments – Panalarm, Series 90B

B. Carbon Monoxide Gas Monitoring System:
  1. General:
    a. The carbon monoxide gas monitoring systems shall measure and provide the control and alarm indication in the event the gas level exceeds the limit SPs.
    b. Provide a large SST tag.
  2. Solid state sensors:
    a. Sensors shall utilize state-of-the-art enhanced MOS sensor technology. Sensor element shall be microprocessor-controlled and compensated for humidity and temperature. Sensor shall not require the addition of reagents.
    b. Sensor transmitters shall have a minimum useful life of 3 years. The Supplier shall provide replacement sensors at no charge for any sensor that does not meet the minimum requirements.
    c. The interconnecting wiring from the sensor to the central panel shall be three-conductor shielded cable for the 4 mA to 20 mA sensors.
    d. The voltage supplied to the sensor shall be a minimum of 21 VDC and a maximum of 30 VDC.
    e. The sensor units shall be capable of being located remote from the central panel by up to 2,000 feet. Sensor units shall receive power from and send signals corresponding to the central panel.
  3. Central panel requirements:
    a. The system shall be a four-point wall-mountable monitor with external solid state sensors.
    b. The enclosure shall be of general purpose metal NEMA 12.

c. Power requirements: The system shall operate on 110 VAC, 60 Hz.

4. Monitor unit requirements:
   a. Discrete LEDs shall indicate warning, alarm, and sensor status. 3.5 digit LCD scanning display for direct reading of the full-scale gas concentrations shall be available.
   b. Two separate field-adjustable SPs for warning and alarm. One non-adjustable SP for system fault.
   c. Relay outputs: Each SP shall have a SPDT relay with dry contacts rated at 10 A, 110 VAC resistive. The alarm relay shall have field-optional 60-minute on delay to reduce nuisance activation and shall be selectable as latching or non-latching. Relays shall be capable of being normally energized for fail-safe operation; four discrete warning relays with adjustable (off delay) shall be provided.
   d. Audible alarm shall have a solid on sound pulse.
   e. Sensor inputs shall be capable of receiving a 4 mA to 20 mA sensor signal.
   f. CSA or NRTL approved.
   g. System shall be factory-tested and calibrated. System shall be automatically zero compensated and not require any field calibration.
5. Manufacturer and product:
   a. RKI Instruments, Model M2A.

C. Alternator Relay:
1. Requirements:
   a. Contact arrangement and wired as shown on the Drawings; two form C contacts minimum.
   b. Contact rating: 10 A minimum at 120 VAC.
   c. Coil voltage: 120 VAC.
   d. Coil power: 1.2 W.
   e. Expected mechanical life: 10,000,000 operations.
   f. Expected electrical life at rated load: 100,000 operations.
   g. Provided and installed with Manufacturer recommended and provided surge suppressors across the coil terminals. The surge suppressor shall be designed to absorb energy surges that appear on the line.
2. Manufacturer and product:
   a. Eaton D853 series with three-position selector switch.
3. Enclosure: Rugged metal case designed for utility and industrial applications.
   a. Manufacturer and product:
      1) Yokogawa; Model Type JUXTA series 2469.

D. Timer, Mechanical Spring Wound:
1. Sized and designed to fit in a single gang 2 1/2 inch deep junction box.
2. The timer shall be equipped with a press-on type black knob and a brushed aluminum plate with a spiral time scale for ease of time setting selection.
3. The timer shall be UL listed for the following ratings:
   a. 1 hp at 125 VAC, 60 Hz.
   b. 20 A at 125 VAC, 60 Hz.
   c. 7 A at 125 VAC, 60 Hz, tungsten.
4. Field wiring points of connection shall be secured by means of a teeter type terminal screw.
5. The timer shall be configured for SPDT switching capability.
6. The timer shall have a hold feature.
7. The timer shall have a time cycle of 2 hours.
8. Manufacturer and product:
   a. Intermatic: FF Series.

E. Timer, Reset:
1. The unit shall provide a dial-selectable, timed interval upon external initiation. The reset timer shall provide on delay function.
2. The unit shall have scale range as noted with repeat accuracy of ±1.0% of full scale. Reset time shall not exceed 0.5 second and minimum setting shall be less than 4% of full scale. The unit shall operate on 120 V, 60 Hz power. Contacts shall be rated for 10 A continuous, at 120 VAC. Contacts shall be rated for 250,000 operations at full resistive load.
3. The panel-mounting reset timer shall have two sets of instantaneous SPDT contacts, and one set of delayed SPDT contacts. The panel unit shall have a cycle progress indicator and a pilot light.
4. Manufacturers and products:
   a. Automatic Timing and Controls, Series 305E; Eagle Signal, HP5 Series.

F. Switches, Current:
1. General:
   a. Function: Operate contacts at preset current signal level.
   b. Type: Electronic with electromechanical relays.
   c. When required, provide multiple current switches for the number of contacts shown on the Drawings.
2. Performance:
   a. SP: As shown on the Drawings and as required.
   b. Repeatability: ±0.1% of input span.
   c. Temperature, operating range: 32°F to 120°F.
3. Features:
   a. Dead band: Continuously adjustable 1% to 100% full input span, accessible on the front of the unit.

b. Activation: Rising or falling; internally selectable.
c. SP adjustment: Continuously adjustable over full input span, accessible on the front of the unit.
d. Input resistance: 50 ohms maximum.
e. Dual SPs: When noted; independent, with independent output contacts.
f. Response time: Less than 100 ms.
g. Isolation: Input, output, and power.

4. Signal interface:
   a. Input: 4 mA to 20 mA DC.
   b. Contacts: Rated 5 A continuous at 120 VAC; DPDT for single SP, SPDT for dual SP.
5. Enclosure: NEMA 1.
6. Power: 24 VDC.
7. Manufacturer and product:
   a. Acromag, Model 361A.

G. Isolator, Current-to-Current:
1. General:
   a. Function: Isolate current signals.
   b. Type: Electronic, back of panel.
2. Performance:
   a. Range: As required.
   b. Accuracy: ±0.1% of span.
   c. Temperature, operation: 0°F to 150°F.
3. Features:
   a. Adjustments: Span and zero; external, front, multi-turn potentiometers.
   b. Isolation: Input, output, and power.
   c. Provides 24 VDC power to two-wire output-loop powered instruments, unless otherwise required by the instrument and approved by the ENGINEER.
   d. Input impedance: 50 ohms maximum.
4. Signal interface:
   a. Input: 4 mA to 20 mA DC.
   b. Output: 4 mA to 20 mA DC for load impedance 0 ohms to 1,200 ohms. Dual 4 mA to 20 mA DC for load impedance 0 ohms to 1,200 ohms, where shown on the Drawings.
5. Enclosure: Metallic case with dust cover and integral bracket for rear of panel mounting.
6. Power: 24 VDC.
7. Manufacturer and product:
   a. Moore Industries, Model ECT/4-20MA/4-20MA/24DC/-TX [DIN].

H. Flow Element and Transmitter, Electromagnetic:
1. General:
   a. Function: Measure, indicate, and transmit the flow of a liquid in a full pipe.
   b. Type: Electromagnetic flow meter, with operation based on Faraday's Law, utilizing the pulsed DC type coil excitation principle with high impedance electrodes.
   c. Parts: Flow element, transmitter, interconnecting cables, mounting hardware, ground rings and calibrator.
   d. Submergence protection IP68 rating when shown on the Drawings. Provide and install using IP68 approved cable glands.
2. Service:
   a. Stream fluid: Water with 5% solids. Electromagnetic flow meters used shall be provided and installed with isolation transformers.
3. Performance:
   a. Flow range: 0 to 5,000 gpm.
   b. Accuracy: ±0.5% of rate for flows resulting from pipe velocities of 1 fps to 39 fps.
   c. Turndown ratio: Minimum of ten to one when flow velocity at minimum flow is at least 1 fps.
4. Features:
   a. Zero stability feature to eliminate the need to stop flow to check zero alignment.
   b. No obstructions to flow.
   c. Very low pressure loss.
   d. Low flow contact output alarm.
   e. Empty pipe detection contact output alarm.
5. Process connection:
   a. Meter size: As shown on the Drawings.
   b. Connection type: 150 lb ANSI raised-face flanges or wafer type depending on meter size, unless otherwise shown on the Drawings.
   c. Flange material: Carbon steel, unless otherwise shown on the Drawings.
6. Signal interface: 4 mA to 20 mA DC for load impedance 0 ohms to 800 ohms minimum for 24 VDC supply.
7. Power: 24 VDC, unless otherwise shown on the Drawings.
8. Element:
   a. Meter tube material: Type 316L SST, unless otherwise shown on the Drawings.
   b. Liner material: Teflon, unless otherwise shown on the Drawings.
   c. Liner protectors: Covers on each end to protect the liner during shipment.

d. Electrode type: Flush or bullet nose as recommended by the Manufacturer for the noted stream fluid.
e. Electrode material: Hastelloy C.
f. Enclosure: NEMA 4, unless otherwise shown on the Drawings.
g. Grounding ring/electrode material: Type 316L SST ground disks.

9. Transmitter:
   a. Remote when shown on the Drawings.
   b. Display: Indicating and totalizing.
   c. Mounting: Pipe.
   d. Enclosure: NEMA 4X.
   e. Zero and span: Field-adjustable.
   f. Indicator: Digital sixteen-character display, with scale range as shown on the Drawings.
   g. Totalizer: Digital sixteen-character display, with totalizer unit digit value as shown on the Drawings.
10. Cables:
    a. Types: As recommended by the Manufacturer.
    b. Lengths: As required to accommodate device locations.
11. Calibration system:
    a. Features:
       1) Field-programmable electronics.
       2) Self-diagnostics with troubleshooting codes.
       3) Ability to program electronics with full-scale flow, engineering units, meter size, zero flow cutoff, desired signal damping, totalizer unit digit value, etc.
       4) Initial flow tube calibration and subsequent calibration checks.
    b. Equipment:
       1) Built-in electronics with each unit provided.
       2) Alternatively, one portable calibrator of each type required for the various electromagnetic flow meters provided on the project.
12. Install in accordance with the Manufacturer's recommendations and requirements.
13. Isolate the meter flow tube and the transmitter from the ground.
14. Isolate the meter flow tube from piping and provide piping bonding jumper around the flow tube.
15. Provide an ENGINEER-approved, electrical conduit, non-conductive isolating section.
16. Provide and install a Manufacturer recommended isolating transformer on the input power to the flow meter.
17. Mount the transmitter on an insulating surface.
18. Install a GFI on the input to the isolating transformer.
19. Measure and verify that the impedance to ground at the flow tube is infinite.
20. Manufacturer and product:
    a. Rosemount 8750W.

I. Limit Switches:
   1. General:
      a. Function: Actuate contact.
      b. Type: Heavy duty, adjustable roller/rotary arm.
      c. Features:
         1) Rating: 120 V, 10 A continuous rating.
         2) Contact configuration: DPDT.
      d. Switches shall be of the same Manufacturer.
      e. Manufacturers:
         1) Cutler-Hammer.
         2) Square D.

J. Indicator, Digital Meters:
   1. General:
      a. Function: Display analog signal.
      b. Type: Seven segment digital, horizontal edgewise.
   2. Performance:
      a. Range and engineering units as required and shown on the Drawings.
      b. Accuracy: Maximum of ±0.1% full scale.
      c. Temperature, operating: 32°F to 120°F.
   3. Features:
      a. Digits: Five; 0.56 inch high minimum; red sunlight readable seven segment LED.
      b. Decimal point: Field-selectable.
      c. Input impedance: 100 ohms maximum.
      d. Service legend: Permanent, display of engineering units and nameplate without the Manufacturer's logo.
      e. Response time: 1 second maximum to 0.1% accuracy.
      f. Two control relay outputs with adjustable SPs, unless otherwise shown on the Drawings.
      g. Submit certified factory calibration.
   4. EMI suppression devices shall be provided and installed as approved by the Digital Meter Manufacturer, the Suppression Device Manufacturer, and the ENGINEER. Ferrite suppression cores for signal and control cables. Line filters for input power cables.
   5. Signal interface: 4 mA to 20 mA DC.

6. Enclosure:
    a. Type: NEMA 4X.
    b. Mounting: Panel; approximately 1.95 inches high by 3.8 inches wide by 4.1 inches deep.
7. Power: 120 VAC unless otherwise shown on the Drawings.
8. Manufacturer and product:
    a. Precision PD765.

K. Indicator, Analog Meters:
1. General:
    a. Function: Display analog signal.
    b. Type: Pivot and jewel movement; switchboard type; circular.
2. Performance:
    a. Range: As required and approved by the ENGINEER.
    b. Accuracy: ±1% of scale.
3. Features:
    a. Type: Circular.
    b. Case size: 4 1/2 inches square, concentric scale type, with white scales, black markings, and black pointers or indictors.
    c. Scale: 250 degrees, synchroscope shall be 360 degrees.
    d. High grade designed for mounting on steel panels.
    e. Submit certified factory calibration.
    f. Input: Current transformer secondary 5 A or potential transformer secondary 120 V.
    g. Low input burden.
4. Enclosure: Drawn steel case with zinc chromate coating. Polycarbonate-UL94V-0 cover, no anti-glare window.
5. Manufacturer and product:
    a. Crompton Model 007.

L. Indicator, Digital Clock:
1. General:
    a. Function: Display time.
    b. Type: Seven segment digital, horizontal edgewise.
2. Performance:
    a. Range: Hours/minutes/seconds.
    b. Temperature, operating: 32°F to 120°F.
3. Features:
    a. Digits: Six digit LED display with 2 1/4 inch high digits.
    b. Service legend: Permanent, display of engineering units and nameplate without the Manufacturer's logo.
    c. Submit certified factory calibration.
4. Synchronizes to any network time protocol source for accurate traceable time. Retains time and date during loss of power and/or reference using a battery basked real-time clock chip and maintenance-free rechargeable battery.
5. Enclosure:
    a. Type: NEMA 1.
    b. Mounting: Panel.
6. Power: 120 VAC, 60 Hz.
7. Manufacturer and product:
    a. MasterClock NTDS26.

M. Indicator, Large Process Display:
1. General:
    a. Function: Display analog signal.
    b. Type: Seven segment digital, horizontal edgewise.
    c. Provide 36 inch long by 6 inch high phenolic, white with black core, labels with lettering as large as possible above each display, with lettering shown on the Nameplate Schedule Drawing.
2. Performance:
    a. Range and engineering units as required, indicated, and approved by the ENGINEER.
    b. Accuracy: Maximum of ±0.1% full-scale.
    c. Temperature, operating: 32°F to 120°F.
3. Features:
    a. Digits: Five; 4 inches high minimum, red sunlight readable seven segment LED.
    b. Decimal point: Field selectable.
    c. Input impedance: 100 ohms maximum.
    d. Service legend: Permanent, display of engineering units and nameplate without the Manufacturer's logo.
    e. Response time: 1 second maximum to 0.1% accuracy.
    f. One control relay output with adjustable SPs, unless indicated otherwise.
    g. Submit certified factory calibration.
4. EMI suppression devices shall be provided and installed as approved by the Digital Meter Manufacturer, the Suppression Device Manufacturer, and the ENGINEER. Ferrite suppression cores for signal and control cables. Line filters for input power cables.
5. Signal interface: 4 mA to 20 mA DC.
6. Enclosure:

a. Type: NEMA 4X.
b. Mounting: panel; 8 inches high, 26 inches wide, and 2 1/2 inches deep.
7. Manufacturer and product:
a. Red Lion LD4A05P0.

N. Level Element and Transmitter, Radar:
1. General:
a. Function: Provide continuous non-contacting level measurement with the output proportional to the level being sensed.
b. Type: Radar.
c. Parts: Level element, temperature element, transmitter, and cable for connection from elements to transmitter.
2. Service:
a. Medium: Water.
b. Pressure: Atmospheric.
c. Altitude: Level element shall be capable of operating at project site conditions.
d. Temperature range: Level element shall be capable of operating in the range of -40°C to 80°C.
3. Performance:
a. Range: As shown on the Drawings or required.
b. Zero reference: As shown on the Drawings or required.
c. Accuracy: ±0.5% of full-scale for analog output signal and alarm SPs shall be repeatable within ±1% of full scale.
d. Resolution: 2 mm or 0.1% of range, whichever is greater.
4. Features:
a. The unit shall be provided with an output indicating meter with a four-character LCD display programmable in engineering units of feet, inches, meters, centimeters, or percent of span.
b. Interconnecting cable: The cable between the level element and the transmitter shall be supplied with the unit, 1,200 feet maximum length.
c. Discrete outputs: The transmitter shall provide up to four discrete outputs, each adjustable over the entire scale range by screwdriver or programming module.
d. Alarm messages: Loss of echo and cable circuit open or shorted.
5. Signal interface:
a. Transmitter output: 4 mA to 20 mA DC for load impedance of 0 ohms to 600 ohms. Output shall also be reversible, 4 mA to 20 mA over range selection.
b. Power supply: The unit shall operate on 120 V, 50/60 Hz power, unless otherwise shown on the Drawings.
c. Discrete outputs: The unit shall transfer SPDT contacts rated at 5 A, non-inductive, continuous, at 120 VAC.
6. Element:
a. Type: Shall be of a waterproof/weatherproof design for outdoor installation.
b. Process connection: 1 inch NPT, unless otherwise shown on the Drawings or required.
c. Shall be provided with an air temperature velocity compensation sensor.
d. Shall be chemically-resistant to the process fluid to be measured.
7. Transmitter:
a. Mounted in a NEMA 4X enclosure, unless otherwise shown on the Drawings, suitable for mounting.
b. Mounting: Wall, unless otherwise shown on the Drawings. Provide stainless bolts for outdoor applications.
8. Manufacturer and products:
a. Transducer: Vega PULS 64.
b. Transmitter: Vega DIS176.

O. Level Switch, Float Type (Narrow Angle) with Integral Non-Mercury Switch:
1. General:
a. Function: Actuate contact at preset liquid level.
b. Type: Direct-acting float with an enclosed snap-action switch and integral cable.
c. Verify the chemical resistance of wetted parts.
d. UL listed for use in water and sewage.
e. Passed NSF/ANSI 61 protocol by an approved Water Quality Association laboratory.
2. Service:
a. Liquid: Water, unless otherwise shown on the Drawings.
b. Pressure: Atmospheric.
c. Temperature: 0°C to 60°C.
3. Performance:
a. Control differential: 1 1/2 inch above or below horizontal.
b. Temperature: 0°F to 140°F (60°C).
4. Features:
a. Entire assembly: Watertight and impact-resistant.
b. Cable: Combination support and signal; length as noted or required to run continuous without splicing.
c. Materials:
1) Float, cable, and clamps: Chemical-resistant and corrosion-resistant material.
2) Cable: 18-3 AWG minimum, rated 600 V. Type SJOW-A Flexible Cord, water-resistant to 140°F.
3) Clamps: Type 316 SST, unless otherwise shown on the Drawings or required by the ENGINEER.
d. Mounting: Pipe, suspended only when shown on the Drawings.

1) Pipe: Corrosion-proof cable clamp for 1-inch pipe.
2) Suspended: Necessary brackets and clamps for tank top or vessel; integral or attached weight assembly for stabilization and positive operation.

5. Signal interface:
   a. Switch: SPDT arrangement unless otherwise shown on the Drawings.
   b. Contact: Rated 5 A minimum continuous at 120 VAC.
6. Manufacturer and product:
   a. ITT Centripro A2N Series.

P. Accumulator Level Control Switch:
1. General:
   a. Provide a large SST tag.
   b. Function: Differential level control of pressurized accumulator tank.
   c. Type: Heavy duty, industrial type.
   d. Liquid: Hydraulic oil. Specific gravity equals 0.864, unless otherwise shown on the Drawings.
2. Performance:
   a. Differential level control of hydraulic oil accumulator tank level between a maximum oil level of 74 gallons and a minimum oil level of 54 gallons, unless otherwise indicated by the ENGINEER.
   b. Tandem operation (two switch mechanisms) providing the same functions as two single units. Adjustable calibration to give individual switching actions throughout the range of the float travel.
   c. Temperature: 0°F to 100°F minimum, or as required.
   d. Pressure: 250 psi minimum, or as required.
3. Features:
   a. Complete float and trim construction Type 316 SST.
   b. Mounting: Side-mounted; coordinate mounting connection with the Accumulate Tank Manufacturer and the ENGINEER.
4. Signal interface:
   a. Switch: Two DPST, arrangement.
   b. Contact: Rated 5 A continuous at 120 VAC.
5. Manufacturer and product:
   a. Magnetrol Level Control Model TF-63.

Q. Level Control System (Surge Tanks):
1. General:
   a. Function: Provide continuous level measurement with output to control surge tank operation.
   b. Parts: Level electrodes, flanged CI electrode holder, solid state relays to interface electrodes to controls, Manufacturer recommended cables for connection from electrodes to relays.
2. Service:
   a. Medium: Water.
   b. Pressure: Atmospheric.
   c. Temperature range: Level element shall be capable of operating in range of 32ºF to 120ºF.
3. Performance:
   a. Range: As shown on the Drawings or as required.
   b. Zero reference: As shown on the Drawings or as required.
   c. Accuracy: ±0.5% of full-scale for analog output signal and alarm SPs shall be repeatable within ±1% of full-scale.
   d. Resolution: 2 mm or 0.1% of range, whichever is greater.
4. Features:
   a. Interconnecting cable: Cable between level electrodes and relays.
   b. Shall be supplied with the unit.
   c. Rod spacers every 2 feet.
5. Signal interface:
   a. Power supply: Unit shall operate on 120 V, 50/60 Hz power, unless otherwise shown on the Drawings.
   b. Relay contact outputs: DPDT load contacts, SPDT holding contacts rated at 10 A, non-inductive, continuous, at 120 VAC.
6. Element:
   a. Type: Shall be of a waterproof/weatherproof design for outdoor installation.
   b. Process connection: Flanged CI electrode holder.
   c. Shall be chemically resistant to the process fluid to be measured.
7. Manufacturer and product:
   a. Electrodes: Ametek/BW Controls 6013-GP-316-SS-P-8B with RS rod spacers.
   b. Electrode holder: 6012 flanged CI.
   c. Relays: BW Controls 5200-LF1-OC.

R. Pressure Transmitter, Electronic:
1. General:
   a. Function: Measure pressure and transmit a signal proportional to pressure or level.
   b. Type: Electronic variable capacitance, two-wire transmitter.
   c. The CONTRACTOR and the Manufacturer shall be responsible for verifying the correct product and installation for the site conditions.

d. The manifold for the pressure sensing line shall be vacuum-filled following the Manufacturer's recommendations and requirements.
e. SST sensing lines shall be provided and installed as recommended and required by the Annular Pressure Sensor Pressure Transmitter Manufacturer to provide a complete, fully functioning pressure sensing system.
f. Coordinate annular pressure sensors and pressure transmitters' interface, connection, distance of sensing lines, and requirements with the Manufacturers and other Contractors to provide a complete, fully functioning pressure sensing system.

2. Performance:
   a. Range: As shown on the Drawings.
   b. Maximum adjustable range: Such that the noted range shall lie between 40% and 80% of the maximum adjustable range.
   c. Accuracy: ±0.25% of calibrated span.
   d. Temperature: -20°F to +185°F, minimum.
3. Features:
   a. Type: Gauge pressure, unless otherwise shown on the Drawings.
   b. Damping: Fluid or electronic type with adjustment.
   c. On-site LCD display.
   d. Suppressed or elevated zero: When shown on the Drawings.
   e. Type 316 SST or ceramic diaphragm sensor; other parts Type 316 SST.
   f. Wetted O-rings: Viton, unless otherwise shown on the Drawings.
   g. Housing: Modular with separate compartments for electronics and field connections.
   h. Fill fluid: Silicone, unless otherwise shown on the Drawings.
4. Process connections:
   a. Line size: 1/2 inch or 1/4 inch, selectable.
   b. Connection type: NPT.
5. Signal interface:
   a. 4 mA to 20 mA DC output with digital signal based on HART Protocol (Code A).
   b. Output into a load impedance of 0 ohms to 500 ohms minimum without load adjustment with 24 VDC supply.
6. Enclosure:
   a. Type: NEMA 4X, unless otherwise shown on the Drawings.
   b. Mounting: Pipe or wall as shown on the Drawings. Provide brackets with Series 300 SST bolts.
   c. Manufacturer and product:
      1) Rosemount, Model 3051.

S. Pressure Gauge, Corrosion-Resistant:

1. General:
   a. Function: Pressure indication.
   b. Type:
      1) Direct reading bellows for ranges below 10 psig.
      2) Bourdon tube actuated for ranges 10 psig and above.
2. Performance:
   a. Range: As shown on the Drawings. Compound-scale when noted. Gauge maximum pressure shall be twice the normal operating pressure.
   b. Accuracy: ±0.5% of span.
3. Features:
   a. Mounting: As shown on the Drawings.
   b. Dial: 4 1/2 inch diameter.
   c. Case material: Phenolic plastic.
   d. Element material: Type 316 SST.
   e. Dampening:
      1) Pulsation dampener when shown on the Drawings, piston type with multiple choice of piston placement to vary the desired amount of dampening.
      2) Material: SST.
   f. Case type: Solid front design with a solid wall between the window and the element. Rear of case, gasketed pressure relief.
   g. Pointer: Micrometer pointer with self-locking adjustment.
   h. Movement: SST, rotary geared.
   i. Case fill liquid: Glycerin.
4. Process connection:
   a. Line size: 1/2 inch.
   b. Connection type: Threaded.
5. Manufacturers and products:
   a. Bellows type:
      1) Ashcroft; General Service Series 1180.
      2) Robert Shaw Acragage.
   b. Bourdon tube type:
      1) Ashcroft Duragauge Model 1279/1379.
      2) Robert Shaw Acragage.

3) Marsh Mastergauge.

T. PS, Adjustable Dead Band:
1. General:
   a. Function: Monitor pressure, activate switch at SP, and deactivate switch at reset point.
   b. Type: Piston actuated; SP, and dead band adjustable.
2. Performance:
   a. SP: Adjustable over the full range.
   b. Reset point: As shown on the Drawings.
   c. Dead band: Adjustable up to 60% of range.
   d. Range: Such that noted SP shall fall between 20% and 80% of the range.
   e. Provide manual reset when indicated on the instrument list.
3. Features:
   a. Materials:
      1) Pressure port: Type 316 SST.
      2) Diaphragm and wetted O-ring: Buna-N.
4. Process connections: 1/4 inch NPT.
5. Signal interface:
   a. Contact type: SPDT.
   b. Contact rating: 5 A at 125 VDC.
6. Enclosure: Die-cast aluminum NEMA 4X.
7. Manufacturer and products:
   a. Ashcroft, N Series above 2000 psi.
   b. Ashcroft, P Series below 2000 psi.

U. Pressure Differential Switch, Adjustable Dead Band:
1. General:
   a. Function: Monitor differential pressure and provide contact closure(s) when differential pressure is at the SP shown on the Drawings.
   b. Type: Piston actuated; SP, and dead band adjustable.
2. Performance:
   a. SP:
      1) Adjustable over the full range.
      2) Set as shown on the Drawings.
   b. Range: The SP shown on the Drawings shall fall between 20% and 80% of the range.
   c. Dead band: Adjustable up to 60% of range.
   d. Provide manual reset when indicated on the instrument list.
3. Features:
   a. Diaphragm materials: Buna-N.
   b. Pressure connection: Type 316 SST.
4. Enclosure: Die-cast aluminum NEMA 4X.
5. Signal interface:
   a. Contact type: SPDT, snap-action switch rated for 5 A at 125 VDC.
6. Manufacturer and products:
   a. Ashcroft, N Series above 2000 psi.
   b. Ashcroft, P Series below 2000 psi.

V. Annular Pressure Sensor:
1. Protect and isolate instrument.
2. Full 360-degree pressure readings.
3. Self-cleaning, flexing action.
4. SST class 150 flanges.
5. Sleeve: Viton or as recommended by the Manufacturer for application.
6. Fill fluid: Vegetable oil (rated for 230°F) unless otherwise approved by the ENGINEER.
7. The CONTRACTOR and the Manufacturer shall be responsible for verifying the correct product and installation for the site conditions.
8. System shall be vacuum-filled following the Manufacturer’s recommendations and requirements.
9. SST sensing lines shall be provided and installed as recommended and required by the Annular Pressure Sensor and Pressure Transmitter Manufacturer to provide a complete, fully functioning pressure sensing system.
10. Coordinate annular pressure sensors and pressure transmitters’ interface, connection, distance of sensing lines, and requirements with the Manufacturers and other Contractors to provide a complete, fully functioning pressure sensing system.
11. Manufacturer and product:
    a. Red Valve Series 40.

W. Temperature Transmitter, Electronic:
1. General:
   a. Function: Measure temperature and transmit the signal proportional to the temperature.
2. Performance:
   a. Range: As shown on the Drawings.

b. Maximum adjustable range: Such that the noted range shall lie between 40% and 80% of the maximum adjustable range.
c. Accuracy: ±0.25% of calibrated span.

3. Features:
   a. Damping: 5 seconds.
   b. On-site LCD display.
   c. Housing: Modular with separate compartments for electronics and field connections.
4. Signal interface:
   a. 4 mA to 20 mA DC output with the digital signal based on HART Protocol.
   b. Output into a load impedance of 0 ohms to 500 ohms minimum without load adjustment with 24 VDC supply.
5. Enclosure:
   a. Type: NEMA 4X.
   b. Mounting: Wall, as shown on the Drawings. Provide brackets with SST bolts.
6. Manufacturer and product:
   a. Rosemount, Model 3144.

X. Temperature/Humidity Transmitter:
1. General:
   a. Function: Measure temperature and humidity and transmit signals proportional to temperature and humidity.
   b. Type: Temperature – solid state band gap; humidity – capacitance polymer.
2. Performance:
   a. Temperature range: -40°F to 140°F, minimum.
   b. Temperature accuracy: ±0.9°F
   c. Humidity range: 0% to 100% relative humidity.
   d. Humidity accuracy: ±2%.
3. Features:
   a. NEMA 4X polycarbonate enclosure.
   b. Calibration free.
   c. Signal interface: 4 mA to 20 mA DC output.
   d. Output into a load impedance of 0 ohms minimum without load adjustment.
   e. Power supply: 24 VDC supply.
4. Manufacturer and product:
   a. Dwyer, RHP Series.

Y. Electronic Timer:
1. General:
   a. Function: Timed heating and ventilation.
   b. Type: Electronic timer with dial-selectable time setting.
2. Features:
   a. Time range: 0.1 second to 600 hours.
   b. Contact configuration: DPDT.
   c. Contact load rating: 240 VAC, 10 A.
   d. Coil voltage rating: 24 VAC.
   e. UL and CE listed.
3. Timers shall be of the same Manufacturer.
4. Manufacturer and product:
   a. IDEC, RTE-P1AF20.

Z. Switches, Current:
1. General:
   a. Function: Operate contacts at preset current signal level.
   b. Type: Electronic with electromechanical relays.
   c. When required, provide multiple current switches for the number of contacts shown on the Drawings.
2. Performance:
   a. SP: As shown on the Drawings and as required.
   b. Repeatability: ±0.1% of input span.
   c. Temperature, operating range: 32°F to 120°F.
3. Features:
   a. Dead band: Continuously adjustable 1% to 100% full input span, accessible on the front of the unit.
   b. Activation: Rising or falling; internally selectable.
   c. SP adjustment: Continuously adjustable over the full input span, accessible on the front of the unit.
   d. Input resistance: 50 ohms maximum.
   e. Dual SPs: When noted; independent, with independent output contacts.
   f. Response time: Less than 100 ms.
   g. Isolation: Input, output, and power.
4. Signal interface:
   a. Input: 4 mA to 20 mA DC.
   b. Contacts: Rated 5 A continuous at 120 VAC; DPDT for single SP, SPDT for dual SP.
5. Enclosure: NEMA 1.
6. Power: 24 VDC.

7. Manufacturer:
    a. Acromag, Model 361A.

AA. HPU System Reservoir Level Switch:
1. General:
    a. Provide large SST tag.
    b. Function: Full-size, multi-point liquid level switch.
    c. Type: Heavy duty, industrial type.
    d. Liquid: ISO 46 hydraulic oil. Specific gravity = 0.865.
2. Performance:
    a. Level control of hydraulic oil reservoir tank level.
    b. Adjustable switching heights and actions throughout the range of the float travel.
    c. Temperature: 30°F minimum, 150°F maximum.
    d. Pressure: 50 psi minimum, or as required.
3. Features:
    a. Complete float and trim construction Type 316 SST.
    b. Mounting: Side-mounted, coordinate mounting connection and length with the Tank Manufacturer and the ENGINEER.
4. Signal interface:
    a. Switch: Two DPST, arrangement.
    b. Contact: Rated 5 A continuous at 120 VAC.
5. Manufacturer:
    a. Madison, M Series.

BB. Power Transducers:
1. General:
    a. Function: Provide 4 mA to 20 mA DC analog signal proportional to AC input.
    b. Type: True RMS.
2. Performance:
    a. Range: As required and approved by the ENGINEER.
    b. Accuracy: ±0.5%.
3. Features:
    a. Standards: Exceed IEEE C37.90.1 surge withstand capability.
    b. Submit certified factory calibration.
    c. Input: CT secondary 5 A or PT secondary 120 V.
    d. Low input burden.
4. Enclosure: Rugged metal case designed for utility and industrial applications.
5. Manufacturer and product:
    a. Yokogawa, Model Type JUXTA Series 2469.

CC. 24 VDC Power Supply:
1. General:
    a. Primary switched type.
    b. Power input: 120 VAC or 125 VDC.
    c. Power output: 24 VDC.
2. Features:
    a. Voltage input range: 85 VAC to 264 VAC, 90 VDC to 350 VDC.
    b. Input configuration: Positive, negative, and ground.
    c. Power: Individual power supplies shall be rated for 10 A output. A minimum of two power supplies shall be provided. The total number of power supplies provided shall be sized for actual loads with 50% spare capacity. Residual ripple: Less than 150 mV peak to peak.
    d. Efficiency: Greater than 85%.
    e. Rated for the environmental conditions specified.
    f. Overcurrent protection: Each power supply shall be fused on the primary and secondary sides.
    g. Circuit breakers:
        1) Instruments: For each DC supply line to each individual two-wire transmitter or DC relay:
            a) Type: Thermomagnetic-fast blow: Phoenix Contact, TMC-1-F1.
        2) Power supplies: For each power supply provided:
            a) Type: Thermomagnetic-normal blow: Phoenix Contact, TMC-1-M1.
3. Power supplies shall be provided with a DC OK signal output that shall alarm on improper operation or failure.
4. Rail-mount such that dissipated heat does not adversely affect other components.
5. Power supplies shall be furnished with the equipment necessary for the proper conditioning of the input power to prevent interruption, damage, or improper operation of the power supplies.
6. Multiple power supply operation:
    a. Parallel connection: Power supplies shall be connected to operate in parallel, as recommended by the Manufacturer. To ensure even current distribution, the output voltages shall not differ by more than 5 mV.
    b. Availability: Each output power of the power supplies connected in parallel shall be connected individually to the load to be supplied to ensure the availability of the equipment if one voltage fails due to connection faults.
    c. 24 VDC power supplies shall be provided with external decoupling diode modules.
7. Power supplies shall run in balanced, parallel mode without external circuitry to provide redundancy.

8. DC current limiting in case of short-circuit; shall automatically reset when fault is corrected.
9. Enclosure:
    a. Type: NEMA 1.
    b. Mounting: Panel.
10. Manufacturer and product:
    a. Phoenix Contact, QUINT-PS-100-240AC/24DC/10 with QUINT-DIODE/40 module.

DD. Converter, 125 VDC to 110/24 VDC:
1. General:
    a. Function: Provide 110 VDC or 24 VDC power from 125/130 VDC power.
    b. Type: Heavy duty, industrial quality, solid state.
2. Features:
    a. Voltage input range: 105 VDC to 145 VDC.
    b. Input configuration: Positive, negative, and ground.
    c. Power: 3,000 W minimum, sized for actual loads at site conditions with 50% spare capacity.
    d. Output: 110 VDC and 24 VDC
    e. Efficiency: Minimum 80% at full load.
    f. Rated for Project site conditions.
    g. The unit shall include breaker/over current protection disconnecting means.
    h. Provide converter fail and alarm contacts.
    i. Submit sizing calculations.
    j. Conformal coating to protect the circuitry against the environment.
    k. Heavy ruggedizing for industrial protection.
    l. Input protection:
        1) Inrush current limiting varistor.
        2) Reverse polarity protection by series diode.
        3) Internal safety fuse.
    m. Isolation:
        1) 1,500 VDC input to chassis.
        2) 2,250 VDC input to output.
        3) 1,000 VDC output to chassis.
    n. EMI: EN55022 Class A with margins.
    o. MTBF: 150,000 hours minimum at 45˚C.
3. Enclosure:
    a. Type: NEMA 1.
    b. Mounting: 19-inch rack.
4. Manufacturer and product:

EE. Absopulse, Model BAP Series Inverter, 125 VDC to 120 VAC:
1. General:
    a. Function: Provide 120 VAC power from 125 VDC power.
    b. Type: Heavy duty, solid state.
2. Features:
    a. Voltage input range: 105 VDC to 145 VDC.
    b. Input configuration: Positive, negative, and ground.
    c. Power: 500 VA minimum, sized for actual loads with 50% spare capacity.
    d. PF: 0.9 lagging to unity.
    e. Harmonic distortion: Less than 3% at full load.
    f. Output: 120 VAC, 60 Hz.
    g. Rated for the environmental conditions specified.
    h. Overcurrent protection: I/O fusing.
    i. Provide inverter fail and alarm contacts.
    j. Submit sizing calculations.
3. Enclosure:
    a. Type: NEMA 1.
    b. Mounting: Panel, inside GCP.
4. Manufacturer and product:
    a. Philtek, Model PIV.

FF. Hand Switches, Push Buttons, and Indicating Lights:
1. General:
    a. Function: Select, initiate, and display discrete control functions.
    b. Type: Heavy duty, watertight, oiltight, industrial.
    c. Mounting: 30.5 mm single round hole. Panel thickness 1/16 inch to 1/4 inch.
    d. Legend plate: Large size square style aluminum field and black markings, unless otherwise shown on the Drawings. Minimum letter and number height: 7/64 inch. Markings as shown on the Drawings.
    e. Configuration: Light, push button, or switch as shown on the Drawings.
2. Light features:
    a. Lights: Full voltage 120 VAC high-visibility LED, push-to-test type.

b. Lens color, unless otherwise shown on the Drawings.

Tag Function	Inscription(s)	Color
POWER ON	POWER ON	Green
ON	ON	Red
OFF	OFF	Green
OPEN	OPEN	Red
CLOSED	CLOSED	Green
LOW	LOW	Amber
FAIL	FAIL	Amber
HIGH	HIGH	Amber
AUTO	AUTO	White
HAND OR MANUAL	HAND OR MANUAL	Yellow
LOCAL	LOCAL	White
REMOTE	REMOTE	Yellow

3. Push button and switch features:
   a. Guard: Full guard with flush button, unless otherwise shown on the Drawings.
   b. Push button color, unless otherwise shown on the Drawings:
      1) Off, emergency stop, stop, and reset: Red.
      2) Others: Black.
   c. Switches shall be maintained or spring-return to the center position as required.
   d. Push buttons and selector switches shall be lockable in the OFF position where shown on the Drawings.
4. Signal interface:
   a. Contact block:
      1) Type: Silver-coated butting, unless otherwise shown on the Drawings.
      2) Rating: 10 A continuous at 120 VAC.
      3) Sequence: Break-before-make, unless otherwise shown on the Drawings.
      4) Arrangement: Normally open or normally closed as indicated and to perform the functions required.
      5) Terminals: Screw with strap clamp, unless otherwise shown on the Drawings.
      6) Switches and push buttons shall have a minimum of one spare contact in addition to the required contacts.
      7) Minimum contact requirements: NEMA ICS 2, Type A600.
5. NEMA rating: NEMA 4, watertight and dusttight; NEMA 13, oiltight.
6. Manufacturers and products:
   a. Indoor and outdoor areas (NEMA Type 4/Type 13):
      1) General Electric, CR104P.
      2) Allen-Bradley, Bulletin 800T.
      3) Eaton, 10250T.
      4) Schneider Electric/Square D, Class 9001, Type K.
   b. Corrosive areas (NEMA 4X):
      1) Allen-Bradley Type 800H.
      2) Eaton/Cutler Hammer, Type E34.
      3) Schneider Electric/Square D, Class 9001, Type SK.

GG. UPS System:

1. General: An UPS shall be furnished to provide a reliable source of isolated, regulated uninterruptible power with no break in AC output power during a complete or partial interruption of incoming line power. The UPS shall provide a high degree of lightning and surge protection. The UPS shall include an intelligent interface and audiovisual alarms to keep operators continuously advised of system status. The UPS shall be UL listed.
   a. Lightning and surge protection: The UPS shall be tested using lightning standard in accordance with ANSI/IEEE C62.41.2 Category A (6,000 V spike and 200 A) and Category B (6,000 V spike and 3,000 A) test, and IEEE C62.45 test procedures. The UPS shall reduce the input spike to less than 3 V on the output for a 2,000 to 1 spike attenuation.
   b. Isolation, including output neutral to ground bonding: The UPS shall provide a true, separately derived power source as defined by NFPA 70, with output neutral bonded to ground. There shall be no direct connection between I/O and less than 2 pF of effective input to output capacitance.
   c. Regulation: The UPS output shall be regulated to within the CBEMA and ANSI C84.1 point of utilization range of 104 VAC to 127 VAC over the full dynamic range from no load to full load and low line VAC to high line VAC and low battery voltage to high battery voltage.
   d. Continuous no-break power: The UPS shall provide continuous no-break power during a power outage or momentary interruption. Standby power systems that have any measurable transfer time and interruption of the output wave form are unacceptable.
   e. Sine-wave power: The UPS shall provide computer-grade sine-wave power with 5% or less THD capability. It shall meet or exceed CSA C22.2 No. 107.1 for harmonic distortion.
   f. Switch-mode power supply rated: Capacity shall be rated in VA while loaded with typical computer-grade switch-mode power supplies having a PF of 0.7 and crest factor of 2.7 to 3.5.

g. Intelligent interactive interface: The UPS shall provide an RS232 interface or equal with full-duplex output capable of providing monitoring and a CRT display of meter functions and alarm conditions. The UPS interface will also include a remote test capability, a selectable baud rate from 50 to 38,400, and an ability to view and change system SPs. Interface capability shall be provided for monitoring and a CRT display of twenty-three meter functions including: AC volts out, AC volts in, battery voltage, AC current out, VA load, watts, PF, percent of full load, DC out, frequency, heat sink temperature, ambient temperature, transformer temperature, time, date, number of power outages, log of power outages, log of alarm conditions, projected runtime available, system hours, inverter minutes, number of overloads, and VA limit.
   1) Also included for computer interface output shall be nineteen alarm conditions: Low battery, near low battery, high battery, low runtime left, low AC out, high AC out, output overload, high ambient temperature, high heat sink temperature, user test alarm, high transformer temperature, check battery, check inverter, memory check, emergency power off, high PFM temperature, probe missing, high AC input, and call service.
   2) Remote emergency off, alarm contacts, and inverter contacts shall be connected at the RS232 port.

h. Reliability engineered: The UPS shall have a dual-track redundant configuration that utilizes either line or inverter source for power and shall be designed to meet or exceed an expected MTBF of at least 150,000 hours per proven field service.

i. Efficiency: The UPS shall have an efficiency of at least 90% when operated from the AC line.

j. Third-party listing; certifications or testing standards: UL 1778 and UL 1449. FCC subpart J of part 15 dealing with separately derived power systems. OSHA 29 CFR 1910, IEEE C62.45, and NEMA PE 1.

k. Production:
   1) Output: Ferroresonant transformer provides inherent overload protection (current limiting).
   2) Input: DC fuse provides input protection. Fuse for battery charger circuitry.
   3) Remote emergency off shall completely shut off UPS AC output to the protected load when activated from an external switch. Alarm contacts shall be relay contacts that close upon any alarm condition. Inverter contacts shall be relay contacts that close when the inverter turns on.

l. Miscellaneous Specifications: Overload capability shall be 150% surge and 125% for 10 minutes online (with nominal AC volts in), and 150% surge and 110% for 10 minutes on inverter (with nominal DC volts in) if battery runtime allows. VA ratings are at a PF of 0.7, which would be the result of a capacitive or switch-mode power supply load exhibiting a high crest factor. Overload operation shall not be thermally limited.
   1) The minimum UPS sizes shall be as follows:

Local Control Panel	Output Capacity	Runtimes Full Load / 1/2 Load
LCP-UPS	7,000 VA	12 / 33

I/O Voltage: 120 VAC single phase
Voltage Regulation: ±3% nominal regulation
Frequency (Input): 60 Hz ± to ±3 Hz
Operating Temperature: 0˚C to 40˚C
Storage Temperature: -20˚C to +60˚C (-20˚C to +40˚C, unless battery is removed)

m. Operation: The UPS shall be comprised of an inverter, a precision battery float charger, a sealed, maintenance-free battery, a full-duplex RS232 computer interface port, and contained in a single compact package.
   1) Under normal operating conditions, the critical load shall be powered by the normal AC line supply that has been filtered through a ferroresonant transformer. When AC line power is present, the inverter shall be normally off.
   2) When AC line power fails or goes out of tolerance, the inverter shall supply AC power from the battery source. There shall be no break in the output of the system during transfer from the normal AC line supply to the inverter battery supply or back to the line. A single switch shall turn the system on and off.

n. The UPS shall be rack-mount type.

o. External bypass switch: Systems shall include or have as a provided option an external bypass switch to permit operation during UPS servicing. The external bypass switch shall be make before break type. Provide phase shifting transformers and equipment necessary for make before break operation without transients.

2. Manufacturers and products:
   a. 600 VA and smaller:
      1) APC, SUA500PDR-S including the following options:
         a) Network Management card with environmental monitoring and out of band management.
         b) APC temperature sensor.
         c) 3-year extended warranty.
         d) Isolate serial extension cable
         e) Dry contact I/O Smartslot card.
         f) Communications Cable Smart Signaling.
      2) Rockwell, 1609-B, 1609-D:
         a) Model selection based on-site conditions and criticality.
         b) Network card, 1609-NMC.
         c) External battery housing, 1609-EXBAT.
   b. Larger than 500 VA:
      1) Eaton, FERRUPS Model FE series with external bypass switch model BPE.

2) Eaton, 5P1000 with Network Card.
3) Rockwell, 1609-P, 1609-D:
   a) Model selection based on site conditions and criticality.
   b) Network card, 1609-NMC.
   c) Service bypass switch, 1609-PSB1.
   d) External battery housing, 1609-EXBAT.

HH. PLC (All Facilities Except Hydroelectric):

1. ControlWave Micro unless hydroelectric facility or indicated otherwise.
2. ControlWave Micro PLC/RTU/PAC hybrid controller:
   a. 8-slot panel-mount base, PSSM, Micro 150 CPU, System Controller with keylock, and watch dog.
   b. Data memory: 1 MB SRAM battery backed memory, 4M SD, 16M flash.
   c. Communications: Two 10/100 Base T Ethernet port with RJ45 connectors and two serial communication ports, one RS 485, one RS 232.
   d. Hot swap I/O replacement.
   e. 24 VDC power.
   f. Power fail detection and recovery sequencer.
   g. Display and keypad.
   h. Power supply isolation: 500 VDC.
   i. I/O cards and additional chassis as required to meet PAC I/O count. Spare cards shall not be used to meet the requirement.
   j. AOs maintain last/preset value on CPU watch dog.
   k. DOs maintain last or zero value on CPU watch dog.
   l. I/O cards shall be wired to fused terminal blocks in lieu of the remote terminal blocks. The complete installation shall be approved by the ENGINEER .
   m. I/O modules:
      1) Discrete input:
         a) High density sixteen-point input.
         b) Dry contact: 21 VDC on-board isolated loop power supply for contacts.
         c) Optical isolation: 1,500 V field input to logic.
         d) Input voltage range: 24 VDC nominal.
         e) Input current: 5 mA nominal.
         f) 16-bit wide bus access.
         g) Status indication: LED per point status and module ok/fail LED.
         h) Surge suppression: 500 VDC MOV to chassis 31 VDC transorb between signal and isolated ground.
         i) Input filtering 30 ms time constant.
      2) Discrete output:
         a) High density sixteen-point output with LEDs.
         b) Electrical isolation: 1,500 VDC.
         c) Operating voltage range: 10 VDC to 31 VDC.
         d) 16-bit wide bus access.
         e) Status indication.
         f) Surge suppression: 500 VDC MOV to chassis 31 VDC transorb between signal and isolated ground.
         g) Configurable fail state: Off or hold last value.
         h) Output type: Solid state open source MOSFET.
         i) Power consumption: 143 mA maximum at 5 VDC (all LEDs ON).
      3) Analog input:
         a) Isolated eight-channel input.
         b) A/D resolution: 14-bit.
         c) Internally or externally sourced current input: Single-ended inputs 4 mA to 20 mA.
         d) Input filtering: 300 ms to 99.9% of input signal.
         e) Channel settling time: 680 microseconds.
         f) Conversion time: 25 microseconds.
         g) Accuracy: 0.1% of span at 25°C; 0.2% of span -20°C to 70°C.
         h) Surge suppression: 31 VDC transorb across input signal and (-) input to chassis.
         i) Status indication: Normal, over-range/under-range, module FAIL/OK.
      4) AO:
         a) Isolated four-channel input.
         b) A/D resolution: 14-bit.
         c) Internally or externally sourced current output: Single-ended inputs 4 mA to 20 mA.
         d) Electrical isolation: 500 VDC channel to bus, minimum.
         e) Channel settling time: 50 microseconds.
         f) Accuracy: 0.1% of span at 25°C; 0.2% of span -20°C to 70°C.
         g) Surge suppression: 31 VDC transorb across output signal and (-) output to common.
         h) Status indication: Normal, over-range/under-range, module FAIL/OK.
3. PLC communications:
   a. General: Hi-speed network communication system shall link RTUs, DPCs, PLCs, GUIs, and the office OPC server as required.

b. Performance:
   1) In accordance with IEEE 802.3, standard for carrier sense multiple access/collision detection.
   2) Bus or star topology.
   3) Data transfer rates of 10 Mbps.
   4) Protocol: Transmission control protocol/internet protocol.
c. PLC to device communications shall be Modbus protocol.

4. Cable (RS-485, Coax, RJ-45) interface: Cables and devices required for the interconnection between the PLC ports and the specific system-required cable shall be provided and installed including, but not limited to, cables, connectors, patch panels, power supplies, communications ports, I/O racks, cables, etc.
5. Manufacturer and products:
   a. Hardware and software:
      1) Emerson/Bristol Babcock.

II. PLC (Hydroelectric Facilities):

1. The PLC process automation controllers shall have a multi-core microprocessor that provides system timing and is responsible for scheduling I/O updates, with no user-programming required to ensure discrete or analog update. It shall execute user programs, communicate with intelligent I/O modules, and perform on-line diagnostics. The CPU shall consist of a single module which solves application logic, stores the application program, stores numerical values related to the application processes and logic, and interfaces to the I/O.
2. The GCP common PLC (GCP-PLC) shall be provided with the following, at a minimum:
   a. Cyber secure 32-bit, dual-core ARM Cortex processor with advanced secure real-time operating system.
   b. Program memory: 512 MB.
   c. Flash memory: 32 GB.
   d. MRAM for extended retained variables.
   e. Controller integrated with two 1000/100/10 Mbps secure Ethernet ports with SFP connectors supporting copper.
   f. Controller embedded secure OPC UA Server for secure uplink to SCADA/HMI software.
   g. 100/10 Mbps connection to third-party I/O and field devices via Ethernet modules, five individually configurable ports; supports Ethernet-based protocols including Ethernet/IP and Modbus TCP/IP.
   h. Serial communication via serial I/O module, five individually configurable ports – RS232/422/485.
   i. Sealed all-metal construction I/O slot panel or rack-mount chassis: Twenty pinless I/O card slots; the mounting method shall be approved by the ENGINEER.
   j. Hot swap I/O replacement.
   k. Chassis mounted power supplies to power the chassis backplane and provide power for the processor and applicable modules. Dual 24 VDC power Inputs with single auxiliary 24 VDC output up to 5 A.
   l. Open standards for programming (IEC61131-3 compliant), network configuration, and communication.
3. I/O modules:
   a. Discrete input:
      1) High density twenty-point input.
      2) Electric isolation: Per channel, 1,200 V channel-to-channel and 1,500 V channel-to-ground galvanic isolation.
      3) Input voltage range: Nominal 24 VDC, 60 VDC/42.4 VAC maximum voltage.
      4) Full duplex communications with CPU. Maximum 3 ms update rate with single CPU, maximum 10 ms with redundant CPUs.
      5) Status indication: Led per point status and module secure/ok/fail led.
      6) Debounce filtering: Soft-selectable from 0 ms to 255 ms.
      7) Sequence of events enabled with time stamp accuracy to ± 0.5 ms.
   b. Discrete output:
      1) High density twenty-point output.
      2) Electric Isolation: Per channel, 600 V channel-to-channel and 1,500 V channel-to-ground galvanic isolation.
      3) Operating voltage range: 0 VDC to 30 VDC (24 VDC nominal).
      4) Full duplex communications with CPU. Maximum 3 ms update rate with single CPU, maximum 10 ms with redundant CPUs.
      5) Status indication: LED per point status and module secure/ok/fail LED.
      6) Sequence of events enabled with time stamp accuracy to ± 0.5 ms.
      7) Configurable fail state: Off or hold last value on CPU watchdog.
      8) Output type: High-powered MOSFET capable of switching up to 1 A at 30 VDC (12 A maximum per module).
      9) Overcurrent limiting with software configurable retries per channel.
      10) Power consumption: 4 W maximum.
   c. Universal analog and digital I/O:
      1) Ten-point universal I/O module.
      2) Configurable per channel, soft-selectable (AI, AO, DI, DO, Counter/Pulse/NAMUR, HART).
      3) Integrated analog and digital readback for DO and AO configured channels.
      4) Electric isolation: Per channel, 1,200 V channel-to-channel and 1,500 V channel-to-ground galvanic isolation.
      5) Overcurrent limiting with software configurable retries per channel for digital outs.
      6) Status indication: LED per point status for DI/DO and module secure/ok/fail LED.
      7) Sequence of events enabled with time stamp accuracy to ± 0.5 ms.

8) Configurable fail state for DO and AO: Off or hold last value on CPU watchdog.
9) Analog inputs:
   a) A/D resolution: 20-bit.
   b) Types:
      (1) 4 mA to 20 mA: two-wire, internally or externally powered loop transmitters. four-wire externally powered loop transmitters. Supports HART7 digital protocol.
      (2) 0 V to 10 V.
      (3) Pulse Input: 10 kHz to 100 kHz (5 VDC, 12 VDC, 24 VDC thresholds supported).
   c) Sampling rate: Soft-selectable 8 to 120 samples per second.
   d) Accuracy: ± 0.015% of span at 23°C.
10) Analog outputs:
   a) D/A resolution: 14-bit.
   b) Output: 3.25 mA to 22 mA output, 750 ohm maximum drive impedance.
   c) Accuracy: ± 0.035% of span at 23°C.

4. PLC I/O expansion rack (GCP-PLC I/O EXP) shall be provided with the following, at a minimum:
   a. Secure remote communication module with one 1,000/100/10 Mbps secure ethernet port with SFP connectors supporting copper.
   b. Sealed all-metal construction I/O slot panel or rack-mount chassis: Five pinless I/O card slots; the mounting method shall be approved by the ENGINEER.
   c. Hot swap I/O replacement.
   d. Chassis mounted power supplies to power the chassis backplane and provide power for the processor and applicable modules. Dual 24 VDC power inputs with single auxiliary 24 VDC output up to 5 A.
   e. Configurable fail state for DO and AO: Off or hold last value on CPU watchdog.
5. Pre-manufactured UTA: UTAs shall be provided for Bedrock Automation I/O modules. UTAs shall be DIN rail-mountable and connect to the I/O module with prewired connector cables.
6. Manufacturer and products:
   a. Hardware and software:
      1) Bedrock Automation.
      2) PLC equipment shall be provided and supported by Process Control Dynamics, Inc. 6480 S. Quebec St., Centennial, CO 80111, 303-741-4264, unless otherwise approved by the ENGINEER.
   b. I/O models:
      1) Discrete input:
         a) Bedrock Automation SIO7.20, 20 channel, low voltage, secure discrete input module.
      2) Discrete output:
         a) Bedrock Automation SIO8.20, 20 channel, low voltage, secure discrete output module.
      3) Analog I/O:
         a) Bedrock Automation SIOU.10, 10 channel, universal (DI/DO/AI/AO) secure I/O module.
   c. Chassis mounted power supplies: Bedrock Automation SPM.24.
   d. Processor:
      1) GCP-PLC: Bedrock Automation SCC.
      2) GCP-PLC I/O expansion: Bedrock Automation SCS.5.
   e. Pre-manufactured UTAs:
      1) Bedrock Automation UTAs:
         a) UTA.N – Universal 20 channel, channel isolated without power distribution.
         b) UTA.P – Universal 10 channel, group isolated with power distribution.

JJ. Telephone Horn/Strobe:
1. General:
   a. Function: Visual and audible indication.
2. Performance:
   a. Strobe: 3 to 7 flashes per cycle.
   b. Sound output level: 94 dB nominal at 5 feet, volume adjustable.
3. Features:
   a. Polycarbonate white translucent lens with black lettering.
   b. Solid state circuitry.
   c. Piezo horn – warble tone output.
   d. Xenon strobe lamp.
   e. Hooks up with RJ-11 plug.
4. Enclosure:
   a. Mounting: Surface-mount.
5. Power: 120 VAC for strobe. Piezo activation via 24 VDC or 24 VAC.
6. Manufacturer and product:
   a. Viking SR-IP.

KK. Horn, Indoor/Outdoor:
1. General:
   a. Function: Audible alarm.
2. Performance:
   a. Temperature, operating: -65°F to 150°F.

b. Sound output level: 100 dB nominal at 10 feet.
3. Features:
   a. Dimensions: 4 3/8 inches in height and width, and 2.5 inches in depth, for horn and enclosure.
   b. Diaphragm: SST.
   c. Projector: On HQ alarm horn.
   d. Provide a volume control kit.
   e. Listings: UL listed, FMG, CSA approved.
4. Enclosure:
   a. Type: Cast aluminum neoprene-gasketed weatherproof housing.
   b. Mounting: Surface-mount.
5. Power: 125 VDC or 120 VAC.
6. Manufacturer and products:
   a. Federal Signal Corp. 350-120VAC-WB with panel mount gasket kit and volume control kit.
   b. Federal Signal Corp. 450-125VDC-WB with panel mount gasket kit and volume control kit.

LL. Warning Light, Indoor/Outdoor:
1. General:
   a. Function: Visual alarm.
   b. Type: Rotating reflector, strobe light, or flashing bulb.
   c. Parts: Light and spare bulbs.
2. Performance:
   a. Temperature, operating: -35°F to 190°F.
   b. Flash rate: Nominally 90 per minute.
3. Features:
   a. Dome color: Amber.
   b. Lamp life: 200 hours.
   c. Lamp: 100,000-hour LED module.
   d. Nameplate: Laminated plastic, white surface engraved to black core, 4-inch letters.
4. Enclosure:
   a. Type: Water-resistant closed-cell neoprene gasket.
   b. Mounting: Wall bracket.
   c. UL listing: Indoor/outdoor use.
5. Power: 120 VAC
6. Spare module: One for each light.
7. Manufacturers:
   a. Federal Signal.
   b. Benjamin Electric Manufacturing.

MM. Converter, Resistance-to-Current:
1. General:
   a. Function: Convert resistance signal to a current signal.
   b. Type: Solid state, back of panel.
2. Performance:
   a. Potentiometer resistance: 0 ohms to 1,000 ohms, unless otherwise indicated or required.
   b. Accuracy: ±0.03% of output span.
   c. Temperature, operating: -13°F to 149°F, minimum.
   d. Isolation: 1,000 V RMS between case, input, output, and power terminals.
   e. Noise rejection: Common mode, 120 dB at 60 Hz.
   f. Outside ripple: 10 mV peak to peak maximum when measured across a 250 ohm resistor for current output.
   g. RMI/EMI protection: 30 V/M – ABC ≤0.5% of reading when tested according to SAMA PMC 33.1 standard.
   h. Response time:
      1) Output: 800 milliseconds maximum for an output to reach full-scale response to a full-scale input change.
      2) Alarm: 700 milliseconds maximum for step change in input and alarm point at midpoint of full-scale.
3. Features:
   a. Display: Two by four character backlit, alphanumeric LCD.
   b. LEDs: Trip, input, relay.
   c. Isolation: Power supply isolation.
   d. Adjustments: Four front-panel push buttons control settings for span, zero, alarm point trip, etc.
   e. On-site programming in plain English of inputs, outputs, alarms, ranging.
4. Signal interface:
   a. Input: Three-wire potentiometer.
   b. Output: 4 mA to 20 mA DC for load impedance 0 ohms to 1,200 ohms when configured as internally powered.
5. Enclosure: Metallic case with dust cover and integral bracket for rear of panel mounting.
6. Power: 24 VDC, unless otherwise noted.
7. Manufacturer and product:
   a. Moore Industries, Model SPT/TPRG/PRG/U/[DIN].

NN. Ultrasonic Flowmeter:
1. Transit-time ultrasonic flowmeters shall be installed as shown on the Drawings and in accordance with the Manufacturer's recommendations. The flowmeters shall consist of acoustic transducers, interconnecting cable,

remote microprocessor-based electronic transmitter console, testing, startup, commissioning and accessories as required for the installation.

2. Provide flowmeter console and transducers for eight-path flowmeter.
3. The flowmeter(s) shall utilize crossed measurement planes. Each path shall consist of acoustic transducers mounted as shown on the Drawings and as recommended by the Manufacturer. The flowmeter(s) console shall measure average velocity across the diameter of the pipe. The measured velocities are numerically integrated in the flowmeter(s) to provide accurate flow measurement.
4. Flowmeter console shall contain the circuitry necessary to produce a minimum of four 4 mA to 20 mA DC signals linear with the flow rate. The flowmeter console shall be capable of measuring and totalizing forward and reverse flow. The flowmeter console shall be housed in a NEMA 4 enclosure suitable for wall mounting.
5. Outputs shall be four isolated 4 mA to 20 mA DC signal linearly proportional to flow rates. It shall have up to three relay contacts. The power requirements for the meter shall nominally be 26 W operating on 90 VAC to 250 VAC at 47 Hz to 63 Hz. The temperature range for the transmitter shall be from 35ºF to 122ºF.
6. The flowmeter console shall be equipped with a serial communication and Ethernet ports capable of interactive communication with handheld microcomputers or mainframe machines. One handheld keypad shall be provided.
7. Transducers:
   a. Transducer locations in accordance with the Drawings are estimates. The transducers shall be positioned and installed by the Manufacturer.
   b. Transducers shall be rated for a service pressure of at least 250 psi (17 bar).
   c. The mounting hardware and transducers shall have sufficient integrity to maintain accurate transducer placement withstanding normal flow pressure and shall be capable of operating over a temperature range of 32ºF to 122ºF.
   d. The acoustic transducers shall alternately transmit and receive 1 MHz acoustic energy pulses. The pulses are propagated along their assigned path through the fluid. Only multiple-path ultrasonic transit-time technique of measurement will be accepted.
8. The flowmeter shall measure, indicate, and totalize the flow to within the following parameters:
9. Flowmeter: Accuracy equal to or better than ±0.5% of actual flow above 1 fps velocity.
10. Examine installation area to ensure there is enough clearance to install and remove transducers.
11. Verify field measurements in accordance with the Contract Documents, instructed by the Manufacturer, and as approved by the Engineer.
12. Furnish and completely install the flowmeter equipment in accordance with the Contract Documents.
13. Install equipment in accordance with the Standards, Submittal Drawings, and the Manufacturer's instructions and recommendations.
14. Commission and test system for proper functioning.
15. Furnish a Manufacturer's Representative as specified in SECTION 01 44 33, for the following services at the jobsite or the classroom as designated by the OWNER, for the minimum person-days listed herein, travel time excluded:
    a. Functional and performance testing: 2.
    b. Training: 1.
    c. Installation Drawings shall be provided by the Manufacturer. Provide for an extended site visit for a factory-certified field engineer to supervise and perform the installation of the flowmeter(s).
16. Manufacturer and product:
    a. Accusonic technologies:
       1) Model 8510+10AC Flowmeter Consoles in NEMA 4X wall-mounted enclosure.
       2) Model 7601-654 feedthrough transducers with 65 degree faces, SST construction.
       3) Model 7641 SST feedthrough assemblies for 7601 transducers.
       4) Model 7600-0011-050 75 foot non-submersible cables including E-O connectors. Verify adequate lengths.
       5) Model 7642 Installation/Extraction Tool for 7601 transducers.
       6) A fully licensed software package, including complete software package, interface cables, and keys.

OO. Autodialer:

1. General:
   a. Function: Automatic dialing of up to sixteen telephone numbers. The unit shall have programmable phone numbers and messages.
2. Features:
   a. Alarms are acknowledged either by pressing a touch tone 9 as the call is being received, or by calling back the unit after having received an alarm call.
   b. The unit shall contain a gel cell rechargeable battery that is automatically kept charged when AC power is present.
   c. The unit shall be equipped with a real-time clock.
   d. Capable of both normal and alarm advisory messages.
   e. The unit shall have two different categories of speech message capability, implemented with permanent non-volatile solid state circuitry with no mechanical mechanisms.
3. Signal interface:
   a. The dialer shall use a standard dial-up telephone line and shall be F.C.C. approved.
   b. Connection to the telephone is through a 4-pin modular jack (RJ-11).
   c. Field contacts: Accepts eight normally open contacts.
4. Enclosure:
   a. Rating: NEMA 1.

5. Power: 120 VAC input.
6. Manufacturer:
   a. RACO Manufacturing Verbatim Series VSS-8C.

PP. Generator Digital Speed Control:
1. General:
   a. Provide and install a digital speed control system in accordance with the Contract Documents. The digital speed control system shall be supplied as a complete, packaged unit including sensors, electronic interface, and any appurtenances required for a complete, functioning unit.
   b. The governor shall control turbine characteristics as required by the use of a proportional – integral control system with sensors upstream and downstream of the distributing valve providing inputs to the control system that in turn provides inputs into the proportional valve. The proportional valve, in turn, pilots the wicket gate cylinder.
2. Qualifications:
   a. The Manufacturer of the digital governor shall have a minimum of 15 years of experience in projects of similar scope and size.
   b. The installation technician shall have a minimum of 5 years of experience in installing hydroelectric governor systems. A resume of past experience is required.
3. Control features:
   a. The speed control system shall supply, at a minimum, the following control functions:
      1) Turbine speed control (automatic, remote, and manual).
      2) Remote SP, 4 mA to 20 mA DC, input.
      3) ModBus communications.
      4) Speed feedback, 4 mA to 20 mA DC, output.
      5) Emergency shut down.
      6) Stop/start input.
      7) Speed/load lower and raise inputs.
      8) Wicket gate position feedback (4 mA to 20 mA DC) output.
      9) General alarm indication.
      10) Brake permissive.
      11) Automatic synchronizing.
      12) Auto follow.
      13) Generator breaker.
      14) Control enable, utility or island operation derived from generator and main transformer breaker inputs.
      15) Shutdown to speed-no-load.
      16) Speed pickup.
      17) Bus voltage/speed sensing.
   b. The governor shall be 32-bit microprocessor based digital control, field configurable, with a user-friendly format. It shall be fully programmable through the use of a personal computer and a handheld programmer.
4. Accessories:
   a. Magneto-restrictive linear displacement transmitter:
      1) The replacement governor shall include a magneto-restrictive linear displacement transmitter to provide an indication of gate/servo position. It shall provide tighter control and shall not be subject to hysteresis, large dead bands, and lost motion. It shall be mounted on the existing distributor valve assembly according to the Manufacturer’s instructions, and shall contain the following design features at a minimum:
         a) Analog output capability.
         b) Long life expectancy with a MTBF of 195 X 10^6 hours or greater.
         c) No maintenance required.
         d) No wearing components.
         e) Non-contacting sensing elements.
         f) Linearity of the output signal.
         g) Precise resolution of .006 inch/inch or better.
         h) Low hysteresis (less than .00001 inch).
         i) Sealed electronics.
         j) Shock and vibration resistant.
         k) Short-circuit protection of the output drivers.
         l) Over voltage protection to 40 V.
         m) Industry rated, meeting or exceeding IP 67 and NEMA 6.
   b. Proportional valve interface: The proportional valve shall interface electronically with the digital speed controller and electronic control system. The proportional valve shall be a closed centered, four connection valve, operating with a 24 VDC connection and 4 mA to 20 mA input signals.
   c. Bus voltage speed sensing: Active PT interface module.
   d. Speed pickup speed sensing: Zero velocity pickup.
   e. Linear variable differential transformer: Provides electronic feedback to the proportioning valve to make adjustments to the gate positioning.
5. Installation:
   a. The new governor control system shall be installed in accordance with the Manufacturer’s instructions. In accordance with the Contract Documents, the Manufacturer’s instructions, the ENGINEER, and the

CONTRACTOR shall determine locations of selector knobs, indicating lights, sensing components, valves, terminal box locations, control panels, and other related governor equipment.
b. The Manufacturer's Representative shall be at the site for a minimum of 1 day as specified in SECTION 01 44 33. The technician shall program the governor and set user inputs to the proper values and run necessary tests to prove unit functionality before unit startup, and perform any adjustments.
c. Demonstrate to the OWNER a complete functioning governor with indicated functions tested and operational before initial commissioning of the equipment.
d. Witness unit startup and provide assistance where necessary. Address and correct any problematic issues that occur during startup.

6. Manufacturer and product:
   a. The Woodward 723PLUS Digital Controller shall be located in the GCP. Provide handheld programmer.

QQ. Process Controller, Loading Station:
1. General:
   a. Function: Control process variable.
   b. Type: Microprocessor based time proportional; self-tuning.
   c. Provide controllers for devices shown as FIC on the Drawings.
2. Features:
   a. Type: Self-tune.
   b. Accuracy: ±0.2%.
   c. Memory: Nonvolatile to retain configuration and parameters during power outage.
   d. Indicators on front panel:
      1) Display: Four digit and decimal, minimum; PV and SV. Engineering units.
3. Controller features:
   a. Control action: P, PI, or PID as shown on the Drawings.
      1) Proportional: 1% to 400% proportional band.
      2) Integral: Off, and 1 second to 6,000 seconds.
      3) Derivative: Off, and 0 seconds to 6,000 seconds.
      4) Action: Switch selectable direct or reverse control.
   b. Controller output:
      1) Manual: Adjusted by increase/decrease push buttons.
      2) Auto: Internally derived from the process variable and the SP according to control action shown on the Drawings.
   c. SP Type:
      1) SP: Adjusted by front panel increase/decrease.
4. Signal interface:
   a. Interfaces common to all controller types:
      1) Controller output:
         a) Output 1: 4 mA to 20 mA DC
         b) Output 2: SPDT contacts 3 A resistive at 250 VAC.
      2) PV input: 4 mA DC to 20 mA DC.
5. Enclosure:
   a. Mounting: Panel, self-mounting.
6. Power: 120 VAC.
7. Manufacturer: Honeywell UDC2500 Controller with option card auxiliary output/digital input/Ethernet Communications.

RR. Synchronizing Lights:
1. General:
   a. Function: Manual synchronizing lights.
   b. Provide a minimum of ten spare lamps.
2. Features:
   a. For dim-bright applications.
   b. Incandescent, extra-long-life, bulb with clear lens.
   c. Mounting: Panel-mount.
3. Power: 120 VAC.
   a. Manufacturer: General Electric ET-16.

SS. Flow Switch:
1. General:
   a. Function: Monitor flow and provide contact closure when flow deviates from SP.
   b. Type: Thermal dispersion flow switch to detect the rate of flow as a function of the temperature difference between the two sensors.
2. Service:
   a. Fluid: Varies.
   b. Operating pressure: As shown on the Drawings.
   c. Operating temperature: -50°F to 350°F.
3. Performance:
   a. SP: Adjustable throughout full range. Set as shown on the Drawings.
   b. Range: As shown on the Drawings or chosen so that the noted SP is between 30% and 70% of the range.

c. Repeatability: ±0.5% of full range.
d. Temperature, operating:
   1) Sensor element: -50°F to 350°F.
   2) Electronics: -40°F to 150°F.
e. Proof pressure: 150 lbs.
f. Response time: 1 second.

4. Features:
   a. Materials of construction: Type 316 SST.
   b. Process temperature compensation: Furnish.
5. Process connections:
   a. Line size: 1/4 inch.
   b. Connection material: Type 316 SST.
6. Conduit connection: 3/4 inch RGS.
7. Element:
   a. In-line: Determined by the Supplier based upon pipe size and sensor mounting requirements.
8. Electronics:
   a. Location: Integral with element.
9. Signal interface:
   a. Contact: DPDT, rated 125 VDC, 0.5 A.
   b. Connection: Screw terminal block.
10. Enclosure:
    a. Type: Watertight O-ring seal.
    b. Material: Cast aluminum.
    c. Approval: FMG for hazardous area.
11. Power: 120 VAC.
12. Manufacturer:
    a. Magnetrol TD2-7D00-030 with TMA Spherical tip.
    b. Allen Bradley 839E-DA1BA2A#D4.

TT. RTD:
1. Provide a 100 ohm platinum, three-wire, RTD that shall be installed with leads brought out to a Pyromation, Inc. connecting head, Series 904-905.
2. The RTD shall be designed for 100 ohms at 0°C, with a temperature coefficient of 0.385 ohms per °C.
3. Verify and provide a SST RTD well to interface as required and recommended by the Manufacturer.

UU. Industrial Thermostat:
1. General:
   a. Function: Monitor hydraulic and lube oil reservoir temperature and control immersion heaters.
   b. Type: Industrial with nickel plated copper bulb and capillaries.
2. Service:
   a. Fluid: Hydraulic and lube oil.
   b. Operating pressure: As noted.
   c. Operating temperature: As noted.
3. Performance:
   a. SP: Adjustable throughout full range. Set as noted.
   b. Range: As noted or chosen to that the noted SP is between 0ºF to 100ºF.
4. Signal interface:
   a. Contact: TPST, open on rise, rated 600 VAC, 15 A.
5. Manufacturers and products:
   a. Caloritech, model AR046843.

VV. Vibration sensors:
1. Vibration detection sensors shall be suitably affixed to the structural steel base frame of the assembly at right angles to each other to measure and transmit vibration levels in the X, Y, and Z axis of operation.
2. Vibration sensors shall have adjustable alarm and trip output contacts and 4 mA to 20 mA DC output.
3. 24 VDC input power.
4. Manufacturer: Metrix 440-DR-2-Ø-4-4-2-2- Ø- Ø.

WW. Oil System Reservoir Level Switch:
1. General:
   a. Provide large SST tag.
   b. Function: Full-size, multi-point liquid level switch.
   c. Type: Heavy duty, industrial type.
   d. Liquid: ISO 68 oil.
2. Performance:
   a. Level control of oil reservoir tank level.
   b. Adjustable switching heights and actions throughout the range of the float travel.
   c. Temperature: 30°F minimum, 150°F maximum.
   d. Pressure: 100 psi minimum, or as required.
3. Features:
   a. Complete float and trim construction Type 316 SST.

b. Mounting: Side-mounted, coordinate mounting connection and length with the Tank Manufacturer and the ENGINEER.

4. Signal interface:
   a. Switch: Two SPDT, arrangement.
   b. Contact: Rated 0.5 A continuous at 120 VDC.
   c. Power rating: 100 W.
5. Manufacturer:
   a. Madison, M Series.
6. Battery System Hydrogen Gas Detector:
   a. Provide and install a complete battery system hydrogen gas monitoring system.
   b. Manufacturer: SBS-H2 with two hydrogen sensors.

XX. Temperature Transmitter (interior):

1. General:
   a. Function: Measure temperature and humidity and transmit signals proportional to temperature.
   b. Type: Temperature – solid state.
2. Performance:
   a. Temperature range: 0°F to 100°F, minimum.
   b. Temperature accuracy: ±0.5°F
3. Features:
   a. NEMA 4X polycarbonate enclosure.
   b. Calibration free.
   c. Signal Interface: 4 mA to 20 mA DC output.
   d. Output into a load impedance of 0Ω minimum without load adjustment.
   e. Power supply: 24 VDC supply.
4. NIST traceable certificate
5. Manufacturer and product:
   a. Kele model TT859PW1H2.
   b. Kele model T91 – U Series, only when approved by the ENGINEER.

YY. Temperature Transmitter (Duct and Immersion):

1. General:
   a. Function: Measure temperature and humidity and transmit signals proportional to temperature.
   b. Type: Temperature – solid state.
2. Performance:
   a. Temperature range: 0°F to 100°F, minimum.
   b. Temperature accuracy: ±0.5°F.
3. Features:
   a. NEMA 3R/4X enclosure.
   b. Calibration free.
   c. Signal Interface: 4 mA to 20 mA DC output.
   d. Output into a load impedance of 0Ω minimum without load adjustment.
   e. Power supply: 24 VDC supply.
4. NIST traceable certificate.
5. Manufacturer and product:
   a. Kele model ST-U with options S for immersion, O, XD, XN1.

ZZ. Pressure Differential Switch, Adjustable Dead Band (Dirty Filter Only):

1. General:
   a. Function: Monitor differential pressure and provide contact closure(s) when differential pressure.
2. Performance:
   a. SP: Adjustable over the full range.
   b. Range: SP approved by the Manufacturer and the ENGINEER shall fall between 20% and 80% of the range. Unless otherwise indicated: 0.05 inch to 12.0 inch WC.
   c. Dead band: Adjustable up to 60% of range.
3. Features:
   a. Diaphragm materials: Buna-N.
   b. Pressure connection: Type 316 SST 0.25-inch tubing.
4. Signal interface:
   a. Contact type: SPDT, snap-action switch rated for 0.5 A at 125 VDC, unless otherwise approved by the ENGINEER.
5. Manufacturers and products:
   a. Kele RH-3.
   b. UE Delta-Pro 24-014.

AAA. Tachometer:

1. General:
   a. Function: Dual channel instrument to convert magnetic pickup/sensors input frequency to analog output and contacts set at various values.
2. Manufacturer:
   AI-Tek TACHPAK 30.

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SUPPLEMENT B
INSTRUMENT LIST
(Note: All required instruments are not listed)

Unit Process	Tag Number	Component Code	Component Description	Design Characteristics

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SUPPLEMENT C
LOOP STATUS REPORT

Project Name:					Project No.:	
Functional Requirements:						
Component Status (Check and initial each item when complete)						
Tag Number	**Delivered**	**Tag ID Checked**	**Installation**	**Termination Wiring**	**Termination Tubing**	**Calibration**
Remarks:						
Loop Ready for Operation		By:		Date:		Loop No.:

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SUPPLEMENT D

INSTRUMENT CALIBRATION SHEET

Component	Manufacturer	Project
Code:	Name:	Number:
Name:	Model:	Name:
	Serial No.:	

Functions					
	Range	Value	Units	Computing Functions? Y / N	Control? Y / N Action? Direct / Reverse
Indicate? Y / N	Chart:			Describe:	Modes? P / I / D
Record? Y / N	Scale:				Switch? Y / N Unit Range:
Transmit/	Input:				Differential: fixed/adjustable
Convert? Y / N	Output:				Reset? automatic / manual

Analog Calibrations							Discrete Calibrations					Note.
Required			As Calibrated				Required			As Calibrated		No
Input	Indicated	Output	Increasing Input		Decreasing Input		Number	Trip Point	Reset Pt.	Trip Point	Reset Pt.	
			Indicated	Output	Indicated	Output		(note rising or falling)		(note rising or falling)		
							1.					
							2.					
							3.					
							4.					
							5.					
							6.					
Control Mode Settings:			P:	I:	D:		7.					

No.	Notes:	Component Calibrated and Ready for Startup
		By:
		Date:
		Tag No.:

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SUPPLEMENT E
PERFORMANCE ACCEPTANCE TEST SHEET

Project Name:	Project No.:
Demonstration test(s): For each functional requirement of the loop: (a) List and number the requirement. (b) Briefly describe the demonstration test. (c) Cite the results that will verify the required performance. (d) Provide space for signoff.	

Forms/Sheets Verified	By	Date	Loop Accepted By ENGINEER
Loop Status Report			By:
Instrument Calibration Sheet			Date:
I&C Valve Calibration Sheet			
Performance Acceptance Test	By	Date	
Performed			
Witnessed			Loop No.:

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SUPPLEMENT F
PLC INPUT AND OUTPUT TESTING RECORD

DENVER WATER

Project Name:
Contract Number:
Project Tracker Number:
Work Order Number:
Contractor Name:

PLC	Type, Slot, Channel	Description	Tag	Signal Zero	Signal Span or Action	Signal Units	Alarm Points or Set Points Related to this Signal	Signal Origin or Initiating Device	Related DW Drawing Number	Related Manufacturer Dwg. Number	Contractor ORT Verification at PLC (Initials & Date)	DW Inspector or Engineer Signal Verification at PLC (Initials & Date)	DW Process Control Signal Verification at PLC (Initials & Date)	DW Verification Signal displayed on SCADA Graphic, Trends or Alarm History (Initials & Dat	Variable Name (By DW Process Control)	Comments & Observations

Notes:

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SUPPLEMENT G
CONTROL LOOP DESCRIPTIONS

UNIT PROCESS AND CONTROL LOOP DESCRIPTION

Overview:

The information in this supplement is intended to provide the CONTRACTOR with a better understanding of the P&IDs process and control loops and to provide the OWNER with the necessary information for software programming. The information is not intended for construction purposes.

Terminology/Definitions:

Auto—When a piece of equipment is in the Auto mode, control is Local STAND-ALONE Control which can be used to bypass the DCS if necessary.

GUI—Graphical User Interface.

LCP—Local Control Panel, control panel centralized to a process or area.

Local—When a piece of equipment is in Local, it is controlled by a hand switch Local to the equipment or at a LCP.

MCC—Motor Control Center. Power distribution and control center.

Off—The term Off means that a piece of equipment is not running or is meant to not be running. The term Off is usually associated with a maintained switch rather than a push button.

On—The term On means that a piece of equipment is running or meant to run. The term On is usually associated with a maintained switch rather than a push button. On loss of power, a piece of equipment which is On may still have its power circuit closed such that when power is reestablished, the item of equipment will come back On.

P&ID—Process and Instrumentation Diagram. Drawings EI-# through EI-#

Stop—The term Stop means that a piece of equipment is meant to be Stopped. The term Stop is usually associated with a push button.

Start—The term Start means that a piece of equipment is meant to be Started. The term Start is usually associated with a push button. On loss of power, a piece of equipment which is Started has its power circuit opened such that when power is reestablished, the equipment will not restart.

Remote—When a piece of equipment is in Remote, it is controlled at a Motor Control Center or through the DCS.

CONTROL LOOP ####:

(Refer to P&ID Drawing No. #)

Overview Description:

Components:

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SECTION 40 67 54
PACKAGED CONTROL SYSTEM

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for the packaged control system.

B. Related Sections:

1. SECTION 01 78 23 – OPERATION AND MAINTENANCE DATA
2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
3. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES

A. American National Standards Institute/InterNational Electrical Testing Association (ANSI/NETA):

1. ATS – Standard for Standard for Acceptance Testing Specifications for Electrical Power Equipment and System

B. ASTM International (ASTM):

1. B 8 – Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft

C. Institute of Electrical and Electronics Engineers (IEEE):

1. 519 – Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
2. 802.3 – Standard for Ethernet
3. C62.41.1 – Guide on the Surge Environment in Low-Voltage (1,000 Volts and less) AC Power Circuits

D. International Society of Automation (ISA):

1. 5.1 – Instrumentation Symbols and Identification
2. 5.4 – Instrument Loop Diagrams
3. 20 – Specification Forms for Process Measurement and Control Instruments, Primary Elements, and Control Valves

E. National Electrical Manufacturer's Association (NEMA):

1. ICS 2 – Industrial Control and Systems: Controllers, Contactors, and Overload Relays Rated 600 V

F. National Fire Protection Association (NFPA):

1. 70 – National Electric Code (NEC)

G. Underwriters Laboratories, Inc. (UL):

1. 489 – Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures
2. 508 – Industrial Control Equipment
3. 508A – Industrial Control Panel
4. 508C – Power Conversion Equipment
5. 1283 – Standard for Electromagnetic Interference Filters
6. 1449 – Standard for Surge Protective Devices

1.3 DEFINITIONS

A. Calibrated Range: The range that the transmitter is configured to measure. The low end of the calibrated range shall be greater than the low range value of the transmitter. The high end of the calibrated range shall be less than or equal to the upper range value.

B. Clamp: Imposed upper and lower limits on SPs to eliminate entries outside the allowable control parameters.

C. Control Circuit: Any circuit operating at 120 VAC or VDC or less, whose principal purpose is the conveyance of information (including performing logic) and not the conveyance of energy for the operation of an electrically powered device.

D. Critical Load: Load supplied by the UPS.

E. Development Operating Software: The software provided by the PLC Manufacturer for use in programming the PLC.

F. Digital Bus: A communication network, such as Profibus, Foundation Fieldbus, or DeviceNet, allowing instruments and devices to transmit data, control functions, and diagnostic information.

G. FAT: Factory acceptance test also known as source test.

H. Hardwired Control: Control circuitry that does not utilize software to initiate functionality.

I. Hardwired Interlocks: A safety or protective feature that will interrupt operation of the equipment in all operating modes with no required operator intervention.

J. HMI: Human machine interface is a software application that presents information to an operator or user about the state of a process, and to accept and implement the operators control instructions. Typically, information is displayed in a graphical format.

K. HOA: Hand-Off-Auto control function that is totally PLC based. In the Hand mode, equipment is started or stopped, valves are opened or closed through operator direction under the control of the PLC software. In the Auto mode, equipment is started or stopped and valves are opened or closed through a control algorithm within the PLC software. In the Off mode, the equipment is prohibited from responding from the PLC control.

L. ICSC: Instrumentation and Control System Contractor: Subcontractor who specializes in the design, construction, fabrication, software development, installation, testing, and commissioning of industrial instrumentation and control systems.

M. IP: Internet protocol or ingress protection.

N. LAN: Local area network: A control or communications network that is limited to the physical boundaries of the facility.

O. LCP: Local control panel: Operator interface panel that may contain an HMI, pilot type control devices, operator interface devices, control relays, etc., and does not contain a PLC or RIO.

P. LOI: Local operator interface is an operator interface device consisting of an alphanumeric or graphic display with operator input functionality. The LOI is typically a flat panel type of display mounted on the front of an enclosure with either a touch screen or tactile button interface.

Q. LOR: Local-Off-Remote control function. In the Remote mode, equipment is started or stopped, and valves are opened or closed through the PLC based upon the selection of the HOA. In the Local mode, equipment is started or stopped, valves are opened or closed based upon hardwired control circuits completely independent of the PLC with minimum interlocks and permissive conditions. In the Off mode, the equipment is prohibited from responding to any control commands.

R. Panel: An instrument support system that may be either a flat surface, a partial enclosure, or a complete enclosure for instruments and other devices used in process control systems. Unless otherwise specified or clearly indicated by the context, the term panel in these Contract Documents is interpreted as a general term, which includes flat surfaces, enclosures, cabinets, and consoles. The term panel in this Section is interchangeable with the term enclosure.

S. PCS: Packaged control system including, but not limited to, LCPs, instrumentation, and controls that are furnished with particular equipment by the System Supplier not the ICSC. These LCPs may contain PLCs, LOI, VFD, starter, etc.

T. Power Circuit: Any circuit operating at 90 V (AC or DC) or more, whose principal purpose is the conveyance of energy for the operation of an electrically powered device.

U. Powered Transmitters: A transmitter that requires a separate power source for the transmitter to develop its signal. As used in this Section, the produced signal may either be a 4 mA to 20 mA current signal, a digital bus communications signal or both.

V. RIO: Remote I/O device for the PLC consisting of RIO racks, or RIO blocks.

W. SCADA: A general name for the computerized system that gathers and processes data from equipment and sensors and applies operational controls to the process equipment. It includes the PLCs and/or LOIs, HMIs, LCPs, PCSs, and data management systems accessible to staff.

X. Signal Circuit: Any circuit operating at less than 50 VAC or VDC, which conveys analog information or digital communications information.

Y. Slew Rate: Rate of change in respect to time.

Z. Software Interlocks: A safety or protective feature that will interrupt operation of the equipment when the PLC has control.

AA. Two-Wire Transmitter (loop powered): A transmitter that derives its operating power supply from the signal transmission circuit and requires no separate power supply connections.

1.4 COORDINATION

A. The Work of this Section includes design, fabrication and assembly of vendor provided instrumentation enclosures, control panels, and components provided under this Contract. Also included with this Work are design, construction, and commissioning support services and training. Performance of equipment is warranted as specified in this Section. PCSs shall include controls necessary for manual and fully automatic operation in accordance with the Contract Documents and as recommended by the Equipment Manufacturer to provide a complete operational system. Provide control functions of an incidental nature, which may be necessary for proper system operation and performance.

B. Coordination:

1. The OWNER's programmer shall take the lead in coordinating the software requirements for seamless communications between the vendor control system and the plant HMI and control system. The System Supplier shall be responsible to provide standard programming data exchange and copies of PLC/HMI programming language and match OWNER standards for HMI color. Provide copies of PLC and LOI programs and configurations in native format for disaster recovery purposes.
2. The System Supplier shall program the PCS PLCs to aggregate the data into contiguous registers for efficient transfer to the plant control system.
3. Minimum data transfer shall be as specified in the control strategies. The System Supplier shall supplement the I/O requirements with SPs and virtual I/O required to implement the control strategies as specified in this Section.
4. Unless otherwise stated, the packaged control system shall provide data to the plant control system with data in engineering units.

C. Panel designs shall include motor starters, power supplies, and distribution components required to derive the necessary power and control components and voltages.

D. Provide PLC hardware as specified in this Section.

E. Provide LOI hardware as specified in this Section.

F. Provide network equipment as specified in this Section.

G. Enclosure Dimensions: It is the responsibility of the System Supplier to design and size the enclosures.

1. Size enclosures to provide space for the equipment, wiring, terminations, and other items in the panel.

H. Structural Design:

1. Completed and installed panel Work shall safely withstand seismic requirements at the Project site.

1.5 PRE-INSTALLATION MEETINGS

A. As specified in SECTION 26 05 00 and SECTION 40 50 00.

1.6 SEQUENCING AND SCHEDULING

A. As specified in SECTION 40 50 00.

B. The System Supplier shall schedule a coordination meeting with the OWNER, the ICSC, the Programmer, and the ENGINEER.

1. The meeting shall take place before installation of control systems equipment.
2. Meeting discussion points shall include the following at a minimum:
   a. Tag naming conventions.
   b. PLC-to-PLC global data mapping.
   c. PLCs to HMI tags mapping.
   d. LOI screen colors and navigation.
   e. Interlock and permissive definitions.

f. Communication methods.
g. Standard code blocks for common control functionality.
h. Alarms: Clearing, formats, colors, and status.

3. The System Supplier shall bring sample LOI graphic screens, including pop-up, trends, and alarm screens. Sample LOI graphic screens shall be reviewed and discussed.

1.7 SUBMITTALS

A. General: As specified in SECTION 26 05 00 and SECTION 40 50 00.

B. Action Submittals:

1. Product data overview:
    a. General:
        1) Submitted for non-custom manufactured material in accordance with the Contract Documents and as shown on the Shop Drawings.
        2) Furnish sufficient information to evaluate the suitability of the proposed material or equipment for the intended use, and for accordance with the Contract Documents.
        3) Include:
            a) Catalog cuts.
            b) Bulletins.
            c) Brochures.
            d) Quality photocopies of applicable pages from these documents.
            e) Identify on the data sheets the Project name, applicable Specification Section, and paragraph.
            f) Identify model number and options for the actual equipment being furnished.
        4) Legibly cross out options that do not apply or equipment not intended to be supplied.
        5) Use equipment and instrument tags as depicted on the P&IDs for Submittals.
    b. Detailed sequence of operation for equipment or systems.
    c. Material and equipment schedules: Furnish a complete schedule and/or matrix of the materials, equipment, apparatus, and instruments that are proposed.
        1) Include sizes, names of the Manufacturer's, catalog numbers, and such other information required to identify the items.
    d. Itemized instrument summary:
        1) Submit a hardcopy of the instrument summary.
        2) List the key attributes of each instrument including:
            a) Tag number.
            b) Manufacturer.
            c) Model number.
            d) Service.
            e) Area location.
            f) Calibrated range.
            g) Loop drawing number.
            h) Associated PCS.
    e. Instrument data sheets:
        1) Furnish fully completed data sheets, both electronically in Microsoft Word or Excel and in hardcopy, for each instrument and component in accordance with ISA 20. Include the following information on the data sheet:
            a) Component functional description as specified in this Section.
            b) Manufacturer's model number or other product designation.
            c) Tag numbers (shall be provided at a later date).
            d) System or loop of which the component is a part.
            e) Location or assembly at which the component is to be installed.
            f) I/O characteristics.
            g) Scale range with units and multiplier.
            h) Requirements for electric supply.
            i) Requirements for air supply.
            j) Power consumption.
            k) Response timing.
            l) Materials of construction and of component parts that are in contact with, or otherwise exposed to, process media, and/or corrosive ambient air.
            m) Special requirements or features, such as specifications for ambient operating conditions.
            n) Features and options that are furnished.
            o) Accessories such as diaphragm seals, valve manifold, snubbers, and pulsation dampeners.
        2) Provide a technical brochure or bulletin (cut sheet) for each instrument on the Project. Submit with the corresponding data sheets:
            a) Where the same make and model of instrument is used in two or more applications on the Project, and the process applications are nearly identical, and the materials, features, and options are identical submit one brochure or bulletin for the set of identical instruments.
            b) Include a list of tag numbers for which it applies with each brochure or bulletin.
            c) Furnish technical product brochures that are complete enough to verify accordance with the Contract Documents, and to reflect only those features supplied with the device.

d) Cross out models, features, options, or accessories that are not being provided.
e) Clearly mark and identify special options and features.
3) Organization: Index the data sheets and brochures in the Submittal by systems or loops.
4) Accessories such as diaphragm seals, valve manifold, snubbers, and pulsation dampeners.
a) Manufacturer’s installation instructions.
b) Seal type.
c) Body materials.
d) Diaphragm material.
e) Fill fluid type.
f) Seal size.
g) Options.
h) Process connection.
5) Provide complete documentation covering the traceability of calibration instruments.
f. PLC:
1) Product data:
a) CPU:
(1) Processor type.
(2) Processor speed.
(3) Memory.
(4) Internal processor battery backup time.
b) I/O modules:
(1) Type.
(2) Standard wiring diagram.
2) PLC calculations:
a) Submit calculations or documented estimate to verify that memory requirements of this Section are met, including spare requirements. If possible, use the PLC Manufacturer's calculation or estimating worksheet.
b) Submit calculations to verify that spare I/O requirements of this Section are met.
c) Submit calculations to verify that PLC power supply requirements of this Section are met.
3) Software product data:
a) Programming languages.
b) Operating system requirements.
4) Control logic:
a) Fully annotated copy of programmed PLC logic.
b) Cross-referenced index of PLC registers or points.
5) Provide application software for the specific Project process requirements.
a) Fully annotated copy of programmed PLC logic in its native format.
b) Cross-referenced index of PLC registers or points.
g. LOI:
1) Product data:
a) Complete the Manufacturer’s brochures for each item of equipment.
b) Complete the Manufacturer’s brochures that identify LOI software and options.
(1) Mark to clearly show options and components to be provided, and cross out any options or components that will not be provided.
c) Manufacturer’s operation and installation instructions.
d) Copy of programmed LOI screens and configuration in native format.
e) Additional requirements:
(1) Screen design and layout.
(2) Display type and size.
(3) Operator input.
(4) Processor type and speed.
(5) Memory size.
(6) Programming protocols.
(7) Communication protocols.
(8) Power requirements.
(9) Operating temperature and humidity ranges: NEMA ratings.
h. Network equipment:
1) Product data:
a) Include information on the network equipment.
b) Manufacturer’s operation and installation instructions.
2. Shop Drawings:
a. System block diagram showing relationship and connections between devices. Include the Manufacturer and model information, and address settings.

b. Shop Drawings overview:
   1) General:
      a) Show interfaces between any of the following: instruments, Supplier control panels, MCCs, motor starters, variable speed drives, control valves, flowmeters, chemical feeders, and other equipment related to the control Work provided.
      b) Furnish sufficient information to evaluate the suitability of the proposed material or equipment for the intended use, and as specified in this Section.
   2) Shop Drawing requirements:
      a) Front, side, and, rear elevations, and top and bottom views, showing dimensions.
      b) Locations of conduit entrances and access plates.
      c) Component layout and identification.
      d) Schematic and wiring diagrams with wire numbers and terminal identification.
      e) Connection diagrams, terminal diagrams, internal wiring diagrams, conductor size, etc.
      f) Anchoring method and leveling criteria including the Manufacturer's recommendations for the seismic conditions.
      g) Weight.
      h) Finish.
      i) Nameplates with legends.
      j) Temperature limitations, as applicable.
      k) Complete and detailed Bill of Materials identified by each cabinet. Include with each Bill of Materials item the following:
         (1) Quantity.
         (2) Description.
         (3) Manufacturer.
         (4) Full part numbers with supplied options specified.
   3) Use equipment and instrument tags as depicted on the P&IDs for Submittals.
   4) Wire numbers shall appear on equipment drawings.
   5) Organize the Shop Drawings Submittals for inclusion in the O&M manuals:
      a) Furnish the initial Shop Drawings Submittal for preparation in the O&M manuals in accordance with the Contract Documents.
      b) Include the letterhead and/or title block of the firm responsible for the preparation of the Shop Drawings. Include the following information in the title block, as a minimum:
         (1) The firm's registered business name.
         (2) The firm's physical address, email address, and phone number.
         (3) OWNER's name.
         (4) Project name and location.
         (5) Drawing name.
         (6) Revision level.
         (7) The personnel responsible for the content of the drawing.
         (8) Date.
         (9) The Work includes modifications to existing circuits:
            (a) Clearly show modifications to existing circuits.
            (b) Show existing unmodified wiring to clearly depict the functionality and electrical characteristics of the complete modified circuits.

c. Loop drawings:
   1) Submit loop drawings for every analog and discrete signal and control circuit:
      a) Provide a loop drawings Submittal that completely defines and documents the contents of each monitoring, alarming, interlock, and control loop for System Supplier provided equipment.
   2) Show every instrument and I/O point on at least one loop diagram.
   3) Provide a complete index in the front of each bound volume:
      a) Index the loop drawings by systems or process areas.
   4) Provide Drawings showing definitive diagrams for every instrumentation loop system:
      a) Show and identify each component of each loop or system using requirements and symbols from ISA 5.1.
      b) Furnish a separate drawing sheet for each system or loop diagram.
   5) In addition to the ISA 5.4 requirements, show the following details:
      a) Functional name of each loop.
      b) Reference name, drawing, and loop diagram numbers for any signal continuing off the loop diagram sheet.
      c) Show terminal numbers, regardless of the entity providing the equipment.
      d) MCC panel, circuit, and breaker numbers for the power feeds to the loops and instrumentation.
      e) Designation of and, if appropriate, terminal assignments associated with, every manhole, pull-box, junction box, conduit, and panel through which the loop circuits pass.
      f) If a circuit is continued on another drawing, show the name and number of the continuation drawing on the loop drawing. Provide complete references to the continuation drawings.

d. Control panel drawings:
   1) Layout drawings:
      a) Scaled, detailed exterior panel (front and side views) and interior panel layout showing equipment arrangement and dimensional information.
      b) As a minimum, include the following information:
         (1) To scale front, side, and plan views.
         (2) Dimensions.
         (3) Interior and exterior arrangements.
         (4) Mounting information, including conduit entrance location.
         (5) Finish data.
         (6) Tag number and functional name of items mounted in and on each panel, console, and cabinet.
         (7) Nameplate legend including text, letter size, and colors.
   2) Wiring and piping diagrams:
      a) Submit panel wiring and piping diagrams for every panel that contains wiring and/or piping.
      b) Include the following information:
         (1) Name of panel.
         (2) Wiring and piping sizes and types.
         (3) Terminal strip numbers.
         (4) Wire tags and labels.
         (5) Functional name and the Manufacturer's designation for items to which wiring and piping are connected.
   3) Schematic diagrams:
      a) Submit schematic diagrams for electrical equipment in ladder diagram format.
      b) Include device and field connection terminal numbers on schematic diagrams.
      c) Incorporate the Equipment Manufacturer’s Shop Drawing information into the schematic diagrams to document the entire control system.
   4) Calculations:
      a) Provide installation details based on calculated shear and tension forces:
         (1) Calculations shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado, where the cabinets and panels will be installed.
      b) For assembled enclosures and other equipment with a weight of 200 lbs or more, provide calculations for:
         (1) Weight including panel internal components.
         (2) Seismic forces and overturning moments.
         (3) Shear and tension forces in connections.
      c) Cooling calculations shall include, but not be limited to:
         (1) Highest expected ambient temperature for the enclosure's location.
         (2) Internal heat load.
         (3) Exposure to direct sunlight.
         (4) Dimensions of the enclosure in inches.
         (5) Maximum desired temperature inside the enclosure, based on the lowest operating temperature limit of the installed components.
   5) LOI drawings:
      a) Furnish the following:
         (1) System block diagram showing relationship and connections between devices. Include the Manufacturer and model information, and address settings.
         (2) Mounting drawings with dimensions and elevations for each equipment location, including identification of the components, preparation and finish data, and nameplates.
         (3) Electrical connection diagrams.
         (4) Complete grounding requirements.
      b) Graphic screens:
         (1) Color printouts of each graphic screen and control pop-ups at approximately 50% development and 75% development, as required, for approval on general items such as layouts and colors.
         (2) Color printouts of each graphic screen and control pop-ups when development has been completed.
   6) Seismic panel construction:
      a) Seismic anchorage: Provide seismic design calculations and installation details for anchorage of panels, enclosures, consoles, etc., in accordance with the seismic requirements:
         (1) Anchor bolt embedment depth for free standing floor-mounted units shall be based on the thickness of the structure floor slab only and shall not include any portion of the raised concrete pad beneath the equipment structures.
         (2) Prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.
      b) For floor-mounted free standing panels weighing 200 lbs or more (assembled, including contents), submit calculations, data sheets, and other information to substantiate that panel, base, and framing are in accordance with minimum design strength requirements and seismic requirements at the Project site. Calculations shall be prepared, stamped, and signed by a Professional Engineer registered in the State of Colorado.

C. O&M Special Requirements:
  1. O&M data requirements as specified in SECTION 26 05 00 and SECTION 40 50 00. Specific requirements in addition to these Sections shall be as follows:
    a. O&M manuals:
      1) Incorporate changes that occur during process startup and submit as part of the final manuals.
      2) Provide comprehensive information on the systems and components to enable operation, service, maintenance, and repair.
      3) Include Record Documents and the accepted Shop Drawing Submittals, modified for conditions encountered in the field during the Work.
      4) Include signed results from the functional testing and process operational period.
      5) Provide installation, connection, operating, calibration, set points (e.g., pressure, pump control, time delays, etc.), adjustment, test, troubleshooting, maintenance, and overhaul instructions in complete detail.
      6) Provide exploded or other detailed views of instruments, assemblies, and accessory components together with complete parts lists and ordering instructions.
      7) Spare parts list:
        a) Include a priced list of recommended spare parts for the equipment furnished under this Contract with recommended quantities sufficient to maintain the furnished system for a period of 5 years.
        b) Annotate the list to specify which items, if any, and quantity are furnished as part of this Contract.
      8) Provide the name, address, and phone number of the Manufacturer and the Manufacturer's local service representative of these parts.
      9) Additional O&M manual requirements:
        a) Operational manual: Prepare and provide a simplified version of the standard Manufacturer's LOI software and system operations manual that includes basic instructions in the application of the system as required for operators in day-to-day operations.
        b) Control system software record documents:
          (1) Include complete documentation of the software programs provided, including:
            (a) Listings of the application software via the DW approved dropbox.
            (b) Database, via the DW approved dropbox.
            (c) Communication protocols.
            (d) Documentation necessary to maintain, troubleshoot, modify, or update the software system.
        c) Organize the O&M manuals for each process as specified in SECTION 01 78 23.
    b. Furnish parts, materials, fluids, etc. necessary for operation, maintenance, and calibration purposes throughout the warranty period. Deliver these supplies before Project Substantial Completion.
D. Spare Parts Requirements: As specified in SECTION 26 05 00 and SECTION 40 50 00.

1.8 QUALITY ASSURANCE
A. As specified in SECTION 26 05 00 and SECTION 40 50 00.
B. FDT:
  1. Preliminary FDT as specified in SECTION 40 50 00.
  2. Full FDT:
    a. As specified in SECTION 40 50 00.
    b. Perform tests to show that the integrated system hardware and software is fully operational and in accordance with the Contract Documents.
    c. Perform additional factory tests in accordance with the Contract Documents.
    d. The FDT will be witnessed.
    e. The OWNER retains the right to observe the factory test activities including any subsystem preparation, pretests, troubleshooting, retests, warm-up, and software modification and/or update.
    f. The OWNER reserves the right to test any specified function, whether or not explicitly stated in the test Submittal.
    g. Correction of deficiencies: Any deficiencies observed during the test shall be corrected and retested before completion of the test.
    h. Any changes and/or corrections shall be noted on the test forms. The ENGINEER will witness the revisions and/or corrections prior to leaving the test site.
    i. If the corrections and/or revisions are too extensive to be made while the ENGINEER is scheduled to be at the FDT test site, the FDT shall be, at the ENGINEER's sole discretion, considered failed, and the test shall be restarted at a later date. The System Supplier shall be responsible for the costs for the retest.
  3. Panel inspections:
    a. The ENGINEER will inspect each control panel for completeness, workmanship, fit and finish, and to confirm accordance with the Contract Documents and the accepted Shop Drawings.
    b. Provide panel inspection forms as part of the FDT procedures Submittal.
    c. Inspection shall include, as a minimum: Layout, mounting, wire and data cable routing, wire tags, power supply, components and wiring, I/O components layout (including terminals, wiring and relays), device layout on doors and front panels, and proper ventilation operation.
  4. Testing simulation:
    a. The FDT shall make use of hardware simulators that contain switches, pilot lights, variable analog signal generators, and analog signal level displays, which shall be connected to the I/O points within the LOI system. I/O shall be simulated and proper control and system operation shall be validated.

b. The use of jumper wires, terminal block mounted pilot lights, and loose meters shall act as or supply the functionality of a simulator shall not be allowed.
c. The hardware simulator may consist of a PLC, operating under a LOI software package, or other approved software that has its I/O points wired to PLC's I/O points. Software operating on a PC may then act as the switches, pilot lights, variable analog signal generators, and analog signal level displays.

5. I/O test:
   a. Verify that I/O is properly wired to field terminals and is properly mapped into the PLC and the LOI.
   b. Test methodology:
      1) Use the submitted and approved system simulator for this test.
      2) Discrete inputs: Apply appropriate input from the simulator at the panel terminal, observe the input card indicator, the data value at each specified data address, and the data received on the LOI displays.
      3) Discrete outputs: Issue commands from the LOI, verify the output card indicator light, and measure response on the simulator. Repeat for each operator interface screen.
      4) Analog inputs: Apply the appropriate analog input signal at panel terminals on the simulator, observe data value at each specified data address, and observe data properly received at each operator screen. Check each point at 0%, 50%, and 100% of scale.
      5) Analog outputs: Enter scaled values in the output buffer file, observe the output data file value, and measure appropriate response on the simulator.
   c. Test forms shall include, but not be limited to:
      1) PLC and panel number.
      2) I/O type.
      3) I/O tag name.
      4) Panel terminal block numbers.
      5) Rack/slot/number of I/O point.
      6) Check-off for correct response for each I/O point.
      7) Space for comments.
      8) Initials of individual performing test.
      9) Date test was performed.
      10) Witness signature lines.
6. System configuration test:
   a. Demonstrate and test the setup and configuration of the LOI.
   b. Demonstrate utility software and functions, such as virus protection, backup, optical drive burning, network monitoring, etc.
   c. Demonstrate the proper operation of peripheral hardware.
   d. Demonstrate general LOI functions.
   e. Demonstrate proper operation of log-on and other access security functions.
   f. Demonstrate the proper operation of historical data storage, trend, display, backup, and report functions.
   g. Test automatic fail over of redundant equipment.
   h. Demonstrate the proper operation of the alarm display and acknowledgement functions.
   i. Test forms:
      1) For each test, list the Specification page and paragraph of the function demonstrated, and provide a description of the function.
      2) List the specific tests and steps to be conducted.
      3) For each function, list the different sub-functions or ways the function can be used, and provide a test check-off for each including signature and date lines.
7. Control logic test:
   a. Testing requirements:
      1) Demonstrate each function as specified in the Control Strategies. Demonstrate in detail how each function operates under a variety of operating scenarios. Test to verify the application of each general control strategy function to each specific control strategy or loop description.
      2) Demonstrate the proper operation of the programming and configuration for each control strategy or loop description. Test each strategy or loop description on a sentence-by-sentence and function by function basis. Loops with similar or identical logic shall each be tested individually.
      3) Demonstrate the proper operation of digital communication links and networks. Verify each digital communication I/O point.
      4) Failure testing: In addition to demonstrating correct operation of the specified features, special effort shall be made to demonstrate how the system responds to and recovers from abnormal conditions including, but not limited to, equipment failure, operator error, communications subsystem error, communications failures, simulated/forced software lockups, power failure, process equipment failure, and high system loading conditions.
   b. Test forms:
      1) Include the fully revised and approved control strategy for the loop being tested.
      2) Identify the cause and effect as each I/O point is toggled through the simulator. Check boxes shall be provided to track proper and/or improper operation of the loop.
      3) Any deficiencies or operational changes shall be noted on the forms for correction and documentation including signature and date lines.

C. Miscellaneous:
1. Furnish the equipment listed by and bearing the label of the UL or of an independent testing laboratory acceptable to the ENGINEER and the authority having jurisdiction.
2. Assemble panels, enclosures, and rack systems along with the internal and external devices, wiring, equipment, and materials in a facility that is recognized by UL to assemble and certify UL-labeled control panels:
a. Provide components and equipment with UL 508 listing.
b. Control panels shall be UL 508A labeled, unless the equipment in the panel and the design in the Contract Documents cannot be reasonably modified in accordance with UL 508A labeling.
c. Provide fuses for the equipment that is not UL or UR listed.
3. Provide LOI and PLC hardware manufactured at facilities certified in accordance with ISO 9001.
4. Additional LOI requirements:
a. Examine the complete set of Contract Documents and verify that the LOI equipment is compatible with the installed conditions.
b. Notify the ENGINEER if any installation condition is not in accordance with the Manufacturer's recommendations or specifications.
c. System compatibility:
1) The software shall be the standard operating software system designed specifically for use with the LOI hardware.
2) The software shall be furnished and developed by the Manufacturer of the LOI hardware.
5. Additional PLC requirements:
a. Provide PLC system components by a single Manufacturer:
1) Third-party communication modules may be used only for communication or network media functions not provided by the PLC Manufacturer.
b. Use PLC Manufacturer approved hardware, such as cable, mounting hardware, connectors, enclosures, racks, communication cable, splitters, terminators, and taps.
c. PLC hardware, CPUs, I/O devices, and communication devices shall be new, free from defects, and produced by Manufacturers regularly engaged in the manufacture of these products.
6. Structural design: The completed and installed Supplier control panel Work shall safely withstand seismic requirements at the Project site and internal equipment shall be braced to prevent damage from specified forces.
7. Additional instrument requirements:
a. Examine the complete set of Contract Documents and verify that the instruments are compatible with the installed conditions including:
1) Process conditions: Fluids, pressures, temperatures, flows, materials etc.
2) Physical conditions:
a) Installation and mounting requirements.
b) Location within the process.
c) Accessories: Verify that required accessories are provided and are compatible with the process conditions and physical installation.
b. Notify the ENGINEER if any installation condition is not in accordance with the Instrument Manufacturer's recommendations or specifications.
c. Provide instruments manufactured at facilities certified to the quality in accordance with ISO 9001.
8. Additional motor starter requirements:
a. Regulatory requirements:
1) Starters and components shall be UL listed and labeled in accordance with UL 508, UL 508A, and NEMA ICS 2.
2) Combination starters shall be UL listed and labeled.

D. Training requirements for Manufacturer's training on the equipment shall be as specified in SECTION 26 05 00 and SECTION 40 50 00.

1.9 DELIVERY, STORAGE, AND HANDLING

A. As specified in SECTION 26 05 00 and SECTION 40 50 00.

1.10 SITE CONDITIONS

A. Site conditions and general requirements shall be as specified in SECTION 26 05 00 and SECTION 40 50 00. Specific requirements in addition to these Sections shall be as follows:
1. Provide equipment, instruments, LOI, and construction techniques suitable for the installed site conditions including, but not limited to, material compatibility, site altitude, site seismic conditions, humidity, and process and ambient temperatures.
2. Temperature and humidity:
a. Provide equipment and instrumentation fully rated for continuous operation at this altitude, temperature, and humidity conditions with no additional derating factors applied.
b. Provide additional temperature conditioning equipment to maintain the equipment and instrumentation in non-conditioned spaces subject to these ambient temperatures 10ºF above the minimum operating temperature and 10ºF below maximum operating temperature as determined by the Equipment Manufacturer's guidelines. Provide power wiring for these devices (e.g., heaters, fans, etc.).
3. Furnish enclosures that match the area classifications.

1.11 WARRANTY

A. As specified in SECTION 26 05 00 and SECTION 40 50 00.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Provide instruments and other components performing similar functions of the same type, model, or class, and from one Manufacturer.

B. Panels/Enclosures:
   1. NVent Hoffman

C. Hasps:
   1. Abus 110-95

D. Overcurrent Protection:
   1. Molded case circuit breakers:
      a. ABB / General Electric
      b. Eaton / Cutler Hammer
      c. Schneider Electric / Square D
   2. Fuses for 4 mA to 20 mA signals:
      a. Bussmann
      b. Ferraz Shawmut
      c. Littelfuse
   3. Fuse holders:
      a. Allen-Bradley, 1492-FB Series B
      b. Phoenix Contact, UT4-HESI Series
   4. Control circuit breakers:
      a. ABB
      b. Allen-Bradley
      c. Phoenix Contact
      d. Schneider Electric / Square D
   5. Electronic circuit protectors:
      a. Puls PISA11 series
      b. Rockwell Automation 1692-TD014

E. Thermal Management:
   1. Air conditioner:
      a. ICEcube, Blade series or IECEx/ATEX for Zones 1 and 2
      b. Kooltronic, Guardian X DP Series
   2. Heat exchanger:
      a. ICEcube, Blade series
      b. Noren, CC Series
   3. Enclosure temperature switch:
      a. Single contact:
         1) NVent Hoffman ATEMNC
         2) Pfannenberg FLZ
      b. Dual contact:
         1) NVent Hoffman ADLTEMP
   4. Aluminum air filters:
      a. NVent Hoffman Series A-FLT

F. Digital Process Indicators:
   1. Precision Digital Meters, PD765

G. Pilot Devices:
   1. Indoor and outdoor areas (NEMA Type 4/13):
      a. Allen-Bradley, Type 800T
      b. General Electric, Type CR104P
      c. Schneider Electric/Square D, Class 9001, Type K
   2. Corrosive areas (NEMA 4X):
      a. Allen-Bradley Type 800H
      b. Eaton/Cutler Hammer, Type E34
      c. Schneider Electric/Square D, Class 9001, Type SK

H. Signal Isolators and Converters:
   1. Acromag, 1500, 600T, 800T, Flat Pack, or ACR Series
   2. Action Instruments, Q500 Series or Ultra SlimPakII
   3. AGM Electronics, Model TA-4000
   4. Moore Industries, MIT 4-Channel
   5. Phoenix Contact, Mini Analog Pro

I. Relays:
   1. General purpose:
      a. Allen-Bradley: Type 700 HC
      b. IDEC: R* Series (* = H, J, R, S, U)
      c. Potter and Brumfield: Type KRP or KUP
      d. Square D, Type K

2. Terminal block relays:
   a. Allen-Bradley, Type 700 HL TBR Series
   b. Eaton, XR TBR Series
   c. IDEC, RV8H Series
   d. Phoenix Contact, PLC Series
3. Latching:
   a. IDEC, RR2KP Series
   b. Square D, 8501, Type K
4. Time delay:
   a. Allen-Bradley, Type 700-HR
   b. IDEC, RTE Series
   c. Tyco Electronics (formerly Agastat), Series 7000 (pneumatic)

J. Terminal Blocks:
   1. Allen-Bradley, 1492 Series
   2. Phoenix Contact, UT4 Series

K. Wire Duct:
   1. Panduit
   2. Phoenix Contact
   3. Thomas & Betts

L. SPDs:
   1. 120 V control power for panels:
      a. Panels without an integral UPS:
         1) Phoenix Contact, Type SFP Filter
         2) Schneider Electric, ASCO, Model 277 SPD
      b. Panels with an integral UPS:
         1) MTL Surge Technologies, MA15 Series
         2) Phoenix Contact, Plugtrab SEC Series
   2. Instrument, data, and signal line protectors – panel mounted:
      a. Phoenix Contact, Plugtrab Series.
   3. Instrument, data, and signal line protectors – field mounted:
      a. Phoenix Contact, Surgetrab Series

M. Horns and Beacons:
   1. Beacons/horn combination units:
      a. Edwards, Multi-Status LED 108i with tone module
   2. Dedicated beacon unit:
      a. Edwards, 102 Series
      b. Federal Signal Corp., Starfire Series
   3. Dedicated horn unit:
      a. Electromechanical:
         1) Edwards, 878EX or 879EX Series
         2) Federal Signal, 350 or 31X Series
      b. Electronic:
         1) Edwards, 5530M or 5533MD Series
         2) Federal Signal, 300GCX or 300X Series

N. 24 VDC Power Supplies:
   1. Phoenix Contact, QUINT-PS-100-240AC/24DC/10 with QUINT-DIODE/40 module

O. Limit Switches:
   1. Allen-Bradley, 802 Series
   2. Eaton, E47, E49, E50
   3. Honeywell, HDLS Series

P. Current Switches:
   1. Phoenix Contact, EMD Series.

Q. Current Transmitters:
   1. American Aerospace, 1070 Series
   2. CR Magnetics, CR4320 series
   3. Phoenix Contact, Mini Analog Pro Series

R. Corrosion-Inhibiting Vapor Capsules:
   1. NVent Hoffman , Model A-HCI
   2. Northern Instruments, Model Zerust VC

S. Motor Starters:
   1. Rockwell Automation:
      a. Bulletin 509
      b. E300 electronic overload and EtherNet/IP communications

T. VFDs:
   1. ABB
   2. Eaton

3. Rockwell Automation:
    a. PowerFlex with EtherNet/IP communications adapter

U. PLC:
1. Emerson/Bristol Babcock
    a. ControlWave Micro PLC/RTU/PAC hybrid controller
2. Rockwell Automation:
    a. ControlLogix
3. Network communications modules (in-rack):
    a. Ethernet:
        1) Allen-Bradley 1756-EN2T
    b. Modbus TCP or Modbus RTU:
        1) Molex
        2) Moxa
        3) Prosoft
4. Development operating software:
    a. The PLC programming software system shall be manufactured by the PLC Hardware Manufacturer:
        1) Rockwell Automation, RSLogix 5000

V. LOI:
1. Rockwell Automation:
    a. PanelView Plus 7
2. LOI programming software:
    a. The LOI programming software system shall be manufactured by the LOI Hardware Manufacturer:
        1) Rockwell Automation, RS Studio 5000

W. Ethernet Switches:
1. Rockwell Automation:
    a. Stratix 5700

X. Media Converters:
1. Copper to fiber transceiver:
    a. N-tron
    b. Phoenix Contact
    c. Transition Networks

Y. Cabinet DIN Rail Mounted Patch Panels:
1. DINSpace, SNAP XL
2. Hirschmann, MIPP

Z. General Wiring Requirements:
1. Galvanized rigid steel conduit:
    a. Allied Tube and Conduit
    b. Republic Conduit
    c. Western Tube and Conduit
    d. Wheatland Tube Company
2. Liquidtight flexible conduit:
    a. AFC Cable Systems
    b. Anaconda
    c. Electri-Flex Company
    d. Southwire
3. 600 V class wire and cable:
    a. General cable:
        1) Lake Cable
        2) Okonite Company
        3) Omni Cable
        4) Southwire
    b. Instrumentation class wire and cable:
        1) Alpha Wire Co.
        2) Belden CDT
        3) General Cable
        4) Lake Cable
        5) Okonite Co.
        6) Rockbestos Surprenant Cable Corp.
4. Conductor and cable markers:
    a. Heat-shrinkable tubing:
        1) Brady
        2) Raychem
        3) Thomas & Betts

2.2 MATERIALS

A. Construct and finish enclosures using materials capable of withstanding the mechanical, electrical, and thermal stresses, and the effects of humidity and corrosion that are likely to be encountered in normal service:
   1. PCS enclosures shall have the following properties:
      a. NEMA Type 4X: Type 316 SST.
      b. NEMA Type 12: Steel with gasketed door, dust-tight.

B. Bolting Material:
   1. Commercial quality 1/2 inch diameter, SST hex-head Grade 5 bolts, nuts, and washers, with unified coarse threads for panel construction.
   2. Carriage bolts for attaching end plates.
   3. Other bolted joints for panel construction shall have SAE standard lock washers.

2.3 OPERATION

A. PLC and LOI Programming:
   1. General programming requirements:
      a. Use variable names or aliases derived from tag and loop identification on the P&IDs for the process values.
         1) Provide PLC logic to convert raw input values into engineering units in a floating-point format.
      b. Store adjustable parameters in the PLC, and configure so an operator with sufficient security access can change the parameters from the LOI. Update and display the current value at each location, regardless of where the last change was made.
      c. Documentation:
         1) Control logic shall be completely annotated including rungs, instructions, and tags.
         2) Each routine shall have a title and a detailed description of the control strategy represented by the control logic. Where parameters are passed to the routine, parameters shall be defined in the routine description.
         3) Analog tag descriptions representing process variables shall include the engineering unit range of the analog variable.
         4) Digital tag descriptions shall include the On and Off state labels.
         5) Complete, grammatically correct sentences and terminology, consistent with water treatment processes, shall be utilized in the development of rung and routine descriptions.
      d. Program slew rates for the SPs to limit the effect of updated SPs on the process:
         1) Provide for control SPs and manual speed and position selections.
         2) Store new SPs in one register, and gradually ramp the actual SP register at the slew rate until it reaches the new value.
         3) Provide operator access to change slew rates through the controls system.
      e. Saved SPs:
         1) Provide an operator selection to save SP values.
         2) Provide an operator selection to restore SPs to the last saved value.
      f. Calculated values:
         1) Program calculations such that division by zero errors cannot occur.
         2) Prevent calculations from generating values that exceed the limits of the equipment or data type structures (integers) internal to the PLC.
         3) Configure counting functions (start counts and operation counts) to allow a minimum of 10,000 counts and to rollover to zero at an even decimal interval (one followed by four or more zeros).
      g. Timers:
         1) Provide programmable settling and proving timers in control sequences for starting and stopping of equipment to allow the process to settle down before proceeding with any additional control functions.
            a) The settling timers may be overridden by setting the timer to 0 seconds.
      h. PLC status:
         1) Furnish the information that depicts the status of enclosures containing PLC or I/O in the control system, including but not limited to the following:
            a) PLC cabinet over-temperatures from high temperature switch.
            b) Intrusion status on enclosures equipped with intrusion switches.
            c) 480 VAC power failure.
            d) DC power supply failure.
      i. PLC system communication status:
         1) Furnish a minimum of one screen to display the communication errors and status within the Supplier's control system network:
            a) PLC to RIO.
            b) Display status of each node, and a summary of failures over the past 60 minutes.
         2) Generate a communications alarm if any communication fault is detected.
         3) In the event of communications loss: Continue normal operation at each PLC with last known shared values.
   2. Common control functions:
      a. Incorporate common control functions into the control loops and devices and into the control programming, whether or not specifically specified in the control descriptions or elsewhere in the Contract Documents.
      b. Alarms:
         1) Generate alarms within the PLC logic.
         2) Show alarms at the LOI. Enable acknowledgement from the LOI.

3) After the alarm is acknowledged by an operator, display alarm conditions in a steady state (not flashing) while the alarm condition is still present:
    a) Use interlocks and proving timers to prevent alarms from operating due to power loss, except for loss of power alarms.

c. Where run-time accumulation is required, integrate accumulated run time to the nearest 0.1 hours whenever the running status input specifies that the equipment is running:
    1) Display total run time in hours.
d. For monitored analog values:
    1) Maintain trends.
    2) Totalize flows: Display totals on the LOI.
e. Analog data processing:
    1) Engineering units' conversion: Use engineering units for analog point values. Convert analog inputs to engineering units.
    2) Analog magnitude checking: Provide clamps to prevent operator-entered values (SPs, etc.) that fall outside acceptable limits.
f. Tank and vessel levels:
    1) Display tank and vessel levels as both a level (typically in feet) and a volume (typically in gallons):
        a) Some individual displays may be only level or volume, when agreed to by the OWNER and the ENGINEER during the Submittal phase.
    2) Monitor rate of change of volume on tanks and vessel:
        a) Establish the maximum rate at which the volume should decrease (pumps or feeders operating at maximum output). Generate an alarm whenever the volume decreases faster than this rate.
g. I/O filtering and processing:
    1) Analog input filtering:
        a) Provide programming for each analog input to implement an adjustable first order filter, for the purpose of smoothing out spikes and other noise for analog transmitter input signals. By default, shall configure analog inputs with no filtering affect.
        b) Monitor analog input signal quality:
            (1) Over range: The input value is above the normal range (typically over 21 mA).
            (2) Under range: The input value is below the normal range (typically under 3 mA, indicating a probable broken connection).
            (3) Generate alarms for over or under range inputs.
            (4) Do not use over or under range values for control or calculation purposes:
                (a) Where a second instrument is provided to monitor the same condition (a redundant instrument, or additional instruments furnished for averaging or different operating modes), and has a valid signal, use that input for control.
                (b) Otherwise, hold outputs affected by the signal at their last values before the signal went out of range.
                (c) Generate an alarm when redundant instruments deviate in their measurements by an operator adjustable percentage.
        c) Digital input filtering (proving timer): Provide an adjustable time delay function (0 to 10 seconds) on discrete input for the purpose of de-bouncing. By default, discrete inputs shall be configured with de-bounce timers set to 0 seconds.
h. LOI HOA:
    1) Provide HOA and START-STOP selections accessed from an LOI for operators with sufficient security, to provide the following operating modes:
        a) AUTO: The normal, automatic control mode of the strategy which allows full PLC control in response to process conditions and programmed sequences.
        b) HAND: Enables manual control where control decisions are made by an operator through the START-STOP, OPEN/CLOSE, or other selections shown on the Drawings.
        c) OFF: Automated control is disabled and PLC calls for the associated equipment to stop and valves to close or go to their identified safe state.
i. Display the current status of operator selections (HAND/AUTO, START/STOP, etc.) on the LOI.
j. Motor control:
    1) Display current REMOTE status on the screens.
    2) Monitor the device's running status:
        a) Display the current status (running or stopped) on the screens.
k. Identify hardwired controls, hardwired interlocks, and software interlocks.

2.4 COMPONENTS

A. General:
1. Furnish meters, instruments, and other components that are the most recent field proven models marketed by their Manufacturers at the time of Submittal of the Shop Drawings unless otherwise specified to match existing equipment.
2. Unless otherwise specified, furnish individual instruments that have a minimum accuracy of within 0.5% of full scale and a minimum repeatability of within 0.25% of full scale.

B. Panels/Enclosures:
1. Panel assembly:
a. General guidelines for panel fabrication include:
1) Continuous welds ground smooth.
2) Exposed surfaces free of burrs and sharp edges.
3) Base formed of heavy channel iron, either galvanized or powder coated, minimum 1/2 inch holes at 12 inch spacing to accommodate anchoring of freestanding enclosures to floor.
b. Construct enclosure and mounting panel using stretcher-level quality sheet metal having minimum thickness not less than the following sizes (U.S. Standard Gauge):

Enclosure Height (inches)	Minimum Enclosure Steel Thickness (gauge)	Minimum Back Mounting Panel Thickness (gauge)
Wall-mounted up to 48	14	14
Up to 57	12	12
57 to 69	12	10
69 to 82	12, except 10 on back	10
82 or more	10	10

1) Use heavier sheet metal in accordance with seismic requirements at the Project site or when required due to equipment requirements.
c. Construct supporting frame structure with angled, channeled, or folded rigid section of sheet metal, rigidly attached to and having essentially the same outer dimensions as the enclosure surface and having sufficient torsional rigidity to resist the bending moments applied via the enclosure surface when it is deflected.
d. Provide stiffeners for back mounting panels in enclosures larger than 4 feet. In addition, secure the panels in place by collar studs welded to the enclosure.
e. Door construction:
1) Turned-back edges suitably braced and supported to maintain alignment and rigidity without sagging.
2) Sufficient width to permit door opening without interference with rear projection of flush-mounted instruments.
3) Heavy-gauge piano-type continuous SST hinges.
4) For NEMA Type 12, Type 4, and Type 4X, provide oil-resistant neoprene sealing gasket and adhesive to seal cover to enclosure.
5) Gasket installed to seal against roll lip on the enclosure opening.
f. Latches:
1) For panels, provide each door with a three-point latching mechanism and handle with rollers on the ends of the latch rods. Latch rods shall be connected to a common door handle, hold doors securely, and form a compressed seal between door and gasket, at the top, side, and bottom.
a) Provide each enclosure with padlock provisions.
2) For large NEMA Type 4 and NEMA Type 4X cabinets not available with three-point latching hardware, provide multiple clips and padlock hasps.
g. Panel cut-outs:
1) Cut, punch, or drill cutouts for instruments, devices, and windows. Smoothly finish with rounded edges.
2) Allow a minimum of 3 inch envelope around displays, controllers, and monitors.
3) Reinforce around cut-outs with steel angles or flat bars for the following:
a) Large panel cutouts; for example, openings for LOIs.
b) Pilot device groupings, where the removed metal exceeds 50% of the available metal.
h. In addition to the requirements specified above, the following requirements for NEMA Type 4X powder coated SST enclosures apply:
1) Minimum 14 gauge, Type 304 SST.
2) Captive SST cover screws threaded into sealed wells.
3) Inside finish: White polyester powder coating.
4) Specifically designed for use with flange-mounted disconnect handles where required or as shown on the Drawings.
5) NEMA Type 4X powder-coated SST enclosures are not an acceptable substitute for SST unless shown on the Drawings.
i. Outdoor panels. Supplementary requirements for panels located outdoors are as follows:
1) Enclosures located outdoors shall be explicitly designed and rated for outdoor service by the Manufacturer.
2) Door hardware: SST.
3) Provide factory installed rain canopy and sun shield for enclosures with operator interface panels.
4) Bases: Heavy channel, gasketed SST bases, flanges up, for anchoring to pad.
2. Arrangement of components:
a. Arrange panel internal components for external conduit and piping to enter into panel either from above or below.
b. Arrange panel instruments and control devices in a logical configuration, associating pushbutton and selector switches with related readout devices, or as shown on the Drawings.

c. Mount internal control components on an internal back panel. Devices may be mounted on the side panel only by special permission from the ENGINEER.
d. Control-panel-mounted operator interface devices shall be mounted between 3 feet and 5 feet above finished floor.

C. Hasps:
1. Material: SST or the Manufacturer's recommended to match corrosion resistance of enclosure material.
2. Hidden screws.
3. Suitable for doors not closing flush.
4. Usable with standard size padlock.

D. Overcurrent Protection:
1. Main overcurrent device:
a. Where the electrical power supply voltage to the control panel is more than 120 VAC, provide the panel with a flange-mounted disconnect handle operating a molded-case circuit breaker and provide a control power transformer for 120 VAC circuits:
1) Door-mounted disconnect handles are not acceptable.
2) Mechanically interlock the disconnect switch with the control enclosure doors so that no door can be opened unless the power is disconnected, and the disconnect switch cannot be closed until all doors are closed.
3) Provide means to defeat the interlock.
4) Lockable in the off position.
b. Control panels supplied with 120 VAC:
1) Provide an internal breaker with the line side terminals covered by a barrier.
2) Provide a nameplate prominently positioned on the control panel identifying the location of the power source and a warning statement requiring the source to be disconnected before opening the door to the enclosure.
c. Provide low voltage molded case circuit breakers:
1) In accordance with UL 489.
2) Operating mechanism:
a) Quick-make, quick-break, non-welding silver alloy contacts.
b) Common trip, open and close for multi-pole breakers such that the poles open and close simultaneously.
c) Mechanically trip free from the handle.
d) Trip indicating handle shall automatically assume a position midway between the manual ON and OFF positions to clearly indicate the circuit breaker has tripped.
e) Lockable in the OFF position.
f) Arc extinction: In arc chutes.
3) Selection and ratings of protective devices:
a) Interrupting ratings: Not less than the system maximum available fault current at the point of application.
b) Voltage rating: Not less than the voltage of the application.
c) Select current rating and trip characteristics to be suitable for:
(1) Maximum normal operating current.
(2) Inrush characteristics.
(3) Coordination of the protective devices to each other and to the source breaker feeding the panel.
2. Selection and ratings of protective devices:
a. Interrupting ratings: Not less than the system maximum available fault current at the point of application.
b. Voltage rating: Not less than the voltage of the application.
c. Select current rating and trip characteristics to be suitable for:
1) Maximum normal operating current.
2) Inrush characteristics.
3) Coordination of the protective devices to each other and to the source breaker feeding the panel.
3. Provide a separate protective device for each powered electrical device:
a. An individual circuit breaker for each 120 VAC instrument installed within its respective control panel and clearly identified for function.
b. An individual fuse for each PLC discrete output. Provide with individual blown fuse indication external of the I/O card:
1) Size external fuse to open before any I/O-card-mounted fuses.
2) Individual discrete inputs shall use a 0.5 A fuse.
c. Control loops can use individual 5 A fuse for the loop.
d. Install protective devices on the back mounting panel and identify by a service nameplate in accordance with the wiring diagrams.
4. Fuses for 4 mA to 20 mA signals:
a. Provide durable, readily visible label for each fuse, clearly indicating the correct type, size, and ratings of replacement fuse:
1) Label shall not cover or interfere with the Equipment Manufacturer's instructions.
b. An individual 1/2 A fuse for each 4 mA to 20 mA analog loop powered from the control panel.
c. Provide fuses rated for the voltage and available short-circuit current at which they are applied.

5. Fuse holders:
    a. Modular type:
        1) DIN rail mounting on 35-mm rail.
        2) Touch-safe design: Connection terminals shall be protected against accidental touch.
        3) Incorporates blown-fuse indicator.
        4) Plug-in style fuse terminals and fuse plugs are not acceptable.
    b. Provide nameplate identifying each fuse.
6. Control circuit breakers:
    a. DIN rail mounting on 35-mm rail.
    b. Manual OPEN-CLOSE toggle switch.
    c. Rated for 250 VAC.
    d. Interrupting rating: 10 kA or available fault current at the line terminal, whichever is higher.
    e. Current ratings: As required for the application.
    f. Provide nameplate identifying each circuit breaker.
7. Electronic circuit protectors:
    a. Used where equipment is equipped with an NEC Class 2 power supplies requiring 100 W to 8 A.
    b. DIN rail mounting on 35-mm rail.
    c. Rated for 24 VDC.
    d. Four channels to feed four independent power feeds to separate devices.
    e. Output current ratings: As required for the application.
    f. LED input status indication.
    g. LED failure status of each channel indication.
    h. Fail contacts.
    i. Provide nameplate identifying each circuit breaker.
8. Provide harmonic filtering in accordance with IEEE 519.

E. Thermal Management:
1. Provide heating and cooling devices to maintain instrumentation and control devices to within a range as specified in SECTION 40 50 00.
2. Air conditioner:
    a. Provide solid-state cabinet coolers or air conditioning units on outdoor panels containing electronic components such as LOIs, panel instruments, PLCs, or remote I/O.
    b. Provide filters on intake and exhaust openings.
    c. Increase panel sizes as needed to accommodate cooling units.
    d. Enclosure rating: NEMA Type 4X.
    e. Closed-loop design.
    f. Power supply: 120 VAC.
3. Heating:
    a. Provide panels located in areas that are not climate controlled with thermostatically controlled strip heaters, except where all of the following conditions apply:
        1) The panel is not supplied with 120 VAC power.
        2) There are no electronics or moisture-sensitive devices in the enclosure.
        3) The panel is smaller than 38 inches high.
4. Heat exchanger:
    a. Closed-loop design ensuring separation of ambient air and clean air inside the cabinet.
    b. Filterless design to facilitate easy cleaning of the core.
    c. Mounting: As shown on the Drawings.
5. Enclosure temperature switch:
    a. Provide wall-mounted bimetallic switch transmitter (to measure internal cabinet temperature in the enclosures) containing electrical components such as PLCs, RTUs, RIO, and VFDs.
    b. Sensor and electronic enclosure.
    c. Accuracy: Within 2ºF.
6. Status relays and discrete inputs for switches, power supplies, and fieldbus devices (if applicable):
    a. Provide as shown on the Drawings.
7. Ventilated panels:
    a. Furnish with louvers and forced ventilation as required to prevent temperature buildup from equipment mounted inside panel or on panel. Size to adequately dissipate heat from equipment mounted inside panel or in panel face. Panel louvers shall have industrial, heavy duty, washable aluminum air filters.
    b. Provide NVent Hoffman fan speed control:
        1) Provide two door/cabinet-mounted vent fans for every 72 inches of cabinet width.
        2) Provide finger-guard kit.
        3) Filter kit with two spare filters for each intake fan.
        4) Provide bezel and gasket kit.
        5) Automatically adjust fan speed depending on remote temperature sensor input.
        6) 120 VAC, 60 Hz.
        7) NEMA Type 5-15R cord connections.

F. Digital Process Indicators:
   1. General:
      a. Integral provisions for scaling.
      b. Scale to process engineering units.
      c. Switch-programmable decimal points.
      d. NEMA Type 4/IP65 sealed front bezel.
   2. Current and voltage indicators:
      a. Three and a half digit minimum.
      b. Minimum character height: 1/2 inch.
      c. Accuracy:
         1) AC/DC volts: Within 0.1% of reading plus two digits.
         2) DC current: 4 mA to 20 mA; within 0.1% of reading plus one digit.
         3) DC voltage: 0 V to 10 V; within 0.1% of reading plus one digit.
   3. Operating voltage: 120 VAC.
   4. Operating temperature: 0ºC to 60ºC.

G. Pilot Devices:
   1. General:
      a. Provide operator pushbuttons, switches, and pilot lights, from a single Manufacturer.
      b. Size: 30.5 mm.
      c. Heavy duty.
      d. Pushbuttons:
         1) Contacts rated: NEMA Type A600.
         2) Furnish one spare normally open contact and normally closed contact with each switch.
      e. Selector switches:
         1) Contacts rated: NEMA Type A600.
            a) Knob type.
         2) Furnish one spare normally open contact and normally closed contact with each switch.
         3) Provisions for locking in the OFF position where lockout provisions are shown on the Drawings.
      f. Pilot lights:
         1) Type: LED for interior installations.
         2) Push to test.
         3) Lamp color:
            a) On/Running/Start: Red.
            b) Off/Stop: Green.
            c) Power: Green.
            d) Alarm: Amber.
            e) Status or normal condition: White.
            f) Opened: Red.
            g) Closed: Green.
            h) Failure: Amber.
   2. Indoor and outdoor areas: NEMA Type 4/13.
   3. Corrosive areas:
      a. NEMA Type 4X.
      b. Corrosion resistant.
      c. Exterior parts of high-impact strength fiberglass-reinforced polyester or multiple-layer epoxy-coated zinc.

H. Signal Isolators and Converters:
   1. Furnish signal isolators that provide complete isolation of input, output, and power input:
      a. Minimum isolation level: 1.0 kV AC/50 Hz for at least 1 minute.
      b. Adjustable span and zero.
      c. Accuracy: Within 1.0% of span.
      d. Ambient temperature range: -20ºC to +65ºC.

I. Relays:
   1. General:
      a. For 120 VAC relays, provide surge protection across the coil of each relay.
      b. For 24 VDC relays, provide a free-wheeling diode across the coil of each relay.
      c. For plug in type relays, provide a relay base from the same Manufacturer as the Relay Manufacturer.
   2. General purpose:
      a. Magnetic control relays.
      b. NEMA ratings:
         1) 300 V.
         2) 10 A continuous (minimum).
         3) 7,200 VA make.
         4) 720 VA break.
      c. Plug-in type.
      d. LED indication for energization status.
      e. Coil voltages: As required for the application.
      f. Minimum poles: DPDT.

g. Touch-safe design: Connection terminals shall be protected against accidental touch.
h. Enclose each relay in a clear plastic heat and shock-resistant dust cover.
i. Quantity and type of contact shall be as shown on the Drawings or as needed for system compatibility.
j. Relays with screw-type socket terminals.
k. Provide additional (slave/interposing) relays when the following occurs:
    1) The number or type of contacts shown exceeds the contact capacity of the specified relays.
    2) Higher contact rating is required to interface with starter circuits or other equipment.
l. DIN rail mounting on 35-mm rail.
m. Ice-cube-type relays with retainer clips to secure relay in socket.
n. Integrated label holder for device labeling.

3. Terminal block relays:
    a. Magnetic control relays.
    b. For use as an interposing relay for PLC based discrete I/O signals.
    c. NEMA ratings:
        1) 250 V.
        2) 6 A continuous.
        3) 1,500 VA make.
    d. Plug-in type.
    e. LED indication for energization status.
    f. Coil voltages: As required for the application.
    g. Minimum poles: SPDT.
    h. Touch-safe design: Connection terminals shall be protected against accidental touch.
    i. Quantity and type of contact shall be as shown on the Drawings or as needed for system compatibility.
    j. Relays with screw-type socket terminals.
    k. DIN rail mounting on 35-mm rail.
    l. Integrated label holder for device labeling.
4. Latching:
    a. Magnetic-latching control relays.
    b. NEMA ratings:
        1) 300 V.
        2) 5 A continuous.
        3) 360 VA make.
        4) 320 VA break.
    c. Plug-in type.
    d. DIN rail mounting on 35-mm rail.
    e. Coil voltage: As required for the application.
    f. Minimum poles: DPDT, as required for the application. Plus, one spare pole.
    g. Touch-safe design: Connection terminals shall be protected against accidental touch.
    h. Clear cover for visual inspection.
    i. Provide retainer clip to secure relay in socket.
5. Time delay:
    a. Provide time-delay relays to control contact transition time.
    b. Contact rating:
        1) 240 V.
        2) 10 A continuous.
        3) 3,600 VA make.
        4) 360 VA break.
    c. Coil voltage: As required for the application.
    d. Provide pneumatic or electronic type with on-delay, off-delay, and on/off-delay:
        1) For off-delay, use true power-off time-delay relays. Where the required timing range exceeds capability of the off-delay relay use, signal off-delay where power loss will not cause undesirable operation or pneumatic time-delay relays.
    e. Minimum poles: DPDT.
    f. Units include adjustable dial with graduated scale covering the time range in each case.
    g. Minimum timing range: 0.1 seconds to 10 minutes, or as required for the application.

J. Terminal Blocks:
1. DIN rail mounting on 35-mm rail.
2. Suitable for specified AWG wire.
3. Rated for 15 A at 600 V.
4. Screw terminal type.
5. Provide mechanism to prevent wire connection from loosening in environments where vibration is present. This mechanism shall not cause permanent deformation to the metal body.
6. Finger-safe protection for terminals for conductors.
7. Construction: Polyamide insulation material capable of withstanding temperature extremes from -40ºC to 105ºC.
8. Terminals: Plainly identified to correspond with markings on the diagrams:
    a. Permanent machine-printed terminal identification.
9. Disconnect-type field signal conductor terminals with socket/screw for testing.

10. Identify terminals suitable for use with more than one conductor.
11. Position:
    a. To ensure the internal and external wiring does not cross.
    b. To provide unobstructed access to the terminals and their conductors.
12. Provide minimum 25% spare terminals.

K. Wire Duct:
  1. Provide flame retardant plastic wiring duct, slotted with dust cover.
  2. Type:
     a. Wide slot.
     b. Narrow slot.
     c. Round hole.

L. DIN Rail:
  1. Perforated steel.
  2. 35 mm width.
  3. 15 mm deep.
  4. Provide 2 inch offset using one of the following:
     a. Offset brackets.
     b. Preformed standoff DIN rail channel.

M. SPD:
  1. 120 V control power for panels:
     a. Panels without an integral UPS:
        1) Provide SPD for panel power entrances:
           a) Nominal 120 VAC with a nominal clamping voltage of 200 V.
           b) Non-faulting and non-interrupting design.
           c) A response time of not more than 5 ns.
        2) Control panel power system level protection, non-UPS powered:
           a) Designed to withstand a maximum 10 kA test current of an 8/20 microseconds (μs) waveform in accordance with IEEE C62.41.1 Category C Area.
           b) For panels receiving power at 120 VAC, provide surge protection at secondary of main circuit breaker.
           c) Provide both normal mode noise protection (line to neutral) and common mode (neutral to ground) surge protection.
           d) DIN rail mounting.
           e) Attach wiring to the SPD by means of a screw-type cable-clamping terminal block:
              (1) Gastight connections.
              (2) The terminal block: Fabricated of non-ferrous, non-corrosive materials.
           f) Visual status indication of MOV status on the input and output circuits.
           g) Dry contact rated for at least 250 VAC, 1 A for remote status indication.
           h) In accordance with the following requirements:
              (1) Response time: Less than or equal to 100 ns.
              (2) Attenuation: Greater than or equal to -40 dB at 100 kV-Hz as determined by a standard 50-ohm insertion test.
              (3) Safety approvals in accordance with UL 1283 and UL 1449.
     b. Panels with a UPS:
        1) Provide surge protection on the control power source at each panel containing power supplies, or electronic components including PLCs, I/O, HMI, and digital meters.
        2) Location:
           a) For panels with a UPS, install surge protection ahead of UPS and maintenance bypass switch.
              (1) Surge protection is not required for 120 VAC circuits that are only used for panel lights and receptacles.
        3) Maximum continuous operating voltage: 150 VAC.
        4) Surge capability (8/20 μs wave): 10 kA.
        5) Peak let-through: 620V L-N, 850V L-G.
     c. For panels receiving power at 480 VAC, provide surge protection on the 120 VAC control power transformer secondary.
  2. Instrument, data, and signal line protectors (traditional I/O) – panel-mounted:
     a. Surge protection minimum requirements: Withstand a 10 kA test current of an 8/20 μs waveform in accordance with IEEE C62.41.1 Category C Area.
     b. DIN rail mounting on 35-mm rail (except field-mounted SPDs).
     c. SPDs consisting of two parts:
        1) A base terminal block.
        2) A plug protection module:
           a) Replacing a plug shall not require the removal of any wires nor interrupt the signal.
           b) Base and plug coded to accept only the correct voltage plug.
  3. Instrument, data, and signal line protectors (traditional I/O) – field mounted:
     a. Surge protection minimum requirements: Withstand a minimum 10 kA test current of an 8/20 μs waveform in accordance with IEEE C62.41.1 Category C Area.

N. Horns and Beacons:
   1. LED colors: Red, green, and amber.
   2. Power: 120 VAC.
   3. Provide accessories such as pipe mount flange, pipe extensions, corner mount brackets, or wall mount brackets as needed.
   4. Horn rated 80 dB minimum at 10 feet.

O. Power Supplies:
   1. Design power supply system so that either the primary or backup supply can be removed, repaired or replaced, and returned to service without disrupting the system operation.
   2. Convert 120 VAC to 24 VDC or other DC voltages required or as required for the application.
   3. Provide redundant backup 24 VDC power supply units to automatically supply the load upon failure of the primary supply.
   4. Provide power supply arrangement that is configured with several modules to supply adequate power in the event of a single module failure in either a 1+1 or N+1 configuration as required:
      a. Provide automatic switchover upon module failure.
      b. Alarm contacts monitored by the PLC.
   5. Provide protective isolation between power supply units either by means of diodes, diode modules, MOSFET modules, or use power supplies with built in redundancy. Power supplies with built in redundancy shall actively isolate each power supply and be designed as such.
   6. Sized to provide 40% excess rated capacity.
   7. UL 508C listed to allow full-rated output without de-rating.
   8. Provide fuse or short-circuit protection.
   9. Provide a minimum of one set of dry contacts for each power supply configured to change state on failure for monitoring and signaling purposes.
   10. Output regulation: Within 0.05% for a 10% line change or a 50% load change.
   11. Operating temperature range: 0ºC to 60ºC.
   12. Touch-safe design: Connection terminals shall be protected against accidental touch.
   13. DIN rail mounting on 35-mm rail: Mount the power supply in the proper orientation as recommended by the Manufacturer to ensure adequate thermal dispersion without derating the power supply.
   14. Provide self-protecting power supplies with a means of limiting DC current in case of short circuit.

P. Limit Switches:
   1. NEMA Type 4X.
   2. AC contact rating 120 V, 10 A.
   3. DC contact rating 125 V, 0.4 A.
   4. Provide robust actuation mechanism not prone to degradation.
   5. Provide complete actuator mechanism with the required hardware.
   6. Allow for contact opening even during contact weld condition.
   7. UL approved.
   8. Operating temperature range: -18ºC to +110ºC (0ºF to 230ºF).

Q. Current Switches:
   1. Operate from 120 VAC supply voltage.
   2. One normally open and normally closed contacts.
   3. Adjustable current setting.

R. Current Transmitters:
   1. Input current range: As shown on the Drawings.
   2. Output: 4 mA to 20 mA.
   3. Operate from 24 VDC supply voltage.
   4. Output overload protected.
   5. Accuracy: Within 0.5% full-scale.
   6. Ripple and noise: 1% maximum, peak-to-peak.
   7. Frequency: 50/60 Hz.

S. Corrosion-Inhibiting Vapor Capsules: Provide corrosion-inhibiting vapor capsules in enclosures, panels, and cabinets.

T. Motor Starters:
   1. Provide combination type starters with motor circuit protector.
   2. NEMA size, design, and rated: NEMA Size 1 minimum.
   3. Coordinate motor circuit protector and overload trip ratings with nameplate horsepower and current ratings of the installed motor.
   4. Provide starters NEMA Size 2 and larger with arc quenchers on load breaking contacts.
   5. Mount extended overload reset buttons to be accessible for operation without opening starter enclosure door.
   6. Full voltage starters:
      a. Across-the-line full voltage magnetic starters.
      b. Rated for 600 V.
      c. Provide positive, quick-make, quick-break mechanisms, pad lockable enclosure doors.
      d. Furnish starter with solid-state electronic overload relays.
      e. Double-break silver alloy contacts.

7. Overloads:
    a. Solid state electronic with communications:
        1) Selectable Class 10, 20, 30 protection.
        2) Ambient insensitive: Operating temperature: -20ºC to 70ºC.
        3) Thermal memory.
        4) Protective functions:
            a) Motor overcurrent.
            b) Phase unbalance (adjustable).
            c) Phase loss.
            d) Ground fault.
        5) 120 VAC powered.
        6) Provide current transformers for metering of motor current.
        7) Visible trip indicator.
        8) Push-to-trip test.
        9) Isolated normally open alarm contact.
        10) Normally closed trip contact.
        11) Manual reset.
        12) Communications: EtherNet/IP.
        13) Conformal coating: Provide conformal coating material applied to electronic circuitry and printed circuit boards to act as protection against moisture, dust, temperature extremes, and chemicals such as chlorine.
8. SPD: Furnish SPDs across the coil of each starter, contactor, and relay.

U. VFD:
1. General:
    a. Sinusoidal pulse width modulated type drive.
        1) Six-pulse insulated gate bipolar transistor power section.
        2) Microprocessor based controls.
        3) Line and load reactors.
2. Operational features:
    a. Protective features:
        1) Provide the following minimum protective features:
            a) Motor overload protection.
            b) Instantaneous overcurrent.
            c) Instantaneous overvoltage.
            d) Undervoltage.
            e) Power unit overtemperature.
            f) Phase loss.
            g) VFD output short circuit.
    b. Control mode:
        1) Operation in either a constant V/Hz or sensorless vector mode: The control mode selectable using the programming keypad.
    c. Frequency control:
        1) Minimum of three selectable skip frequencies with adjustable bandwidths.
        2) Programmable minimum frequency.
        3) Programmable maximum frequency.
    d. Acceleration/deceleration:
        1) Separately adjustable acceleration and deceleration rates: Each rate adjustable from 0.01 to 1,800 seconds.
    e. Spinning load: The VFD shall be capable of determining the speed and direction of a spinning load, catch the load and accelerate or decelerate it without damage to the load.
    f. Programmable loss of signal:
        1) Upon loss of speed reference, the VFD shall be programmable to either:
            a) Stop.
            b) Maintain current speed.
            c) Default to pre-selected speed.
    g. Power interrupt ride-through: The VFD shall be capable of continuous operation in the event of a power loss of five cycles or less.
    h. Communications: Provide each VFD with EtherNet/IP communications interface module.
    i. Diagnostics:
        1) Store a minimum of four fault conditions in non-volatile memory on a first in-first out basis.
        2) Operational parameters stored at the time of the fault:
            a) Operating frequency.
            b) Drive status.
            c) Power mode.
    j. Automatic restart:
        1) User selectable automatic restart feature allowing the VFD to restart following a momentary power failure or other VFD fault:
            a) Programmable for up to nine restart attempts.

b) Adjustable time delay between restart attempts
3. Power disconnect: Motor circuit protector.
4. Input reactor: 3% input line reactor.
5. Output device:
   a. Provide output device type based on the equipment, conductors, and lengths.
      1) 3% output load reactor.
      2) dV/dt filter:
         a) Common mode reduction: 30% minimum.
         b) Motor terminal peak voltage limit: 150% of DC bus voltage with a motor lead length up to 1,000 feet.
         c) Carrier frequency range: up to 12 kHz.
         d) Efficiency: 98% minimum.
         e) Class H insulation minimum.
6. Keypad:
   a. Provide each VFD with a keypad for programming and control.
   b. Keypad requirements:
      1) Password security to protect drive parameters.
      2) Mounted on the door of the VFD.
      3) Back-lit liquid crystal display (LCD):
         a) Minimum of two lines with a minimum of sixteen characters per line.
      4) Programming and display features language: English.
      5) Capable of displaying the following parameters:
         a) Speed (%).
         b) Output current (amperes).
         c) Output frequency (Hz).
         d) Input voltage.
         e) Output voltage.
         f) Total three -phase kW.
         g) kW-hr meter.
         h) Elapsed run time meter.
         i) Rpm.
         j) DC bus voltage.
   c. In addition to the keys required for programming, provide the following controls on the keypad:
      1) Auto/manual selector.
      2) Start pushbutton.
      3) Stop pushbutton.
      4) Jog pushbutton.
      5) Speed increment.
      6) Speed decrement.
      7) Forward/reverse selector.
      8) Run LED indicator.
      9) Program LED indicator.
      10) Fault LED indicator.
7. MOV:
   a. Provide protection for the VFD against:
      1) Line transients: 5,000 V peak minimum.
      2) Line to ground transients: 7,000 V peak minimum.
8. Conformal coating: Provide conformal coating material applied to electronic circuitry and printed circuit boards to act as a protection against moisture, dust, temperature extremes, and chemicals such as chlorine.

V. Control Power Transformer:
1. Furnish a control power transformer mounted and wired inside the enclosure.
2. With primary and secondary fusing.
3. Sized to power the VFD or starter controls and options.

W. PLC:
1. Construction:
   a. Furnish plug-in modular system.
   b. Provide PLCs capable of operating in a hostile industrial environment without fans, air conditioning, or electrical filtering:
      1) Temperature: 0ºC to 60ºC.
      2) RFI: 80 MHz to 1,000 MHz.
      3) Vibration: 10 Hz to 500 Hz.
      4) Humidity: 0% to 95%.
   c. Provide internal power supplies designed to protect against overvoltage and frequency distortion characteristics frequently encountered with the local power utility.
   d. Design the PLC system to function as a standalone unit that performs the control functions described in this Section completely independent from the functions of the plant HMI system PC-based operator interfaces:
      1) Failure of the plant HMI system shall not impact data acquisition, control, scaling, alarm checking, or communication functions of the PLC.

2. PLC backplane housing (applicable to ControlLogix platform only):
   a. Mount the PLC power supply, CPU, communications module, and I/O modules in a suitable standard PLC backplane or housing.
   b. Provide spare slots in each PLC location as specified in this Section.
   c. Provide a blank slot filler module for each spare slot.
3. CPU:
   a. Configure each CPU so that it contains the software relays, timers, counters, number storage registers, shift registers, sequencers, arithmetic capability, and comparators necessary to perform the specified control functions.
   b. Capable of interfacing with discrete inputs, analog inputs, discrete outputs, analog outputs, and communication cards in accordance with the specified requirements.
   c. Capable of supporting and implementing closed-loop floating-point math and proportional-integral-derivative (PID) control that is directly integrated into the CPU control program.
4. Memory:
   a. Non-volatile memory: On-board complementary metal-oxide-semiconductor (CMOS), electrically erasable programmable read-only memory (EEPROM), PCMCIA, compact flash card, or SD card.
   b. Supply with sufficient memory to implement the specified control functions plus a reserve capacity as specified in this Section:
      1) Reserve capacity: Totally free from any system use.
      2) Programmed in a multi-mode configuration with multiple series or parallel contacts, function blocks, counters, timers, and arithmetic functions.
5. Programming: Provide a system where processors are programmed by a portable laptop computer both locally and via the PLC control network.
6. PLC power supply:
   a. Input: 120 VAC.
   b. Mounted in the PLC housing.
   c. Sized to power the modules mounted in that housing including an average module load for any empty housing slots plus 50% above that total.
7. PLC I/O, I/O modules:
   a. General:
      1) Compatible with the PLCs being furnished under the contract and by the same Manufacturer as the PLCs.
      2) Provide I/O modules that:
         a) Isolate in accordance with IEEE Surge Withstand Standards and NEMA Noise Immunity Standards.
         b) Provide A/D and D/A converters with optically or galvanically isolated inputs and outputs.
         c) Accept dual-ended inputs.
      3) The use of common grounds between I/O points is not acceptable.
      4) Provide modules that are removable without having to disconnect wiring terminals:
         a) Utilize a swing-arm or plug-in wiring connector.
      5) Provide at each PLC the I/O modules for the following:
         a) Designated future I/O points contained in the I/O lists and/or shown on the P&IDs and the control schematics or described in the control strategies.
         b) Installed spare capacity as specified in this Section.
         c) Wire the spares provided to the field terminal strip.
      6) Condition, filter, and check input signals for instrument limit conditions.
      7) Filter, scale, and linearize the raw signal into an engineering-units-based measurement.
      8) Alarm measurements for high, low, rate-of-change limits, and alarm trends.
      9) Provide external fuses mounted on the field connection terminal block for discrete input, discrete output, and analog input I/O points.
      10) When multiple cards of the same I/O type are provided and parallel equipment, instrumentation, or redundant processes exist, distribute I/O among cards to ensure that a single card failure will not render an entire process unavailable.
   b. Discrete input modules:
      1) Defined as contact closure inputs from devices external to the input module.
      2) Provide inputs that are optically isolated from low-energy common-mode transients to 1,500 V peak from users wiring or other I/O modules.
      3) Individually isolated inputs.
      4) LEDs shall indicate status of each discrete input.
      5) Input voltage: 120 VAC.
      6) Provide input module points that are individually fused with blown-fuse indicator lights, mounted external of the module on the output terminal strip:
         a) Coordinate external fuse size with the protection located on the module, so that the external fuse opens first under a fault condition.
   c. Discrete output modules:
      1) Defined as contact closure outputs for ON/OFF operation of devices external to the output module:
         a) Triac outputs may be used, with the permission of the ENGINEER. Care shall be used in applying this type of module to ensure that the leakage current through the output device does not falsely signal or indicate an output condition.

        2) Optically isolated from inductively generated, normal mode and low-energy common-mode transients to 1,500 V peak.
        3) LEDs shall indicate status of each output point.
        4) Output voltage: 120 VAC.
        5) Individually isolated outputs.
    d. Analog input modules:
        1) Signal type: Provide 4 mA to 20 mA for most applications; other levels are acceptable to interface to Supplier control panels.
        2) Analog-to-digital conversion: Minimum 12-bit precision with the digital result entered into the processor.
        3) The analog-to-digital conversion updated with each scan of the processor.
        4) Individually isolated each input.
        5) Coordinate the size of the external fuse with the protection located on the module, so that the external fuse opens first under a fault condition.
    e. Analog output modules:
        1) Signal type: Provide 4 mA to 20 mA for most applications; other levels are acceptable to interface to Supplier control panels.
        2) Individual isolated output points each rated for loads of up to 1,200 ohms.
8. Network communications modules (applicable to ControlLogix platform only):
    a. General: Install communications modules in the PLC backplane.
    b. Ethernet:
        1) Ports: One.
        2) Communication rate: 100 Mbit/s.
    c. Modbus TCP or Modbus RTU:
        1) Ports: One.
        2) Each port individually configurable as Modbus Master or Slave.

X. PLC Programming Software:
1. PLC programming laptop/desktop operating system:
    a. The software shall be suitable for the PLCs specified in this Section.
    b. The software for programming, monitoring, searching, and editing shall be Microsoft Windows 10.
    c. Usable both online, while connected to the PLC, and off-line.
    d. The operating software shall display multiple series and parallel contacts, coils, timers, counters, and mathematical function blocks.
    e. Capable of disabling/forcing inputs, outputs, and coils to simulate the elements of the ladder logic; forced elements shall be identifiable by means of color change.
    f. Include a search capability to locate any address or element and its program location.
    g. Display at the engineer console, PLC status information, such as faults and communication errors and amount of memory remaining.
    h. The PLC programming software shall support the following programming languages:
        1) Ladder diagram.
        2) Function block diagram.
    i. Generate a PLC program printout, which is fully documented, through the PLC programming software:
        1) The fully documented program listings include, as a minimum, appropriate rungs, address, and coils shown with comments to clarify to a reader what that segment of the program accomplishes on an individual line-by-line basis.
        2) Include a sufficient embedded comment for every rung of the program explaining the control function accomplished in said rung.
        3) Use a mnemonic associated with each contact, coil, etc. that describes its function.
        4) Utilize the tag and loop identification as contained in the P&IDs:
            a) If additional internal coils, timers, etc. are used for a loop, they shall contain the loop number.
        5) Provide a cross-reference report of program addresses.
2. Program execution:
    a. Application software – program execution scheduled on a priority basis:
        1) A multilevel priority interrupt structure is required.
        2) Enter into a list of pending programs a program interrupted by a higher priority program:
            a) Resume its execution when it becomes the currently highest priority program.
        3) Schedule periodic programs.
        4) Base the allocation of resources to a time-scheduled program on its relative priority and the availability of resources.
3. Startup and restart:
    a. Provide software that initializes and brings a PLC or any microprocessor-based hardware unit from an inactive condition to a state of operational readiness.
    b. Initialization:
        1) Determination of system status before startup of initializing operating system software and initializing application software.
        2) Loading of memory-resident software, initializing timers, counters, and queues, and initialization of the dynamic database values.

4. Shutdown:
   a. Where possible, provide orderly shutdown capability for shutdowns resulting from equipment failure, including other PLC processor failures, primary power failure, or a manually entered shutdown command.
   b. Upon loss of primary power, a high-priority hardware interrupt initiates software for an immediate, orderly shutdown.
   c. Hardware is quickly and automatically commanded to a secure state in response to shutdown command or malfunction.
   d. Alarm PLC failure at the operator interface level.
5. Diagnostics:
   a. Furnish diagnostic programs with the PLC software package to detect and isolate hardware problems and assist maintenance personnel in discovering the causes for system failures.
   b. Use the Manufacturer’s standard diagnostic routines as much as possible.
   c. Furnish diagnostic software and test programs for each significant component in the control system.
   d. As a minimum, provide diagnostic routines to test for power supply, CPU, memory, communications, and I/O bus failures.
6. Calendar/time program:
   a. The calendar/time program to update the second, minute, hour, day, month, and year and transfer accurate time and date information to system-level and application software.
   b. Variations in the number of days in each month and in leap years shall be handled automatically by the program.
   c. The operator shall be able to set or correct the time and date from any operator interface, only at the highest security level.
7. Algorithms:
   a. Implementation of algorithms for the determinations of control actions and special calculations involving analog and discrete data.
   b. Capable of outputting positional or incremental control outputs or providing the product of calculations.
   c. Include alarm checks where appropriate.
   d. Provide, as a minimum, the following types of algorithms:
      1) Performs functions such as summing several variables, raising to a power, roots, dividing, multiplying, and subtracting.
      2) A switch algorithm, which reads the current and value from its input address and stores it as the value of its output address. Two types of switches shall be accommodated: two outputs with one input and one output with two inputs.
      3) A three-mode proportional-integral-derivative, PID, controller algorithm, with each of the three modes independently adjustable, supports both direct and reverse-acting modes.
      4) Lead, lag, dead time, and ratio compensators.
      5) Integration and totalization of analog process variables.
8. Furnish a comprehensive database for the analog inputs, calculated values, control modules, and outputs:
   a. Provide spare database points for future expansion.
9. One integrated database can be utilized for all types of analog points or separate databases for each type; in either case, the database for each point shall include all specified aspects.
10. The entire database shall be available for use by the display, report, and other specified software modules.
11. Data fields and functions specified as follows shall be part of the point definition database at the operator interface. Provide the capability to define new database points through the point display specified as follows well as modifying defined points through these displays. This point definition and modification shall include the features and functions defined below. The analog database software shall support the following functions and attributes:
    a. Analog input signal types: Provide software at the RTUs and PLCs to read variable voltage/current signals and pulse duration/frequency type analog input signals.
    b. Input accuracy:
       1) Inputs shall be read with an accuracy of within 0.05% full-scale or better.
       2) Data conversion errors shall be less than 0.05% full-scale.
       3) Pulse accumulation error shall be less than or equal to one count of actual input count at a scan rate of once per minute.
       4) Maintain for a minimum of 1 year the system accuracy stated without adjustments.
    c. Blocking:
       1) Provide mechanisms to inhibit or block the scanning and/or processing of any analog input through the operator interface.
       2) For any input so blocked, the operator may manually enter a value to be used as the input value.
    d. Filtering: For each analog input, provide a first order lag digital filter with an adjustable filter factor.
    e. Linearizing: Where analog inputs require square root extraction or other linearization, provide a mechanism to condition the filtered data before the process of scaling and zero suppression takes place.
    f. Calculated values:
       1) Provide means to allow for pseudo-inputs calculated by algebraic and/or Boolean expressions utilizing real inputs, other calculated values, constants, etc.
       2) Values shall be handled the same as real inputs in terms of record-keeping, alarming, etc.
    g. Scaling and zero suppression: Provide a conversion program to convert input values into engineering units in a floating-point format.

h. Alarms:
   1) Provide an alarm program to check analog variables against high-high, high, low, and low-low alarm limits.
   2) When an analog value exceeds a set limit, it shall be reported as an alarm based on the individually set priority level for each alarm point.
   3) Provide an adjustable hysteresis band to prevent excessive alarms when a variable is hovering around an alarm limit.
   4) It shall be possible to inhibit alarms based on external events, e.g., lock-out low pump flow alarm when the pump is off.
i. Averages:
   1) Provide a program to calculate and store hourly, daily, and monthly averages of analog variables.
   2) Continuously compute averages, e.g., the average for the current period to the present point in time shall be stored in memory and available for use in displays, etc.
   3) Update hourly averages each minute or at the polling interval for the selected variable.
   4) Update daily averages at least once each hour and calculate using the results of the hourly averages.
   5) Update monthly averages at least once each day and calculate using the results of the daily averages.
   6) At the end of each averaging period, store the average values for the period on the hard disk for historical record-keeping and reset the present period average register to the present value of the variable.
   7) The active database shall include the present period average and previous period average for each variable and averaging period.
j. Totals:
   1) Provide a program to calculate and store hourly, daily, and monthly totalization of analog variables.
   2) Assign a scaling factor to each variable to convert to the appropriate units based on a 1-minute totalizing interval.
   3) Assign a separate factor for each totalizing interval.
   4) Variables for which totalization is inappropriate shall have scaling factors of zero.
   5) At the end of each totalizing period, store the totalized values for the period on the hard disk for historical record-keeping and reset the present period totalization register to zero.
   6) The active database shall include the present period total and previous period total for each variable and totalizing period.
k. Engineering units:
   1) Provide software to allow the system and the operator to convert the measured analog variables to any desired engineering units.
   2) The operator shall be able to view displays and generate reports of any measured variable in one or more engineering units such as flow in gallons per minute, million gallons per day, cubic feet second, and acre-feet per day.
   3) Pre-program the conversion of the engineering units. If not pre-programmed, the operator shall be able to program new engineering unit conversions by using simple methods, e.g., multiplication of the database attributes by a constant.
   4) The programming method shall be at a level and compatible with the specified training of the operator and the OWNER's personnel.
   5) New conversions shall not require the services of a special programmer and/or special, high-level, programming training.
l. Control modules:
   1) For each control function configured, whether processed at the RTU, PLC, or operator interface, maintain a file of necessary data including input values, SPs, constants, intermediate calculated values, output value and limit clamps, etc.
   2) Input and output assignments, SPs, and constants shall be adjustable by the operator through the operator interface.
   3) Provide control algorithms for manual control with output values adjustable by the operator.
m. Analog outputs:
   1) Analog outputs shall be maintained as part of the database.
   2) These outputs shall be adjustable manually by the operator through the operator interface or through automatic control algorithms.

Y. LOI:
   1. General:
      a. Provide LOI located on the face of the PCS.
      b. NEMA rating as specified in SECTION 26 05 00.
      c. LOI consists of graphical display screen with operator input capabilities.
      d. Capable of stand-alone operation in conjunction with one PLC.
      e. Equipped with data network communication capabilities.
   2. Display:
      a. Type: Color TFT LCD screen.
      b. Resolution: Minimum 800 by 600 pixels.
      c. Size: Minimum 10 inch.
      d. Easy display viewing at any angle in various ambient light conditions.
      e. Operator input: Configurable touch screen.
      f. Screen update speed: The screen update speed and screen change speed less than 1 second.

g. Provide following features for outdoor use: Anti-glare screen overlay.
3. Graphic configuration:
   a. Easily configured graphics by:
      1) Portable laptop computer both locally and via the PLC data network.
      2) HMI engineer's console via the PLC data network.
   b. As specified in this Section.
4. Memory: Application: 512 mb random access memory.
5. CPU: Minimum 100 MHz.
6. Communications: EtherNet/IP protocol.
7. Environment:
   a. Temperature: 0ºC to 50ºC.
   b. Relative humidity: 10% to 90%.
8. Electrical:
   a. Power supply: 24 VDC.

Z. LOI Software:
1. Furnish software with preconfigured symbols, objects, graphics, and imported bitmaps for the generation of the displays.
2. Software shall allow bitmaps to be imported or exported to or from other applications.
3. Capable of generating custom reports, complete with screen prints.
4. Capable of working with multiple screens concurrently.
5. Provide dialog boxes for defining object attributes.
6. Configure objects using fill in dialog boxes.
7. Furnish graphic and text editor that allows custom formatting to customize and change the appearance of objects and text:
   a. Allow selection of different fill patterns to define object status.
8. As a minimum, provide the following object capabilities:
   a. Operator inputs:
      1) Momentary pushbutton.
      2) Maintained pushbutton.
      3) Latched pushbutton.
      4) Multistate pushbutton.
      5) Keypad enable button.
      6) Cursor point.
   b. Control list selectors:
      1) Standard control list.
      2) Piloted control list.
   c. Global objects.
   d. Display objects:
      1) Bar graph.
      2) Scale.
      3) Message display.
      4) Multistate indicator.
      5) List indicator.
      6) Numeric data display.
   e. Screen selector objects:
      1) Go to.
      2) Return.
      3) Screen list selector.
   f. Embedded variables:
      1) Time.
      2) Date.
      3) Numeric variable.
   g. Graphics:
      1) Lines.
      2) Shapes.
      3) Freeform Drawings.
      4) Imported graphics.
      5) Background text.
      6) Selection table for standard ISA symbols.
      7) PID controller faceplate.
   h. Alarm screens.
9. Documentation:
   a. Provide complete user documentation, including examples of how to operate the various modules within the system.
   b. Provide the documentation in electronic format, hypertext markup language based with the ability to search for topics by keyword or search or specific text.

10. Online help:
    a. Provide an online help facility, based upon Windows standard hypertext:
        1) Useful, context-sensitive information on the operation of the package:
            a) That can be invoked online through a point-and-click operation.
            b) The help facility shall also support the ability to perform full text word search, add custom comments, bookmark topics, copy and pasting into another application, printing, and use of system fonts and colors.

AA. Ethernet Switches:
1. Properties:
    a. Hardware:
        1) Power supply:
            a) Provide redundant power supplies.
            b) 24 VDC, 170 W per power supply.
        2) No fans or moving parts.
    b. Performance:
        1) Enclosure:
            a) Metal housing.
            b) 15g shock for 11 ms minimum.
        2) 10/100BASE-TX RJ-45 copper ports.
        3) 100BASE-FX LC fiber duplex ports.
        4) 1,000BASE-T RJ-45 copper ports.
        5) 1,000BASE-LX LC duplex fiber ports.
        6) Capable of performing basic switching without special programming or configurations. Additional features available through software setup includes but are not limited to:
            a) Simple network management protocol.
            b) Virtual local area network.
            c) Quality of service.
            d) Port mirroring.
            e) Dynamic host configuration protocol server.
        7) Internet group management protocol snooping with Ethernet I/P plug and play compatibility.
        8) 802.1d, 802.1w, 802.1D RSTP.
    c. Environment:
        1) Operating temperature range: 32ºF to 140ºF.
        2) Humidity: 10% to 95%, non-condensing.
    d. Connector type:
        1) Fiber: LC.
        2) Copper: RJ-45:
            a) Quantity of copper and fiber ports as required to provide the number of connections required plus 20% spare ports of each type used.
    e. Mounting: DIN rail mounting.

BB. Media Converters:
1. Copper to fiber transceiver:
    a. Transceiver shall be used to convert from half/full duplex Ethernet to singlemode fiber Ethernet 100BASE-FX:
        1) In accordance with IEEE 802.3.
        2) Supports half/full duplex.
        3) Connector type:
            a) Fiber: LC.
            b) Copper: RJ-45.
        4) Power supply: 24 VDC, 6 W.
        5) Mounting:
            a) Provide mounting hardware.
            b) DIN rail mounting, unless otherwise shown on the Drawings.

CC. Patch Panels:
1. General:
    a. Fiber:
        1) Optical fibers shall be provided with strain relief and terminated at a fiber patch panel. Final connections between the patch panel and the fiber optic network equipment shall be made via fiber optic patch cords.
        2) Fibers, active and dark, shall be terminated at the patch panels.
        3) Interconnect and patch panel housings shall provide space for excess fiber and provide strain relief for the fiber cable.
        4) Fiber cables shall be installed such that the outer sheath of the cable is carried into the interconnect enclosure or patch panels before breaking out buffer tubes.
    b. Copper:
        1) Final connections between the patch panel and network equipment shall be by patch cords.
        2) Premises cables shall be terminated at the patch panels.
        3) Cables shall be installed such that the outer sheath of the cable is carried into the interconnect enclosure or patch panels before breaking out conductors.

4) Maintain twist of broken out conductors.
2. Cabinet style fiber patch panels:
a. DIN rail mounted:
1) Use for the termination of a single cable inside of cabinets, in small enclosures or as shown on the Drawings.
2) DIN rail mounted fiber interconnects shall be provided as complete units including the housing, the connector panels and the fiber connectors.
3) DIN rail mounted fiber interconnects shall provide physical protection for both the incoming cable and the outgoing patch cords.
4) Capacity: As shown on the Drawings, minimum six connections.
5) Accessories: Blanks for unused connector panels.

DD. General Wiring Requirements within Enclosure:
1. Wiring methods: Wiring methods and materials for panels shall be in accordance with NFPA 70 requirements for General Purpose (no open wiring) unless otherwise specified.
2. Install components in accordance with the Manufacturer's instructions included in the listing and labeling.
3. Provide a nameplate on the cover of the control panel identifying the sources of power supply and foreign voltages within the control panel.
4. Provide transformers, protective devices, and power supplies required to convert the supply voltage to the needed utilization voltage.
5. Provide power surge protection for the control panels.
6. Provide signal surge protection within control panels for each analog I/O, discrete I/O, and data line (copper Ethernet, coaxial, Fieldbus signals) that originates from outdoor devices.
7. Provide non-metallic ducts for routing and organization of conductors and cables:
a. Provide a wiring separation plan.
b. Maximum wire fill capacity based upon 50% cross-sectional fill of duct area, or the Manufacturer's recommendation, whichever is smaller.
c. Size ducts for ultimate build-out of the panel, or for 20% spare, whichever is greater.
d. Provide separate ducts for signal and low-voltage wiring from power and 120 VAC control wiring:
1) 120 VAC: Grey colored ducts.
2) 24 VDC: White colored ducts.
8. Cables shall be fastened with cable-mounting clamps or with cable ties supported by any of the following methods:
a. Screw-on cable tie mounts.
b. Hammer-on cable-tie mounting clips.
c. Fingers of the nonmetallic duct.
9. Wire ties:
a. No wire ties inside wire duct.
b. Use Panduit Cable tie installation tool, with tension control/cutoff.
c. Verify cut ends are cut flush and filed smooth after installed.
10. Provide supports at the ends of cables to prevent mechanical stresses at the termination of conductors.
11. Support panel conductors where necessary to keep them in place.
12. Wiring to rear terminals on panel-mount instruments shall be run in nonmetallic duct secured to horizontal brackets run adjacent to the instruments.
13. Conductors and cables shall be run from terminal to terminal without splice or joints. Exceptions:
a. Factory-applied connectors molded onto cables shall be permitted. Such connectors shall not be considered as splices or joints.
14. The control panel shall be the source of power for 120 VAC devices interconnected with the control panel including, but not limited to:
a. Solenoid valves.
b. Instruments both mounted in the control panel and remotely connected to the control panel.
15. Provide power circuits for Supplier-furnished PLC cabinets as specified.
16. Conductors and cables within an enclosure:
a. Power and control wiring:
1) Materials: Stranded, soft annealed copper.
2) Insulation: 600 V type MTW.
3) Minimum sizes:
a) Primary power distribution: #12 AWG.
b) Secondary power distribution: #14 AWG.
c) Control: #16 AWG.
4) Color:
a) AC power (line and load): Black.
b) AC power (neutral): White.
c) AC control: Red.
d) AC control: Orange for foreign voltages.
e) DC power and control (ungrounded): Blue.
f) DC power and control (grounded): White with blue stripe.
g) Ground: Green.

b. Signal cables:
  1) Materials: Stranded, soft annealed copper.
  2) Insulation: 600 V, PVC outer jacket.
  3) Minimum size: #18 AWG paired triad.
  4) Overall aluminum shield (tape).
  5) Copper drain wire.
  6) Color:
    a) Two-conductor:
      (1) Positive (+): Black.
      (2) Negative (-): White and red.
    b) Three-conductor:
      (1) Positive (+): Black.
      (2) Negative (-): Red.
      (3) Signal: White.
  7) Insulate the foil shielding and exposed drain wire for each signal cable with heat-shrink tubing.
c. Conductor identification within an enclosure:
  1) Identify each conductor and cable with unique wire numbers.
  2) Readily identified without twisting the conductor.

17. Signal Transmission:
  a. Analog signals:
    1) Furnish analog measurements and control signals that vary in direct linear proportion to the measured variable, unless otherwise shown on the Drawings.
    2) Furnish electrical analog signals outside control panels that are 4 mA to 20 mA 24 VDC.
    3) Electrically or optically isolate analog signals from other signals.
    4) Furnish regulated analog signals that are not affected by changes in supply voltage or load resistance within the unit's rating.
    5) Maintain the total 4 mA to 20 mA loop impedance to 10% below the published value at the loop operating voltage.
    6) Where necessary, reduce loop impedance by providing current-to-current (I/I) isolation amplifiers for signal re-transmission.
  b. Pneumatic signals: 3 psig to 15 psig.
  c. Discrete I/O signals:
    1) Dry contacts or TRIAC outputs (with express written approval of the ENGINEER) as needed to coordinate with the field device.
    2) Provide external terminal block mounted fuse with blown fuse indication for discrete outputs.
    3) Provide interposing relays for discrete outputs for voltage and/or current compatibilities.
    4) Provide interposing relays as required for functionality of the control circuit.
  d. Signal performance and design criteria:
    1) Stability: After controls have taken corrective action, oscillation of the final control element shall not exceed two cycles per minute or a magnitude of motion of 0.5% of full travel.
    2) Response: Any change in SP or controlled variable shall produce a corrective change in position of the final control element and stabilized within 30 seconds.
    3) Agreement: SP indication of controlled variable and measured indication of controlled variable shall agree within 3% of full scale over a 6 to 1 operating range.
    4) Repeatability: For any repeated magnitude of control signal, from either an increasing or decreasing direction, the final control element shall take a repeated position within 0.5% of full travel regardless of force required to position the final element.
    5) Sensitivity: Controls shall respond to a SP deviations and measured variable deviations within 1.0% of full scale.
    6) Performance: Instruments and control devices shall perform in accordance with the Manufacturer's specifications.

18. Discrete circuit configuration:
  a. Configure discrete control circuits to fail safe, on loss of continuity or loss of power.
  b. Alarm contacts: Fail to the alarm condition.
  c. Control contacts fail to the inoperative condition unless otherwise shown on the Drawings.

19. Grounding:
  a. Provide control panels with a signal ground bus, isolated from the power ground bus:
    1) Provide multiple panels in one location with a common point for signal ground bus connection to ground.
  b. Ground single-point ground shields and measurement loops at the source panel external terminals, unless otherwise noted, by bonding to the control panel signal ground bus.
  c. Provide isolating amplifiers within control panels for field equipment possessing a grounded input or output, except when the panel circuit is galvanically isolated.

EE. General Wiring Requirements Outside Enclosure:
  1. Conduit and wiring:
    a. Galvanized rigid conduit:
      1) Install and support the rigid conduit as required for a complete and operable system.
      2) Minimum size: 3/4 inch.

b. Liquidtight flexible conduit:
   1) Use flexible conduit for final connections between rigid conduit and motors, vibrating equipment, instruments, control equipment, or where required for servicing.
   2) Minimum size: 3/4 inch.
   3) Provide 1/2 inch where required for connection to instruments.
   4) Maximum length to fixed equipment 18 inches.
      a) Removable instruments or hinged equipment:
         (1) As required to allow complete removal or full movement without disconnecting or stressing the conduit.
c. Terminate at numbered barrier-type terminal blocks.
d. Provide an equipment ground conductor in every conduit.
e. Install conductors only after the conduit installation is complete and the enclosures have been vacuumed clean, and the conduits have been swabbed clean and dry.
   1) Properly coat wires and cables with pulling compound before pulling into conduits.
f. Apply wire markers to the wires at each end after being installed in the conduit and before meg-ohm testing and termination.
g. Install instrumentation class cables in separate raceway systems from power cables:
   1) Install cable without splices between instruments or between field devices and instrument enclosures or panels.
h. Conductor and cable markers.
i. Apply conductor and cable markers before termination.
   1) Heat-shrinkable tubing:
      a) Tubing shall be shrunk using a heat gun that produces low temperature heated air.
      b) Tubing shall be tight on the wire after it has been heated.
      c) Characters shall face the open panel and shall read from left to right or top to bottom.
      d) Marker shall start within 1/32 inch of the end of the stripped insulation point.

2. 600 V class wire and cable:
   a. Size wire in accordance with NFPA 70.
      1) Use 75ºC ampacity ratings.
      2) Ampacity rating after derating factors, equal to or greater than rating of the overcurrent device.
   b. Minimum power conductor size: #10 AWG.
   c. Minimum control conductor size: #14 AWG.
   d. Provide Class B stranding in accordance with ASTM B 8.
   e. Provide Class C stranding where extra flexibility is required.
   f. Insulation:
      1) XHHW-2.
      2) 90ºC rating.
3. Instrumentation class wire and cable:
   a. Suitable for use in wet locations.
   b. Voltage rating: 600 V.
   c. Temperature rating:
      1) 90ºC rating in dry locations.
      2) 75ºC rating in wet locations.
   d. Conductors:
      1) Insulation:
         a) Flame-retardant PVC, 15 mils nominal thickness, with nylon jacket 4 mils nominal thickness.
         b) #16 AWG stranded and tinned.
         c) Color code – ICEA Method 1:
            (1) Pair: Black and white.
            (2) Triad: Black, white and red.
            (3) Multiple pairs or triads: Color-coded and numbered.
   e. Drain wire:
      1) #18 AWG.
      2) Stranded, tinned.
   f. Jacket:
      1) Flame retardant, moisture and sunlight resistant PVC.
      2) Ripcord laid longitudinally under jacket to facilitate removal.
   g. Shielding:
      1) Individual pair/triad: Minimum 1.35 mil double-faced aluminum foil-polyester tape overlapped to provide 100% coverage.
      2) Multiple pair or triad shielding:
         a) Group shield: Minimum 1.35 mil double-faced aluminum foil-polyester tape overlapped to provide 100% coverage.
         b) Completely isolate group shields from each other.
         c) Cable shield: 2.35 mils double-faced aluminum and synthetic polymer backed tape overlapped to provide 100% coverage.
      3) Shielding shall be in contact with the drain wire.

4. Conductor and cable markers:
    a. Machine printed black characters on white tubing.
    b. 10 point type or larger.

FF. Field Instruments:

1. General:
    a. Instrument housing shall be rated NEMA Type 4X.
    b. Wetted materials shall be compatible with process fluid and the Manufacturer's recommendations for the intended service.
    c. For analog field transmitters, provide local LCD display.
    d. Provide sunshades for transmitters located outdoors.
    e. Provide hardware for instrument mounting.
    f. Factory calibrate each instrument.
    g. Analog instrument outputs: Isolated 4 mA to 20 mA DC.
    h. Highway addressable remote transducer instrumentation shall be able to interface with the OWNER's FieldCare software.

2.5 ACCESSORIES

A. Control Panel:

1. Provide panels with an inside protective pocket to hold the panel drawings. Ship panels with one copy of accepted Shop Drawings including, but not limited to, schematic diagram, connection diagram, and layout drawing of control wiring and components in a sealed plastic bag stored in the panel drawing pocket.
2. Provide 15 inch floor stands or legs where needed.
3. Provide a folding shelf for enclosures that contain programmable controllers. The shelf shall be mounted on the inside surface of the door, capable of supporting a laptop computer.
4. Provide nameplate to each panel:
    a. Provide identification for electrical systems on the internal and external instruments and devices.
    b. Provide a nameplate with the following markings that is plainly visible after installation:
        1) Manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the panel can be identified.
        2) Supply voltage, phase, frequency, and full-load current.
        3) Power source or circuit identification.
        4) Short-circuit current rating of the panel based on one of the following:
            a) Short-circuit current rating of a listed and labeled assembly.
            b) Short-circuit current rating established utilizing an approved method.
5. Provide a window kit where specified or where a transmitter with display is mounted inside a control panel. The window shall be in accordance with the following requirements:
    a. Safety plate glass.
    b. Secured by rubber locking seal.
    c. Allow full viewing of devices issuing visual process data or diagnostics.
6. Lighting:
    a. Provide one luminaire for each section, on the interior of the panel, spaced evenly along the top-front of the enclosure door opening(s):
        1) Covered or guarded.
        2) Provide On-Off door-activated switches as shown on the Drawings.
        3) 120 V, single-phase, 15 A style plug.
        4) Provide 4,000 K, 900 lumens – LED fixture.
            a) Provide additional fixtures for every 36 inches of width.
7. Receptacles:
    a. Provide one duplex receptacle located every 4 feet of enclosure width, spaced evenly along the back mounting panels.
    b. GFCI, 120 V, single-phase, 15 A style plug.
    c. Provide circuit breaker or fuse to limit receptacle draw to 5 A.
8. Grounding:
    a. Provide the following:
        1) Grounding strap between enclosure doors and the enclosure.
        2) Equipment grounding conductor terminals.
        3) Provide equipment ground bus with lugs for connection of the equipment grounding wires.
        4) Bond multi-section panels together with an equipment grounding conductor or an equivalent grounding bus.
    b. Identify equipment grounding conductor terminals with the word GROUND, the letters GND, the letter G, or the color green.
    c. Signal (24 VDC) grounding: Terminate each drain wire of a signal (shielded) cable to a unique grounding terminal block, or common ground bus at the end of the cable as shown on the loop drawings.
    d. Ensure the continuity of the equipment grounding system by effective connections through conductors or structural members.
    e. Design so that removing a device does not interrupt the continuity of the equipment-grounding circuit.
    f. Provide an equipment-grounding terminal for each incoming power circuit, near the phase conductor terminal.
    g. Size ground wires in accordance with NFPA 70 and UL standards, unless noted otherwise.

h. Connect the exposed, noncurrent-carrying conductive parts, devices, and equipment to the equipment-grounding circuit.
i. Connect the door stud on the enclosures to an equipment-grounding terminal within the enclosure using an equipment-bonding jumper.
j. Bond together the remote and LCPs, processor racks, and conductive enclosures of power supplies and connect to the equipment-grounding circuit to provide a common ground reference.

9. Provide PLC processor, power supply, I/O backplanes, and modules sized for connected I/O and required spares.
10. An LOI shall be provided on the face of the PCS enclosure for monitoring and control of the system. Additional LOIs may be provided on individual units LCPs at the System Supplier's discretion.
11. The PCS shall exercise control over the aspects of the system. Each unit shall be equipped with a control panel containing I/O modules and necessary interface with the plant control system.
    a. The PCS shall continuously monitor the operating parameters, and shall respond to alarms and emergency conditions by shutting down or activating system components. The PCS shall indicate alarm conditions locally at the LOI, and remotely for monitoring by the SCADA system in accordance with I/O points specified in this Section.
    b. The PCS's shall be integrated into the overall SCADA system via Ethernet/IP protocol without the use of a protocol converter.
    c. The SCADA system (provided by the ICSC) will be configured to store data for the system for reports and alarm generation. The System Supplier shall provide information on register addresses on the data, which shall be transmitted. The data register shall be contiguous for each data type.
12. Installed spare requirements:
    a. I/O points:
        1) Provide total of 25% spare I/O capacity for each type of I/O at every PLC and remote inputs and outputs.
        2) Wire spare I/O points to field terminal blocks in the same enclosure the PLC resides in.
    b. PLC backplane capacity (applicable to ControlLogix platform only): Provide 25% or three spare backplane slots, whichever is greater, in racks containing I/O.
    c. PLC memory: Provide 50% spare program volatile and non-volatile memory.
13. Provide corrosion-inhibiting vapor capsules within the control panels.

B. Provide flow conditioning devices or other required accessories if necessary, in accordance with the accuracy requirements in the Contract Documents.

C. Nameplates:
1. Provide a nameplate for each controller, instrument transducer, instrument power supply, solenoid, or any other control device located either in the field or within panels.
2. Nameplates shall be of identical style, color, and material throughout the facility.
3. Device nameplates shall include:
    a. Designations:
        1) Device tag and loop number identification (e.g., FIT-60.011).
        2) PLC identification (e.g., PLC11).
        3) Power information (e.g., LCP11, 120 VAC).
    b. Black lettering on a white background, laminated plastic.
4. Instruments shall be equipped with Type 316 SST nameplate with the instrument tag stamped in 3/8-inch letters and connected to the instrument using Type 316 SST wire.
5. Pilot devices:
    a. Large size square style aluminum field and black markings.
        1) Minimum letter and number height: 7/64 inch.
        2) Markings as shown on the Drawings and as approved by the ENGINEER.

D. Provide duplex patch cords to connect the interface cards provided with the associated patch panels.

E. Instruments:
1. Supply mounting brackets as needed.
2. Supply vibration dampeners to housing supports as needed.
3. Provide valve manifolds:
    a. Mount valve manifold integrally to the switch, gauge, or transmitter.
    b. Valve manifold and transmitter shall be assembled by the Manufacturer and shipped as an assembly.
4. Provide diaphragm seals as specified in data sheets or as required:
    a. Diaphragm seal and pressure switch, gauge or transmitter shall be assembled by the Manufacturer and shipped as an assembly.
5. Provide tube fitting, female NPT, or pipe butt weld connections if necessary.
6. Provide SST concentric or eccentric pipe nipples when necessary.
7. Provide sunshades for outdoor installations.

2.6 FABRICATION

A. The System Supplier shall provide the electrical and communication cables between the System and control panel, as required.

B. The incoming power supply, conduit, and field terminations shall be the responsibility of the CONTRACTOR.

C. The System Supplier shall identify the interconnection electrical service requirements (voltage, amperage, grounding, etc.) that need to be provided by the CONTRACTOR for a complete installation.

D. The System Supplier shall factory assemble and wire the electrical enclosures such that field wiring shall consists only of connections to terminals.

E. Wiring and cables shall be grouped together in harnesses and secured to the panel structure.

2.7 FINISHES

A. Control Panels:
   1. Finishes:
      a. SST: Type 316 enclosures shall be provided with a #4 brushed finish – not painted.
      b. Colors for non-stainless:
         1) Exterior color of panels mounted indoors shall be the Manufacturer's standard light gray.
         2) Exterior of panels mounted outdoors shall be the Manufacturer's standard white.
         3) Panel interiors shall be the Manufacturer's standard white.

PART 3 EXECUTION

3.1 GENERAL

A. The Work of this Section includes installation and startup of PCSs and associated instruments. Also included with this Work is support services, including training, and demonstration of equipment system performance.

B. Additional requirements as specified in SECTION 26 05 00 and SECTION 40 50 00.

C. Execution by the System Supplier shall involve the following:
   1. Providing special services to the OWNER's representative.
   2. Delivery, storage, and handling of the PCSs.
   3. Factory testing.
   4. Installation.
   5. Startup testing.
   6. Functional testing.
   7. Performance testing and certificate of proper installation.
   8. Training.
   9. Field testing and final acceptance.
   10. End of warranty inspection.

D. PLC:
   1. Utilize personnel to accomplish or supervise the physical installation of the elements, components, accessories, or assemblies: Employ installers who are skilled and experienced in the installation and connection of the elements, components, accessories, and assemblies.
   2. External components of the control system including the data network cables are the installation responsibility of the ICSC unless specifically noted otherwise.
   3. General: The control system logic program shall reside at the PLC level.
   4. Use the tag and loop identifications found on the P&IDs for tags used and/or assigned as part of the application software Work provided by the ICSC.
   5. Program the PLC logic using the following languages:
      a. Ladder diagram.
      b. Function block diagram.

E. Networking:
   1. Provide basic configuration for the managed Ethernet switches. Assign IP addresses per the OWNER's instructions and configure switches so data is transmitted between vendor-supplied components on vendor's network.
   2. The OWNER's programmer will provide advanced configuration of vendor Ethernet switches:
      a. Coordinate with the OWNER before the pre-FAT so the programmer can configure vendor switches.
      b. The process floor managed Ethernet switches for the process control network shall be configured and programmed for rapid fail over protection.
      c. Switches shall be configured to prevent broadcast storms. Installations utilizing Rockwell PLCs and multicast messaging shall employ internet group management protocol snooping on the Rockwell components.
   3. Cables and equipment shall be installed in strict accordance with the Manufacturer's recommendations:
      a. Cables shall be installed avoiding sharp bends.
      b. Install cable using lubricant designed for cable pulling.
      c. Cable ties or other cable supports shall be installed without crimping the LAN cables.
      d. Install LAN cables without splices.
      e. Installed bend radii shall not exceed four times the cable diameter.
      f. Terminated the pairs at the jack and the patch panel.
   4. Install cables a maximize distance between cables and electrical motors and transformers.
   5. Install cables a minimum of 12 inches away from fluorescent lighting.
   6. Individual pairs will be untwisted less than 1/2 inch at termination points.
   7. Each data port shall be individually labeled with its patch panel/switch port identification: Labeling shall be printed – no handwritten labels will be allowed.
   8. At the completion of the wiring installation, provide the following documentation:
      a. A plan-view of the premises showing the jack numbering scheme.
      b. A printed certification report for the entire wiring installation.
      c. Reports such as those generated by Fluke DSP cable certification equipment in accordance with this requirement.

F. Instrument Tagging:
   1. Provide field-mounted instruments with nameplates:
      a. Nameplates engraved with the instrument's full tag number: Affix tags with SST wire fasteners.
   2. Provide back of panel instruments with nameplates: Engraved with the instrument's full tag number.

3. Provide front of panel instruments with a nameplate:
    a. Engraving shall include the following:
        1) Instrument's full tag number.
        2) Service description.
    b. Nameplates:
        1) Secure nameplates to the panel with SST screws.
        2) Use an approved adhesive if screws would violate NEMA or other ratings of the enclosure.

G. Cable and Conductor Termination:
1. Terminate cables and conductors on terminal blocks.
2. Terminal block enclosures: Suitable for the area classification.

3.2 INSTALLATION

A. The System Supplier shall furnish instructions and supervise the Work of the CONTRACTOR regarding installation of the System. The CONTRACTOR shall install the System in strict accordance with the System Supplier's instructions.

B. Control Panel Installation:
1. Install the enclosure in accordance with guidelines and submitted installation instructions in accordance with the seismic requirements at the Project site.
2. Install enclosures so that their surfaces are plumb and level within 1/8 inch over the entire surface of the panel; anchor securely to structural supports at each corner, minimum.
3. Provided fabricated steel support pedestals for wall-mounted panels that weigh more than 200 lbs.
    a. Fabricate pedestals out of welded angle, tube sections, or preformed channel.
    b. If the supported equipment is a panel or cabinet, match the supported equipment in physical appearance and dimensions.
    c. Provide auxiliary floor supports for transformers hung from stud walls and weighing more than 200 lbs.
    d. Support al wall-mounted enclosures on minimum of 7/8 inch preformed mounting channel.
    e. Mount channel vertically along the length of the device so that water or moisture may run freely behind the device.
4. Install gasket and sealing material under panels with floor slab cutouts for conduit: Undercoat floor-mounted panels.
5. Provide a full-size equipment-grounding conductor in accordance with NFPA 70 included with the power feeder. Terminate to the incoming power circuit-grounding terminal.
6. The holes for field conduits, etc. shall be cut in the field. There shall be no additional holes, factory cut holes, or hole-closers allowed. Incorrect holes, additional holes, or mis-cut holes shall require that the entire enclosure be replaced.
7. Side panels shall be kept free of control equipment and devices. Any deviation shall be sent to the ENGINEER in writing asking for a deviation.

C. Equipment Tie-Downs:
1. Anchor instruments, control panels, and equipment by methods that are in accordance with seismic and wind bracing requirements, which apply to the site.
2. Control panels, PCSs, etc., shall be permanently mounted and tied down to structures.

D. Field Instruments Installation:
1. Install field instruments in accordance with API RP 550, API RP 551, the Manufacturer's instructions, and the Contract Documents.
2. Mount field instruments so that they can be easily read, readily approached, and easily serviced, and so they do not restrict access to mechanical equipment: Mount field instruments on a pipe stand or local panel, if they are not directly mounted.
3. Make connections from rigid conduit systems to field instruments with PVC coated flexible conduit:
    a. Type of flexible conduit required for the area classification.
    b. Maximum length of 18 inches.
4. Connect field instruments with cable in accordance with the Contract Documents except when the Manufacturer requires the use of special cable, or otherwise specified in this Section: Special cable applications shall be in accordance with NFPA 70.
5. Verify the correctness of each installation:
    a. Polarity of electric power and signal connections.
    b. Ensure process connections are free of leaks.
6. For instruments located outdoors or where instrument elements and transmitters are separated by conduit located outside the building envelope, provide SPDs at the transmitters.
7. Coordinate the installation with trades to ensure that the mechanical system has the necessary appurtenances including weld-o-lets, valves, etc. for proper installation of instruments and valves.
8. Do not use Teflon thread seal tape on pressure instruments with silicon oil fill fluid.

E. Process Sensing Lines and Air Tubing:
1. Install individual tubes parallel and/or perpendicular to and near the surfaces from which they are supported.
2. Provide supports for rigid tubing at intervals of not more than 3 feet.
3. Slope horizontal runs of instrument tubing at a minimum of 1/16 in/ft to allow for draining of any condensate.
4. Bends:
    a. Use proper tool.
    b. Make bends for parallel lines symmetrical.
    c. Make bends without deforming or thinning the walls of the tubing.
5. Square-cut and clean ends of tubing before being inserted in the fittings.
6. Provide bulkhead fittings at panels requiring pipe and/or tubing entries.

7. Use SST tubing for piping hard piped from the air header, unless not compatible with the fluids or atmosphere in the area: Use flexible connections only on moving equipment and under the constraint that the length shall be less than 1 1/2 times maximum travel of the equipment.

3.3 PROTECTION

A. Equipment shall be properly protected before, during, and after installation in accordance with the System Supplier recommendations.

B. Fully protect instruments after installation and before commissioning. Replace any instruments damaged before commissioning: The sole party responsible for determining the corrective measures is the ENGINEER.

C. Surge Protection:

1. Provide outdoor field instrument loops with voltage SPDs installed on the instruments.
2. Individually fuse each 4 mA to 20 mA DC loop with a 1/16 A fuse between power supplies and receiver surge protectors.
3. Provide voltage surge protection for four-wire transmitters and analyzers: Protect both power source and signal loop.

3.4 QUALITY CONTROL

A. Additional requirements as specified in SECTION 26 05 00 and SECTION 40 50 00.

B. Examine the installation location for the instrument and verify that the instrument will operate properly when installed.

C. Notify the ENGINEER promptly if any installation condition is not in accordance with the Instrument Manufacturer's recommendations or specifications.

D. Factory-calibrate each instrument. Provide complete documentation covering the traceability of calibration instruments.

E. VFD:

1. VFDs furnished under this Section shall be tested and inspected as specified in this Section. Testing of VFDs based on sampling plans is not allowed.
2. The testing procedures specified are the minimum acceptable requirements. The Manufacturer may perform additional tests at its discretion.
3. Failure of any component during testing requires repair of the faulted component and complete retest.
4. Tests:
   a. Perform the Manufacturer's standard FDTs: Provide the Manufacturer's certificate of installation and functionality compliance.
   b. NETA:
      1) Visual and mechanical inspection:
         a) Inspect physical and mechanical condition.
         b) Inspect anchorage, alignment, and grounding.
         c) Verify the unit is clean.
         d) Ensure vent path openings are free from debris and that heat transfer surfaces are clean.
         e) Verify correct connections of circuit boards, wiring, disconnects, and ribbon cables.
         f) Motor running protection:
            (1) Verify drive overcurrent SPs are correct for their application.
            (2) If drive is used to operate multiple motors, verify individual overload element ratings are correct for their application.
            (3) Apply minimum and maximum speed SPs. Verify SPs are within limitations of the load coupled to the motor.
         g) Inspect bolted electrical connections for high resistance using one of the following methods:
            (1) Use of low-resistance ohmmeter.
            (2) Verify tightness of accessible bolted electrical connections by the calibrated torque wrench method: Refer to the Manufacturer's instructions for proper foot-pound levels or ANSI/NETA ATS tables.
         h) Verify correct fuse sizing in accordance with the Manufacturer's published data.
         i) Perform visual and mechanical inspection of input circuit breaker as specified in this Section.
      2) Electrical tests:
         a) Perform resistance measurements through bolted connections with low resistance ohmmeter.
         b) Test the motor overload relay elements by injecting primary current through the overload circuit and monitoring trip time of the overload element.
         c) Perform insulation-resistance tests on control wiring with respect to ground. Applied potential shall be 500 VDC for 300 V rated cable and 1,000 VDC for 600 V rated cable. Apply the test voltage for 1 minute: For solid-state devices that cannot tolerate the applied voltage, follow the Manufacturer's recommendation.
         d) Test for the following parameters in accordance with relay calibration procedures in ANSI/NETA ATS or as recommended by the Manufacturer:
            (1) Input phase loss protection.
            (2) Input overvoltage protection.
            (3) Output phase rotation.
            (4) Overtemperature protection.
            (5) Direct current overvoltage protection.
            (6) Overfrequency protection.
            (7) Drive overload protection.
            (8) Fault alarm outputs.
         e) Perform continuity tests on bonding conductors in accordance with ANSI/NETA ATS.

f) Perform startup of drive in accordance with the Manufacturer's published data. Calibrate drive to the system's minimum and maximum speed control signals.
g) Perform operational tests by initiating control devices:
(1) Slowly vary drive speed between minimum and maximum. Observe motor and load for unusual noise or vibration.
(2) Verify operation of drive from remote start/stop and speed control signals.
h) Perform electrical tests of input circuit breaker as specified in this Section.
i) Measure fuse resistance.

3) Test values:
a) Compare bolted connection resistance values to values of similar connections: Investigate values which deviate from those of similar bolted connections by more than 50% of the lowest value.
b) Bolt-torque levels shall be in accordance with the Manufacturer's published data: Refer to ANSI/NETA ATS tables in the absence of the Manufacturer's published data.
c) Overload test trip times at 300% of overload element rating shall be in accordance with the Manufacturer's published time-current curve.
d) Test values for input circuit breaker shall be as specified in this Section.
e) Insulation-resistance values for control wiring shall not be less than 2.0 megohms.
f) Relay calibration results shall be as specified in this Section.
g) Continuity of bonding conductors shall be in accordance with ANSI/NETA ATS.
h) Control devices shall perform in accordance with system requirements.
i) Operational tests shall be in accordance with system design requirements.
j) Investigate fuse resistance values that deviate from each other by more than 15%.

F. Motor Starters, Low-Voltage:
1. Visual and mechanical inspection:
a. Inspect physical and mechanical condition.
b. Inspect anchorage, alignment, and grounding.
c. Verify the unit is clean.
d. Inspect contactors:
1) Verify mechanical operation.
2) Verify contact gap, wipe, alignment, and pressure is in accordance with the Manufacturer's published data.
e. Motor-running protection:
1) Verify overload element rating/motor protection settings are correct for its application.
2) If motor running protection is provided by fuses, verify correct fuse rating.
f. Inspect bolted electrical connections for high resistance using one of the following methods:
1) Use of low-resistance ohmmeter.
2) Verify tightness of accessible bolted electrical connections by calibrated torque wrench method: Refer to the Manufacturer's instructions for proper foot-pound levels or ANSI/NETA ATS tables.
g. Lubrication requirements:
1) Verify appropriate lubrication on moving current-carrying parts.
2) Verify appropriate lubrication on moving and sliding surfaces.

2. Electrical tests:
a. Perform resistance measurements through bolted connections with a low-resistance ohmmeter.
b. Perform insulation-resistance tests for 1 minute on each pole, phase-to-phase and phase to ground with the starter closed, and across each open pole for 1 minute:
1) Test voltage shall be in accordance with the Manufacturer's published data.
2) Refer to ANSI/NETA ATS tables in the absence of the Manufacturer's published data.
c. Perform insulation-resistance tests on control wiring with respect to ground. Applied potential shall be 500 VDC for 300 V rated cable and 1,000 VDC for 600 V rated cable. Apply the test voltage for 1 minute:
1) For solid-state devices that cannot tolerate the applied voltage, follow the Manufacturer's recommendation.
d. Test motor protection devices in accordance with the Manufacturer's published data.
e. Test circuit breakers as specified in this Section.
f. Perform operational tests by initiating control devices.

3. Test values:
a. Compare bolted connection resistance values to values of similar connections: Investigate values which deviate from those of similar bolted connections by more than 50% of the lowest value.
b. Bolt-torque levels shall be in accordance with the Manufacturer's published data: Refer to ANSI/NETA ATS tables in the absence of the Manufacturer's published data.
c. Insulation-resistance values shall be in accordance with the Manufacturer's published data:
1) Refer to ANSI/NETA ATS tables in the absence of the Manufacturer's published data.
2) Investigate values of insulation-resistance less than the allowable minimum.
d. Insulation-resistance values of control wiring shall not be less than 2 megohms.
e. Motor protection parameters shall be in accordance with the Manufacturer's published data.
f. Circuit breaker test results as specified in this Section.
g. Control devices shall perform in accordance with system design requirements.

3.5 STARTUP

A. As specified in SECTION 26 05 00 and SECTION 40 50 00. Specific requirement in addition to these Sections shall be as follows:

1. Operational readiness test prerequisite activities:
   a. Verification and setup of electrical overcurrent protective devices and circuits are properly functioning and functional.
   b. Verification that electrical instrumentation, control and network conductors sizes, types and quantity are proper.
      1) Conductor test have been performed and documented.
   c. Verification that electrical power supply system(s) are ready to supply power:
      1) 480 VAC power to PCS.
      2) 120 VAC UPS power to PCS.
   d. Conductor point-to-point verification has been performed and documented.
   e. Grounding system integrity has been verified and documented.
   f. Conductor and conduit labeling has been installed and verified.
   g. Verification that necessary monitoring and measuring devices are installed, calibrated, and ready for validation testing.
   h. Verification that related communication networks and systems are tested and functional.
   i. The System Supplier has provided a certificate of proper installation as specified in the SECTION 40 50 00.
2. Operational readiness test equipment devices and components:
   a. Electrical and power tests including field terminations, labeling and power consumption monitoring.
   b. Communication systems and networks test, including transmission rate, reliability, functionality, and performance.
   c. Functional tests including manual, auto, remote control, and operation.
   d. System configuration tests including verification, setup, and configuration of workstations, servers, switches, peripheral hardware and other communication devices or networks
   e. Complete end-to-end tests.
   f. Strategy field testing to verify operation of PLC logic, monitoring and interface with field devices.
3. System acceptance tests.
4. Facility reliability tests.

3.6 CLEANING

A. Vacuum clean control panels and enclosures before startup and again after final completion of the Project.
B. Clean panel surfaces.
C. Return to new condition any scratches and/or defects.
D. Wipe instrument faces and enclosures clean.
E. Leave wiring in panels, manholes, boxes, and other locations in a neat, clean, and organized manner:
   1. Neatly coil and label spare wiring lengths.
   2. Shorten, re-terminate, and re-label excessive spare wire and cable lengths, as determined by the ENGINEER.

3.7 ADJUSTING

A. Perform firmware installations, configuration and other set up, as required, to place the network into proper operation.
B. Verify factory calibration of instruments in accordance with the Manufacturer’s instructions.
C. Control Valves:
   1. Stroke control valves, cylinders, drives, and connecting linkages from the control system and local control devices and adjust to verify proper control action, hand switch action, limit switch settings, torque settings, remote control actions, and remote feedback of valve status and position.
   2. Check control valve actions and positioner settings with the valves in place to ensure that no changes have occurred since the bench calibration.
D. VFD:
   1. Provide the services of a VFD Manufacturer factory technician to make the drive parameters and protective device settings:
      a. Protective device settings provided by the VFD Manufacturer in accordance with the Manufacturer of the driven equipment requirements.
      b. Provide documentation of VFD settings included but not limited to:
         1) Minimum speed.
         2) Maximum speed.
         3) Skip speeds.
         4) Current limit.
         5) Acceleration time.
         6) Deceleration time.

END OF SECTION

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SECTION 40 72 73
RESERVOIR LEVEL GAUGE

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information, products, and execution for reservoir level gauge.

B. Related Sections:

1. SECTION 05 50 00 – METAL FABRICATIONS

1.2 SUBMITTALS

A. Shop Drawings:

1. The Manufacturer's technical literature and installation instructions for staff gauge.
2. Shop Drawings for staff gauge.

PART 2 PRODUCTS

2.1 APPROVED MANUFACTURERS

A. Gauge Strips:

1. Stevens, Stream Gauge Style E

2.2 MATERIALS

A. Gauge Strips and Figure Plates:

1. Constructed of porcelain enamel iron gauge strips graduated in tenths of a foot. Gauge strips and figure plates shall be mounted where shown on the Drawings. Use SST screws with brass grommets in accordance with the Manufacturer's requirements. Supply staff gauge in sections to the nearest foot to the elevations shown.
2. Gauge strips shall be similar to Stevens Stream Gauge Style E:
   a. Style E is 3 1/2 inches wide, graduated in feet and tenths. Separate figure plates (black figures on 3 inch by 4 inch white porcelain enameled) are to be fastened on the wall to number elevations at 1 foot intervals.
   b. For gauges on slopes, a product similar to the Style E with graduated markings for every vertical foot and tenth of a vertical foot shall be supplied for the staff gauge along the slope. The staff gauge shall be porcelain enameled plates or metallic and of a noncorrosive material. Survey the sloped concrete structure before fabrication to confirm markings will be accurate in the vertical elevation over the entire length of the gauge.

B. Gauge Boards: Mount gauge sections and numbers on synthetic boards as recommended by the Gauge Manufacturer. Use separate boards for numbers and gauge sections. Provide sufficient board length so the gauge and numbers are completely supported from top to bottom and side to side.

C. Board Anchors: SST threaded rod and hardware and epoxy adhesive as specified in SECTION 05 50 00.

PART 3 EXECUTION

3.1 GENERAL

A. Allow a minimum of 7 days for concrete to cure before installing staff gauges.

B. Survey staff gauges before installation so that when installed the markings will correspond to elevations within a tolerance of ±0.02 foot vertically.

C. Survey installed staff gauges to confirm installed elevations.

3.2 INSTALLATION

A. Staff Gauge:

1. Install staff gauge in accordance with the Manufacturer's instructions and as specified in this Section.
2. Orient gauge boards and gauge strips where shown on the Drawings.
3. Install figure plate elevation numbers centered at each vertical foot adjacent to the gauge sections. The top and bottom elevation number plates may be installed flush with the bottom and top of the gauge respectively.
4. Mount gauge boards and gauge strips with a reference level of zero at the invert elevation of each structure.
5. Do not over-tighten screws and damage gauge porcelain.

END OF SECTION

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SECTION 40 80 01
PROCESS PIPING LEAKAGE TESTING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for process piping leakage testing.

B. Related Sections:

1. SECTION 40 05 00 – PROCESS PIPING – GENERAL

1.2 REFERENCES

A. Chlorine Institute, Inc. (CI):

1. Pamphlet 6 – Piping Systems for Dry Chlorine

1.3 SUBMITTALS

A. Quality Control Submittals:

1. Testing plan: Submit prior to testing and, at a minimum, include:
   a. Testing dates.
   b. Piping systems and sections to be tested.
   c. Test type.
   d. Method of isolation.
   e. Calculation of maximum allowable leakage for piping section(s) to be tested.
2. Certifications of calibration: Testing equipment.
3. Certified test report.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 PREPARATION

A. Notify the ENGINEER in writing 5 days in advance of testing. Perform testing in the presence of the ENGINEER.

B. Pressure Piping:

1. Install temporary thrust blocking or other restraint as necessary to protect adjacent piping or equipment and make taps in piping prior to testing.
2. Wait 5 days, at a minimum, after concrete thrust blocking is installed to perform pressure tests. If high-early strength cement is used for thrust blocking the wait time may be reduced to 2 days.
3. Prior to testing, remove or suitably isolate appurtenant instruments or devices that could be damaged by pressure testing.
4. Chlorine piping: Test, dry, and clean in accordance with CI Pamphlet 6.
5. New piping connected to existing piping:
   a. Isolate new piping with grooved end pipe caps, spectacle blinds, blind flanges, or as acceptable to the ENGINEER.
   b. Test the joint between new piping and existing piping by methods that do not place the entire existing system under test load, as approved by the ENGINEER.
6. Items that do not require testing: Piping between wetwells and wetwell isolation valves, tank overflows to atmospheric vented drains, and tank atmospheric vents.
7. Test pressure: As specified in SECTION 40 05 00.

C. The test section may be filled with water and allowed to stand under low pressure prior to testing.

D. Gravity Piping:

1. Perform testing after service connections, manholes, and backfilling are complete between the stations to be tested.
2. Determine the groundwater level at the time of testing by using exploratory holes or other acceptable methods to the ENGINEER.
3. 42 inch diameter and larger pipe: A joint testing device may be used to isolate and test individual joints.

3.2 QUALITY CONTROL

A. Hydrostatic Test for Pressure Piping:

1. Fluid: Clean water of such quality to prevent the corrosion of materials in the piping system.
2. Exposed piping:
   a. Perform testing on installed piping prior to the application of insulation.
   b. Maximum filling velocity: 0.25 fps, applied over full area of pipe.
   c. Vent piping during filling. Open vents at high points of the piping system or loosen flanges, using at least four bolts, or use equipment vents to purge air pockets.
   d. Maintain hydrostatic test pressure continuously for 60 minutes, at a minimum, and for such additional time as necessary to conduct examinations for leakage.
   e. Examine joints and connections for leakage.
   f. Correct visible leakage; retest until pipe passes.
   g. Empty pipe of water prior to final cleaning or disinfection.
3. Buried piping:
   a. Test after backfilling is completed.
   b. Expel air from the piping system during filling.
   c. Apply and maintain the specified test pressure with a hydraulic force pump. Valve off the piping system when the test pressure is reached.
   d. Maintain the hydrostatic test pressure continuously for 2 hours, at a minimum, re-opening the isolation valve only as necessary to restore the test pressure.

e. Determine actual leakage by measuring the quantity of water necessary to maintain the specified test pressure for the duration of the test.
f. Maximum allowable leakage for joints with gaskets:

$$L = \frac{SD(P)^{1/2}}{133{,}200}$$

Where:
L = Allowable leakage (gph)
S = Length of pipe tested (ft)
D = Nominal diameter of pipe (in)
P = Test pressure during leakage test (psi)

g. Correct leakage greater than allowable; retest until pipe passes.

B. Pneumatic Test for Pressure Piping:
1. Do not perform on:
   a. PVC or CPVC pipe.
   b. Piping larger than 18 inches.
   c. Buried and other non-exposed piping.
2. Fluid: Oil-free, dry air.
3. Procedure:
   a. Apply a preliminary pneumatic test pressure of 25 psig, at a maximum, to the piping system prior to final leak testing to locate visible leaks. Apply a soap bubble mixture to joints and connections; examine for leakage.
   b. Correct visible leaks and repeat the preliminary test until visible leaks are corrected.
   c. Gradually increase pressure in the system to half of the specified test pressure. Thereafter, increase pressure in steps of approximately 1/10 of the specified test pressure until the required test pressure is reached.
   d. Maintain pneumatic test pressure continuously for 10 minutes, at a minimum, and for such additional time as necessary to conduct the soap bubble examination for leakage.
   e. Correct visible leakage; retest until pipe passes.
4. Allowable leakage: The piping system, exclusive of possible localized instances at the pump or the valve packing, shall show no visual evidence of leakage.
5. After testing and final cleaning, purge with nitrogen those lines that will carry flammable gases to assure no explosive mixtures will be present in the system during the filling process.

C. Hydrostatic Test for Gravity Piping:
1. Testing equipment accuracy: ±1/2 gallon water leakage under specified conditions.
2. Maximum allowable leakage: 0.16 gph/in diameter/100 feet; include service connection footage in the test section, subjected to minimum head specified.
3. Roof drain piping: Test with 15 feet of water to include the highest horizontal vent in filled piping. Where vertical drain and vent systems exceed 15 feet in height, test systems in 15 foot vertical sections as piping is installed.
4. Exfiltration test:
   a. Hydrostatic head:
      1) At least 6 feet above the maximum estimated groundwater level in the section being tested.
      2) No less than 6 feet above the inside top of the highest section of pipe in the test section, including service connections.
   b. Length of pipe tested: Limit length such that pressure on the invert of the lower end of the section does not exceed 30 feet of WC.
5. Groundwater level infiltration test: At least 6 feet above the inside top of the highest section of pipe in the test section, including service connections.
6. Piping with a groundwater infiltration rate greater than allowable leakage rate for exfiltration will be considered defective even if the pipe previously passed a pressure test.
7. Defective piping sections: Replace or test and seal individual joints; retest until pipe passes.

D. Vacuum Testing for Chlorine Gas Vacuum Piping:
1. Isolate and test sections of the vacuum piping to test the vacuum as specified in SECTION 40 05 00.
2. After vacuum is established in the pipe section and verified with a calibrated vacuum gauge, isolate the pipe section and continue to measure the vacuum in the pipe section over a 60-minute period. The maximum allowable vacuum reduction in the pipe section after 60 minutes shall be 5% of the specified test vacuum (e.g., if the test vacuum is specified as 20 inch Hg, the vacuum reading at the end of the test shall be at least 19 inch Hg vacuum).
3. Defective pipe sections shall be corrected and retested.

E. QUALITY CONTROL
1. Test report documentation shall include:
   a. Test date.
   b. Description and identification of piping tested.
   c. Test fluid.
   d. Test pressure.
   e. Remarks, including the type and location of leaks and the repair or replacement performed to remedy excessive leakage.
   f. The signature of the CONTRACTOR and the ENGINEER to attest the test was satisfactorily completed.

END OF SECTION

SECTION 48 70 00
GENERATOR STARTUP AND COMMISSIONING

PART 1 GENERAL

1.1 SUMMARY

A. Section includes general information and execution for startup and commissioning.

B. Related Sections:
   1. SECTION 01 91 00 (.01 or .02) – COMMISSIONING
   2. SECTION 26 05 00 – COMMON WORK RESULTS FOR ELECTRICAL
   3. SECTION 26 08 00 – COMMISSIONING OF ELECTRICAL SYSTEMS
   4. SECTION 40 50 00 – INSTRUMENTATION AND CONTROL SYSTEMS

1.2 REFERENCES

A. Institute of Electrical and Electronics Engineers (IEEE):
   1. C57.13.1 – Guide for Field Testing of Relaying Current Transformers

1.3 DEFINITIONS

A. Commissioning: The commissioning period begins when the facility has been successfully started up, as defined in this Section, and has met Substantial Completion date requirements.

B. Functional Test: A test or tests performed in the presence of the ENGINEER to demonstrate the modified equipment or system meets the OWNER's installation and adjustment requirements.

C. Performance Test: A test performed in the presence of the ENGINEER, and after any required functional test specified, to demonstrate and confirm the equipment and/or system meets the specified performance requirements.

D. Significant Interruption (may include any of the following events):
   1. Failure of the CONTRACTOR to maintain qualified on-site startup personnel as scheduled.
   2. Failure to meet specified performance for more than 4 consecutive hours.
   3. Failure of any critical equipment unit, system, or subsystem that is not satisfactorily corrected within 5 hours after failure.
   4. Failure of a noncritical unit, system, or subsystem that is not satisfactorily corrected within 8 hours after failure.
   5. As determined by the ENGINEER.

E. Startup: Includes putting the complete facility in operating order, cleaning, adjusting, and balancing equipment, initial operation (startup) of equipment item, operating equipment, starting systems, operation of systems, testing of equipment and systems, and the demonstration and verification of the completed facility as a unit.

F. Startup Test Period:
   1. Startup of the entire facility or any portion thereof includes coordinated operation of the facilities by the CONTRACTOR, the Subcontractors, the ENGINEER’s operating personnel, and the Manufacturer's Representative for equipment items and systems after the required functional tests have been completed and those performance tests deemed necessary for the safe operation of the entire facility have been completed.
   2. Startup of the entire facility shall be considered complete when, in the opinion of the ENGINEER, the facility has operated in the manner intended for 7 continuous days without significant interruption. This period is in addition to and shall follow the completion of any functional and performance test periods specified elsewhere. A significant interruption shall require the startup then in progress to be stopped and restarted after corrections are made.

G. System: The overall process, or a portion thereof, that performs a specific function. A system may consist of two or more subsystems as well as two or more types of equipment. Examples of systems:
   1. Pumping system.
   2. Turbine/generator control system.
   3. Hydraulic power unit.
   4. Electric valve operators.
   5. Excitation system.
   6. Protection system.
   7. I&C system.
   8. Dam top equipment.
   9. Electrical distribution system.

1.4 SUBMITTALS

A. As specified in SECTION 26 05 00.

B. ENGINEER's Review: The ENGINEER will act upon the CONTRACTOR's Submittal and transmit a response to the CONTRACTOR no later than 30 days after receipt. Resubmittals will be subject to the same review time.

C. Administrative Submittals:
   1. The startup and commissioning manual shall be approved by the ENGINEER before startup and commissioning can proceed; it shall include:
      a. A schedule including time durations for each test, test plan, procedures, and log format.
      b. A listing of the sequential steps that shall be observed to demonstrate the equipment as a whole functions as intended.
      c. The starting and stopping of auxiliary equipment in manual, automatic, and remote mode. Intermediate events such as auxiliary device operation, auxiliary equipment start/stop, alarms, trips, and monitoring shall be listed for verification in the proper sequence.

D. Quality Control Submittals:
   1. Manufacturer's certificate of proper installation as required.
   2. Test reports: Functional testing and performance testing in a format acceptable to the ENGINEER and certification of functional test for each piece of equipment or system specified.

1.5 QUALITY ASSURANCE

A. CONTRACTOR Facility Startup Responsibilities:

1. General:
   a. Perform Work for tests specified, including existing equipment.
   b. Demonstrate proper installation, adjustment, function, performance, and operation of equipment.

B. OWNER/ENGINEER Facility Startup Responsibilities:

1. General:
   a. Review the CONTRACTOR's test plan and schedule.
   b. Witness each functional or performance test.
   c. Coordinate other OWNER operations, if necessary, to facilitate the CONTRACTOR's tests.
   d. Provide PLC/RTU and computer software support.
   e. Provide water, power, and other items as required for testing.
2. Startup test period: Operate process units and devices with the support of the CONTRACTOR.

PART 2 PRODUCTS (NOT USED)

PART 3 EXECUTION

3.1 PREPARATION

A. General:

1. Complete Work associated with the unit and related processes before testing, including related Manufacturer's Representative services.
2. Furnish a qualified Manufacturer's Representative when required to assist in testing.
3. Schedule and attend pretest, functional, and performance meetings related to the test schedule; plan of test; materials required; facilities' operations interface; and ENGINEER and OWNER involvement.
4. Commissioning Manager as specified in SECTION 01 91 00, is responsible for coordinating and expediting the CONTRACTOR's facility startup duties. The Commissioning Manager shall be present during facility startup meetings and shall be available at all times during the facility startup period.
5. Provide temporary valves, gauges, piping, test equipment, and other materials and equipment required to conduct testing.
6. Coordinate tests, startups, and commissioning with the electric utility and the ENGINEER.

B. Cleaning and Checking Prior to Starting Functional Testing:

1. Calibrate testing equipment for accurate results.
2. Inspect and clean equipment, devices, connected piping, and structures so they are free of foreign material.
3. Lubricate equipment in accordance with the Manufacturer's instructions.
4. Turn rotating equipment by hand and check motor-driven equipment for correct rotation.
5. Open and close valves by hand and operate other devices to check for binding, interference, or improper functioning.
6. Check the power supply to electric-powered equipment for correct voltage.
7. Adjust clearances and torques.
8. Obtain completion of applicable portions of the Manufacturer's certificate of proper installation.

C. Ready-to-Test Determination will be by the ENGINEER based at least on:

1. Notification by the CONTRACTOR of equipment and system readiness for testing.
2. Acceptable testing plan.
3. Acceptable O&M manuals.
4. Receipt of the Manufacturer's certificate of proper installation, if specified.
5. Adequate completion of Work adjacent to, or interfacing with, equipment to be tested, including items to be furnished by OWNER.
6. Availability and acceptability of the Manufacturer's Representative, when specified, to assist in the testing of respective equipment and satisfactory fulfillment of other specified Manufacturer's responsibilities.
7. Equipment and electrical tagging complete.
8. Spare parts and special tools delivered to the ENGINEER.

3.2 QUALITY CONTROL

A. Functional Testing:

1. General:
   a. Coordinated with additional testing as specified in SECTION 26 08 00 and SECTION 40 50 00.
   b. Begin testing at a time mutually agreed upon by the ENGINEER, the Manufacturer's Representative, and the CONTRACTOR.
   c. Notify in writing the ENGINEER and the Manufacturer's Representative at least 14 days prior to the scheduled date of functional tests.
   d. Conduct functional testing until each individual component item or system has achieved 4 continuous hours of satisfactory operation. Demonstrate that operational features and controls function during this period while in automatic modes.
   e. If, in the ENGINEER's opinion, each system meets the functional requirements specified, such system shall be accepted as conforming for purposes of advancing to performance testing phase, if required. If, in the ENGINEER's opinion, the functional test results do not meet the requirements specified, the systems shall be considered nonconforming.
   f. Performance testing shall not commence until the equipment or system meets the functional tests specified.
2. Automatic operation setup:
   a. Tune automatic control loops.

b. Verify the operation of automatic and remote shutdowns and alarms including, but not limited to:
   1) PLC failure/watchdog.
   2) Analog signal failure.
   3) Process controller, loading station failure.

B. Performance Testing:
1. General:
   a. Follow the approved testing plan and the detailed procedures specified.
   b. Begin testing at a time mutually agreed upon by the ENGINEER, the OWNER, the Manufacturer's Representative, and the CONTRACTOR. The ENGINEER will be present during the test.
   c. Unless otherwise indicated, furnish labor, materials, and supplies for conducting the test and taking samples and performance measurements.
   d. Prepare the commissioning report summarizing the test method. Include test logs, pertinent calculations, and certification of performance.
2. Equipment performance tests:
   a. Conduct performance tests on equipment in accordance with the equipment specification and after functional testing is completed.
   b. Conduct performance tests on systems. Demonstrate the correct operation of systems and equipment to the ENGINEER. The ENGINEER shall approve the operation of systems and equipment.
   c. Assist the Manufacturers with the setup, startup, and testing of OWNER-furnished equipment.
3. System performance tests:
   a. Conduct testing on systems. The testing shall include, but not be limited to:
      1) Recording of pertinent data, as directed by the ENGINEER.
      2) Initial hydraulic rotation, speed checks of the equipment.
      3) Operation of equipment at various design conditions and operating points.
      4) Demonstration of automatic and remote control, by the ENGINEER and the CONTRACTOR (a combined effort).
      5) Operation of utility synchronized equipment, after receiving written approval from the electric utility and the ENGINEER.
      6) Demonstrate equipment operation in manual mode, automatic mode, and remote mode.
      7) Load equipment at increments of 25%, 50%, 75%, and 100% of rated capacity.
      8) Demonstration of control in automatic at multiple setpoints.
      9) Demonstration of remote control by a combined effort of the ENGINEER and the CONTRACTOR.
      10) Various trip tests, as required, directed by the electric utility and the ENGINEER.
      11) Continuous uninterrupted off-line operation for 1 day.
      12) Continuous uninterrupted on-line operation for 1 day.
   b. If, in the opinion of the ENGINEER, each system meets the requirements specified, it shall be functionally complete. If, in the opinion of the ENGINEER, the test results do not meet the requirements specified, the system shall be considered non-conforming. In the case of a non-conforming system, advancement to the startup phase shall not commence until the CONTRACTOR has made such adjustments, changes, and additions necessary to correct the system and retest it as specified and, in the opinion of the ENGINEER, the system functions as specified.
   c. Documentation: Prepare a performance testing report for each piece of equipment and complete system tested. Summarize the testing method, including test logs and pertinent calculations, and obtain the Manufacturer's signed statement recommending continuous operation.
4. Startup test period:
   a. Test reports: As applicable to the equipment furnished, certify in writing that:
      1) Necessary hydraulic structures, piping systems, and valves have been successfully tested.
      2) Equipment systems and subsystems have been checked for proper installation, started, and successfully tested to indicate they are operational.
      3) Systems and subsystems are capable of performing their intended functions.
      4) Facilities are ready for intended operation.
   b. Attend planning meetings and arrange for attendance by the Equipment Manufacturer's Representative as required by the Contract Documents.
   c. Designate and furnish one or more persons to be responsible for coordinating and expediting the CONTRACTOR's facility startup duties.
   d. When the facility startup has commenced, schedule remaining Work so as not to interfere with or delay the completion of the facility startup. Support the facility startup activities with adequate personnel to prevent delays and process upsets.
   e. Supply and coordinate the specified Manufacturer's facility startup services.
   f. Make the adjustments, repairs, and corrections necessary to complete facility startup.
   g. After the facility is operating, complete the testing of those items of equipment, systems, and subsystems that could not be or were inadequately or unsuccessfully tested prior to the startup test period.

C. Demonstration of Protective Devices:
1. General:
   a. Demonstrate the correct operation of protective relays and protective device, shutdowns, trips, and alarms to the electric utility and the ENGINEER.
   b. Only qualified electricians and technicians shall perform the demonstrations.

c. The demonstration shall be divided into:
   1) Calibration.
   2) Trip checks.
   3) On-line tests.

2. Calibration:
   a. Proper testing and verification of CTs, PTs, and the settings of the relays shall be demonstrated to the electric utility and the ENGINEER.
   b. Testing and calibration of CTs, PTs, and relays shall be performed with test equipment calibrated to the Manufacturer's specifications. Provide certified documentation of test equipment calibration.
   c. CT verification, perform checks in accordance with IEEE C57.13.1:
      1) Ratio check.
      2) Polarity check.
      3) Excitation, saturation, test reports from the Manufacturer.
      4) Insulation resistance, Megger, test.
   d. PT verification, perform checks in accordance with IEEE C57.13.1:
      1) Ratio check.
      2) Polarity check.
   e. Relays:
      1) Test in accordance with the Manufacturer, electric utility, and ENGINEER's acceptance.
      2) Tests on nominal recommended settings for:
         a) Pickup parameters on each operating element.
         b) Timing at three points on time-current curve.
         c) Pickup target and seal-in units.
         d) Special tests as required to check operation of restraint, directional, and other elements in accordance with the Manufacturer's instruction manual.
      3) Phase angle and magnitude contribution tests on differential and directional relays after energization to vectorially verify proper polarity and connections.
      4) Current injection tests:
         a) For entire current circuit in each section.
         b) Secondary injection for current flow of 1 A.
         c) Test current at each device.

3. Trip checks:
   a. Relays shall be functionally operated to demonstrate proper breaker operation.
   b. Verify that breakers cannot be manually or automatically closed with the trip relay in the latched or tripped position.
   c. Demonstrate that interlocks between breakers operate properly.
   d. Demonstrate that breakers cannot be closed manually or automatically without resetting the 86 lockout device.
   e. The synchronizing system shall be thoroughly tested by injection of two voltage sources that can be varied in both voltage level and phase angle difference.

4. On-line tests: Test relays on-line as directed by the electric utility and the ENGINEER. Tests shall include, but shall not be limited to, removing potential to the relay (27), interchanging two of the potential inputs (47), etc.

D. Commissioning of the entire facility shall be considered complete when:
   1. Successful facility startup is completed and documented.
   2. Reports are submitted and approved.
   3. The continuous hours of operation, without significant interruption, are completed.
   4. The Manufacturer's services are completed for training of the ENGINEER's personnel.

END OF SECTION