

14.0 Electrical

14.1 Design Requirements

14.1.1 Electrical

The Contractor shall design, procure, install, and test electrical items in scope for all areas on the Project. The electrical designs shall include the electrical requirements for the Freeze Protection System and Tunnel Enhanced Fire Safety System as described in Book 2, Section 19, and all associated components listed in Design Requirements and Criteria. The contractor shall refer to Book 1 Section 2.3.5.6 for all Permitting responsibility.

The Contractor shall design and construct all electrical elements required to provide a fully operational system in accordance with the requirements of the standards listed in Table 14-1 as appropriate for the jurisdictional ownership, oversight, and approval of the Work.

Table 14-1: Electrical Standards

	Author	Title
1	CDOT	<i>Standard Specifications for Road and Bridge Construction Section 202, 210, 613, 622</i>
2	NFPA	<i>30 - Flammable and Combustible Liquids Code</i>
3	NFPA	<i>70 - National Electrical Code</i>
5	NFPA	<i>502 - Road Tunnels, Bridges, and other Limited Access Highways</i>

14.1.2 Freeze Protection

14.1.2.1 Freeze Protection Design Requirements

The Contractor shall design, procure, install, and test complete freeze protection system for the piping identified below within the Project area including the north and south tunnels, east and west portals and crosscut electrical rooms, and the roof drains. The design shall include replacing the existing heat trace cables, heat trace controls and associated components with new freeze protection system. The plans shall include any existing heat trace equipment demolition, new routing, new controls, electrical equipment and elevations, electrical connections, and all necessary warning, supplemental, and regulatory labels. No in-line splicing of heat trace cables is allowed without prior approval of CDOT project engineer. Coordinate and verify existing conditions and gather information on the operational needs of each tunnel with CDOT maintenance staff to understand all areas of concern in the scope of the Project.

Within 60 days of NTP 2, the contractor shall perform a field investigation to verify locations of existing heat trace in the existing 16 manholes in the South Tunnel left

lane and existing 30 manholes in the North Tunnel left lane. Investigation will include but not limited to: traffic control, removal of pavement to gain access to manhole, document manhole location, existing number, size and material type of pipes, instances of heat trace, heat trace length and circuiting, then asphalt cold patch to reopen roadway. Field documented information shall be provided in a report to CDOT within 14 days of investigation of each tunnel bore. Based on this report, CDOT will determine if additional work is required. Additional work will be handled via Book 1 Section 13. The contractor shall repair impacted pavement sections from this investigation in accordance with Book 2 Section 10 prior to Substantial Completion.

Where existing heat trace associated electrical panels are removed and existing branch circuits feeding non-related loads are to remain, provide a new 3 phase panelboard. New panelboard shall be provided with a new feeder connected to an existing switchboard. Provide new circuit breaker in existing switchboard. Contractor shall confirm with Tunnel M&O which existing circuiting is still utilized and shall remain.

Required Freeze Protection for North Tunnel Pipes:

- Existing Roof Drains
- Existing Seep Main North: Minimum of 990' of from each side.
- Existing Seep Main South: Minimum of 990' from each side.
- Existing 18" Ductile Iron Sewer: Minimum of 990' from each side.
- Existing 6" Ductile Iron Storm: Minimum of 990' from each side.
- Existing Collector Pipes North Lane: Minimum of 990' from each side.
- Existing Collector Pipes South Lane: Minimum of 990' form each side.
- New 4" Galvanized Steel Water Main: Entire length of pipe.

Required Freeze Protection for South Tunnel Pipes:

- Existing Roof Drains
- Existing Seep Main North: Minimum of 990' from each side.
- Existing Seep Main South: Minimum of 990' from each side.
- Existing 12" Ductile Iron Sewer South Lane: Minimum of 990' from East side.
- Existing 12" Ductile Iron Sewer South Lane: Minimum of 4,500' from West side.
- Existing 6" Ductile Iron Storm: Minimum of 990' from each side.
- Existing Collector Pipes North Lane: Minimum of 990' from each side.
- Existing Collector Pipes South Lane: Minimum of 990' from each side.

Freeze protection solutions presented and approved must be compatible with the existing components in the Project that shall remain. The freeze protection system shall have monitoring and alarming and be able to remotely monitor the new system(s) and / or circuits for power failure. Add to the existing SCADA system ability to monitor freeze protection status and provide alarms for the new freeze protection System. Refer to Special Provisions Revisions to Section 210 - SCADA System Integration and Integrator Requirements. If heat trace is approved freeze protection solution, refer to 14.1.2.2 and Special Provisions Section 220533 - Heat Tracing for Plumbing Piping, Heat Trace Pipe Freeze Protection and Flow Maintenance System. Freeze protection design shall comply with the requirements of the most current publications of the Standard Specifications, and the National Electric Code.

14.1.2.2 Heat Trace Design Criteria

Contractor shall verify and provide calculations for freeze protection required in pipes listed below. Refer to the Heat Trace block diagram for additional requirements and control sequencing in Reference Documents.

North Tunnel:

- Control distribution panels with a main feed, (1) ambient air sensing temperature sensor tied to distribution panel, (1) snow controller wired into distribution panel and (1) snow sensor for roof drains shall be provided. Distance between each manhole is approximately 600 feet.
- Heat Trace Cable
 - Existing Roof Drains
 - Existing Seep Main North: Maximum circuit lengths of 419’.
 - Existing Seep Main South: Maximum circuit lengths of 419’.
 - Existing 18” Ductile Iron Sewer: Maximum circuit lengths of 419’.
 - Existing 6” Ductile Iron Storm: Maximum circuit lengths of 419’.
 - Existing Collector Pipes North Lane: Maximum circuit lengths of 419’.
 - Existing Collector Pipes South Lane: Maximum circuit lengths of 419’.
 - New 4” Galvanized Steel Water Main: Maximum circuit lengths of 600’.

South Tunnel:

- Control distribution panels with a main feed, (1) ambient air sensing temperature sensor tied to distribution panel, (1) snow controller wired into distribution panel and (1) snow sensor for roof drains shall be provided. Contactor Panels shall be installed throughout the tunnel in crosscut electrical rooms to control the freeze protection for the Water Main. Distance between each manhole is approximately 300 feet.

- Heat Trace Cable
 - Existing Roof Drains
 - Existing Seep Main North: Maximum circuit lengths of 419’.
 - Existing Seep Main South: Maximum circuit lengths of 419’.
 - Existing 12” Ductile Iron Sewer South Lane: Maximum circuit lengths of 419’.
 - Existing 6” Ductile Iron Storm: Maximum circuit lengths of 419’.
 - Existing Collector Pipes North Lane: Maximum circuit lengths of 419’.
 - Existing Collector Pipes South Lane: Maximum circuit lengths of 419’.

Existing electrical panels, HOA switches, contactors, and controls shall be removed and replaced with new distribution panels and controls in the East and West Main Electrical Rooms. Identify, inspect, maintain, and label existing branch circuiting.

Existing raceway shall be used if possible after conducting site verification. Associated electrical panels and equipment that are beyond useful life shall be replaced with new, including feeders. Verify existing equipment connection points, where power circuits are fed from and determine the best approach / installation method.

Any heat trace circuits currently fed from existing LCPs in East and West Main Electric Rooms shall be re-fed to new heat trace panels. Heat trace circuits currently fed from crosscut electric room LCPs shall be replaced with new circuiting and new monitoring but fed from same source. The monitoring system(s) shall be linked together to a common location. Electrical equipment shall be placed in easily accessible range of the new heat trace connections for maintenance and operations purposes.

14.2 Construction Requirements

14.2.1 Electrical Work - Required Qualifications of Personnel

All Electrical Work being constructed or installed by the Contractor or its Subcontractors shall be completed by personnel meeting the requirements of Licensed Journeymen Electrician, Licensed Master Electrician, or Electrical Apprentices as defined in Book 1 Appendix A. The Contractor shall provide documentation to CDOT demonstrating compliance with this requirement prior to commencing any Electrical Work activities.

14.2.2 Special Construction Requirements

All Work requiring an electrical outage shall be performed during specific outage periods as identified and approved by CDOT.

All complete or partial outages shall be scheduled with CDOT 48 hours prior to the requested time and shall only be performed during the hours 10 PM to 6 AM each day

Sunday night through Friday morning. The Contractor shall provide back-up power (from a contractor supplied generator or power from a source not affected by the outage) to equipment deemed critical by CDOT.

Prior to performing any work on existing electrical equipment, the Contractor and CDOT will perform an equipment conditions assessment. Any noted deficiencies, non-operable parts and excessive wear & tear shall be documented with pictures and narratively described in a report. CDOT and the Contractor must agree to these pre-existing conditions prior to any work commencing. Upon agreement of both parties, ownership of the equipment becomes the responsibility of the Contractor. The Contractor will then be responsible for operation, maintenance, and repairs. Exception to the stated is, CDOT will be allowed to access and operate equipment in emergency situations to maintain operations of the tunnel. Upon completion of Contractor's work, the Contractor and CDOT shall re-assess the equipment and agree to current condition prior to CDOT taking over ownership.

Written request for power outages shall identify; origin of circuit or feeder, equipment fed from, equipment to be de-energized and / or area(s) affected, planned duration of outage and two contacts for contractor staff on-site during outage. Outage shall proceed only when approved by CDOT.

When working with existing equipment or wiring systems, care shall be taken to avoid damage to equipment. Prior to working in an area, the Contractor shall examine existing conditions. Any defects caused by the Contractor shall result in the Contractor being held liable for damage to existing equipment.

Also Refer to Book 2 Section 1 - Exhibit A, Book 2 Section 622 and Book 2 Section 18 for additional requirements.

14.3 Testing and Commissioning

14.3.1 Testing

14.3.1.1 Construction Acceptance Test

The Construction Acceptance Test shall be performed using the constructed system in the EJMT, at least 30 days prior to the Project Completion of the Project. This test is in addition to any tests needing to be performed under NFPA 30, 70, 72, 110 and 502.

14.3.2 Commissioning

All mechanical, electrical, and software systems shall be tested as part of a complete commissioning program. Commissioning testing shall be performed in accordance with NFPA 13, 30, 72, 110 and 502.

Commissioning tests shall include at a minimum the following elements:

- Component and equipment
- Communication links

- Status, control, alerts, and alarms
- Interfaces between subsystems
- Integration among new and existing subsystems

Commissioning shall be carried out by an independent third party commissioning agent with demonstrated experience in commissioning tunnel systems within the past five years. The Contractor shall complete commissioning of all systems for CDOT Acceptance prior to Project Completion.

The commissioning agent shall prepare and submit a Commissioning Test Plan and Schedule for Approval to CDOT a minimum 90 days before the start of any testing. The test plan shall be based on the technical specifications and performance characteristics of all devices, equipment, parts, assemblies, systems, subsystems, software and devices supplied and installed under this contract. Testing shall be carried out by the Contractor and witnessed and documented by the commissioning agent.

All elements subject to testing shall be included in the testing schedule. Weekly commissioning meetings shall be held beginning 90 days prior to the scheduled start of testing to review the status of the testing and planning for future tests.

All commissioning documentation shall be submitted to CDOT for Acceptance following testing and prior to Project Completion.

14.3.2.1 Maintenance and Operations Training

The Contractor shall provide Maintenance and Operations training a minimum of 90 days prior to Project Completion. The Contractor shall provide a Maintenance and Operations

Training Plan and Syllabus 30 days prior to beginning training for review by CDOT. The training shall be conducted by the manufacturer's technical service personnel or factory authorized representatives for all of the systems installed in the EJMT.

The Contractor shall include in the training; operation instructions, theory of operation, system description, preventive maintenance procedures, troubleshooting and repair of all equipment specified herein. The Contractor shall include with the training all material and manuals required for each participant. Dedicated systems training for CDOT system administrators shall cover computer systems, hardware, communication networks, and software systems.

14.3.2.2 Manuals and Documentation

The Contractor shall provide Maintenance and Operations Manual to CDOT for review and Approval 120 days prior to Project Completion. The Contractor shall provide five printed and bound copies and one electronic copy in native editable format of the final Maintenance and Operations Manual within 90 days after CDOT Approval. The Maintenance and Operations Manual shall include catalog cuts, final as-built shop drawings, hardware and software instruction manuals for all systems

supplied and installed, stored on USB memory, equipment maintenance, and recommended spare parts. Project Completion of Systems will not be provided until the Maintenance and Operations Manual has been Approved.

The Maintenance and Operations Manual shall include a complete parts list. The parts list shall include a list of all parts supplied under the Contract, down to the lowest level part or assembly that is user-replaceable. The parts list shall include part numbers, description, system application or use, manufacturer, and supplier. The parts list shall identify sole-source and propriety parts. For all sole-source and proprietary parts, compatible or alternative parts shall be identified. The estimated service life of parts that have a service life less than 30 years shall be identified.

The Maintenance and Operations Manual shall include a complete consumable supplies list. The supplies list shall include a list of all materials required for routine maintenance of the equipment supplied under the Contract. The supplies list shall include material name, description, function, application rate and frequency, manufacturer, and supplier.

14.4 Deliverables

At a minimum, the Contractor shall submit the following to CDOT for Review, Approval, and/or Acceptance:

Table 14-2: Deliverables by the Contractor

Deliverable	Review, Acceptance, or Approval	Schedule
Documentation of Electrical Work personnel qualifications	Review	Prior to commencing any Electrical Work
Freeze Protection System - Submittals and Shop Drawings	Acceptance	Per Design Schedule
Freeze Protection System SCADA Integration Report	Approval	Within 90 days prior to integration
Freeze Protection System Field Quality Control and System Start Up	Approval	Per Design Schedule
Freeze Protection System Field Quality Control and System Start Up	Approval	Per Construction Schedule
Project Special Provisions Required Submittal Material	Acceptance	Per Design Schedule
Maintenance and Operations Training Plan and Syllabus	Review	Per Construction and Closeout Schedule

Deliverable	Review, Acceptance, or Approval	Schedule
Annual Maintenance Plan	Approval	30 days prior to the start of the Short-Term year
Annual Maintenance Report	Review	30th day of the new Short-Term year

All deliverables shall also conform to the requirements of Book 2, Section 3.

14.5 Project Special Provisions

The following pages provide the modified standard specifications that shall be applicable to the Project.

REVISION OF	DATE
Section 22 05 33 - Heat Tracing for Plumbing Piping	11/12/2021
Section 202 - Removal of Electrical Equipment	11/12/2021
Section 210 - SCADA System Integration and Integrator Requirements	11/12/2021
Section 613 - Electrical Conduit and Raceways	11/12/2021
Section 613 - Electrical Identification	10/21/2021
Section 622 - Electrical Modifications	10/21/2021
Section 622 - Boxes and Fittings	10/21/2021
Section 622 - Grounding and Bonding	10/21/2021
Section 622 - Supporting Devices	10/21/2021
Section 622 - Wires, Cables, Splices, Terminations (600V or less)	10/21/2021
Section 622 - Over-Current Protective Devices (600V or less)	10/21/2021

Section 22 05 33
HEAT TRACING FOR PLUMBING PIPING
HEAT TRACE PIPE FREEZE PROTECTION AND FLOW MAINTENANCE SYSTEM

PART 1 GENERAL

1.1. SUMMARY

- A. Drawings and general provisions of the Contract, Including General and Supplementary Conditions and other Book 1, and Book 3 Specification Sections, apply to this section.
- B. Section includes a UL Listed, CSA Certified, or FM Approved complete pipe freeze protection system that consists of a self-regulating trace heater, connection kits, distribution power panels, accessories, and electronic controller for insulated exposed and underground pipes exposed to risk of freezing.
- C. Related Requirements - Special Provisions
 - 1. Special Provisions 202
 - 2. Special Provisions 210
 - 3. Special Provisions 613
 - 4. Special Provisions 622

1.2. REFERENCES

- A. Reference Standards
 - 1. UL515 - Electrical Resistance Heat Tracing for Commercial Applications
 - 2. IEEE 515.1-2012 Standard for the Testing, Design, Installation & Maintenance of Electric Resistance Trace Heating for Commercial Applications.
 - 3. CSA Standard C22.2 No. 130-03 Requirements for Electrical Resistance Heating Cables & Heating Device Sets
 - 4. NFPA 70 - National Electrical Code
 - 5. NFPA 13 - Standard for the Installation of Sprinkler Systems
 - 6. NFPA14 - Standard for the Installation of Standpipe & Hose Systems
 - 7. CSA Standard C22.1 - Canadian Electrical Code

1.3. SYSTEM DESCRIPTION

- A. System includes a complete pipe freeze protection system for insulated exposed and underground pipes exposed to the risk of freezing. System consists of a self-regulating heating cable, insulated heating cable, connection kits, distribution power panels, accessories, and energy efficient control, monitoring, and Building Management System (BMS) communication capabilities. The heating cable shall be jacketed for use per manufacturer requirements for above ground piping & internally traced lines as appropriate. System shall be designed to account for a 10% spare capacity on all heat trace cable lengths, 20% spare capacity on all branch circuits and circuit breakers and 25% spare capacity on all power distribution panels and power control modules.

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1. Pipe freeze protection of above ground water piping.
2. Pipe freeze protection of below ground drainage and seep piping.
3. Pipe freeze protection of roof drains and downspouts.

1.4. ACTION SUBMITTALS / INFORMATIONAL SUBMITTALS

A. Product Data

1. Heating cable data sheets
2. UL Listed, CSA Certified, or FM Approved certificates for freeze protection or flow maintenance systems.
 - a. Pipe Freeze Protection above ground
 - b. Pipe Freeze Protection below ground
3. Design guide
 - a. Pipe Freeze Protection design guide
4. System installation and operation manual
5. System installation details
6. Connection kits and accessories data sheet
7. Controller data sheet
8. Controller wiring diagram

B. Shop Drawings

1. Provide engineered one-line block wiring and control diagrams, heat tracing circuit layout plan drawings indicating, power connections, power distribution panels, power control modules, control devices, control wiring, tees, end seals, cable length circuit cable length and pipe protected.
2. The system shall be capable of being designed within a BIM model and the manufacturer shall provide a BIM add-in for Autodesk Revit MEP to automate the design process.

1.5. QUALITY ASSURANCE

- A. Source Limitations:** All system components shall be sourced from a single manufacturer, under no circumstances shall any components be installed other than those supplied by the cable manufacturer, to ensure system integrity and to meet warranty requirements.
- B. Qualifications**
 1. Manufacturers

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- a. Manufacturer to show minimum of twenty (20) years of experience in manufacturing electric self-regulating heating cables and components.
 - b. Manufacturer will be ISO-9001 registered.
 - c. Manufacturer to provide products consistent with UL 515, CSA 22.2 No 130-03 and IEEE 515.1 requirements.
 - d. The self-regulating heating cable shall be qualified and tested to demonstrate a useful lifetime in excess of 20 years.
2. Installers
- a. System installer shall be certified by Manufacturer and have complete understanding of product. Installer shall have a minimum of five (5) years' experience installing such systems or similar. Electrical connections shall be performed by a licensed electrician.
- C. Certifications
1. The system (heating cable, connection kits, and controller) shall be UL Listed, CSA Certified, or FM Approved for:
 - a. Freeze protection of above ground water piping
 - b. Freeze protection of below ground water and drainage piping
 - c. Freeze protection of roof drains and downspouts.
- 1.6. DELIVERY, STORAGE, AND HANDLING**
- A. Delivery And Acceptance Requirements
1. Deliver, store and handle products to prevent their deterioration or damage due to moisture, temperature changes, contaminates or other causes.
 2. Deliver products to site in original, unopened containers or packages with intact and legible manufacturers' labels identifying the following:
 - a. Product and Manufacturer
 - b. Length/Quantity
 - c. Lot Number
 - d. Installation and Operation Manual
 - e. MSDS (if applicable)
- B. Storage And Handling Requirements
1. Store the heating cable in a clean, dry location with a temperature range 0°F (-18°C) to 140°F (60°C).
 2. Protect the heating cable from water ingress.

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1.7. WARRANTY

A. Manufacturer Warranty

1. Manufacturer's warranty that warrants all goods listed below for two (2) years from date of purchase against faulty workmanship and use of defective materials when such goods are properly installed, operated, and maintained according to product documentation.
 - a. Heating cables, connection kits & accessories
 - b. Thermostats, controllers, panels contactors, sensors, and accessories

B. Special Warranty -

1. Contractor shall provide the owner an extended product warranty for the heat tracing products listed below. The contractor must complete and forward to owner the Installation, Inspection or Commissioning Record(s), and complete the online warranty registration form within thirty (30) days from the date of installation, otherwise only standard limited warranty applies.
 - a. Heating Cable & Components shall be Ten (10) Years from Date of Purchase
2. Heating cables, connection kits and accessories not automatically offered with a 10-year manufacturer's warranty, as a standard matter, will not be allowed. Warranty information must be published on the manufacturer's website.

PART 2 PRODUCTS

2.1. HEAT TRACING SYSTEM

A. Manufacturers

Basis of Design Manufacturer: Subject to product and performance requirements.

B. Materials

1. Heating cables shall be self-regulating heating cables specifically designed for the intended application, 0-degree startup rated, tested and approved to UL 515, CSA 22.2 No 130-03 and IEEE 515.1 requirements.
 - a. The heating cable shall be self-regulating.
 - b. The heating cable shall have a thicker gauge (5/24) tinned copper braid with minimum 70% coverage for ground path and mechanical ruggedness.
 - c. The heating cable shall have a self-regulating factor of at least 90 percent for 5XL and 8XL, and at least 66 percent for 12XL. The self-regulating factor is defined as the percent reduction of the heating cable power output going from a 40°F pipe temperature to 150°F pipe temperature.
 - d. The heating cable shall have an outer jacket that is approved and clearly marked for the install conditions.

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- 1) For above ground water piping applications, the heating cable shall have a MODIFIED POLYOLEFIN (-CR) outer jacket printed with cable model number, agency listings, batch number and meter marks (for ease of installation within maximum circuit length).
 - 2) For below ground water piping with internal heat tracing, the heating cable shall have a POLYOLEFIN (-CR) outer jacket printed with cable model number, agency listings, batch number and meter marks (for ease of installation within maximum circuit length).
 - 3) For below ground water piping with external heat tracing, grease waste piping, fuel oil piping, the heating cable shall have a FLUOROPOLYMER (-CT) outer jacket printed with cable model number, agency listings, batch number and meter marks (for ease of installation within maximum circuit length).
- e. The heating cable shall be included in a UL Listed, CSA Certified, or FM Approved system.
 - f. Constant wattage cables are acceptable for pressurized lines.
2. Heating Cable Connection Kits
- a. Contractor shall provide power connections, splices/tees, and end seal kits to properly connect and terminate the heating cable circuit along the specified length of the piping.
 - b. On insulated pipes, all splices, tees, and crosses shall be installed underneath the pipe insulation with service loops installed to allow for future service of the piping.
 - c. On below grade buried applications, all connection kits must be located above grade or in accessible manholes.
 - d. Connection kits shall be rated NEMA 4X to prevent water ingress and corrosion. All components shall be UV stabilized and shall not require the installing contractor to cut into the heating-cable core to expose the bus wires.
 - e. Connection kits shall be UL Listed, CSA Certified, and FM approved.
3. Attachment of Heating Cable
- a. Attachment method of heating cable to the piping shall be:
 1. General purpose, high temperature, glass filament tape for installation @ 40°F and above. Contractor to affix the heating cable to the pipe every 12" by wrapping the tape around the pipe and over the heating cable.

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2. General purpose, high temperature, glass filament tape for installation @ 40°F and below. Contractor to affix the heating cable to the pipe every 12" by wrapping the tape around the pipe and over the heating cable.
3. Aluminum tape, high temperature for all non-metallic piping for installations @ 32°F and above. Tape is installed lengthwise over the heating cable.
 - b. Metal cable ties are not permitted
4. Identification of Heating Cable System
 - a. Contractor shall provide and install labels on exterior of exposed pipe insulation every ten (10) feet on opposite sides of the pipe for the entire length of heat traced piping.
 - b. In addition, all splices, tees, crosses, and power connections shall be labeled on the exterior of the pipe insulation indicating the presence of a connection kit.
5. Energy Efficient Control System
 - a. Multi-Circuit, Distributed Digital Control System
 1. All pipe freeze protection circuits shall be controlled and monitored using a centralized control system with distributed power and control modules.
 2. Multi-application: Distributed digital control system shall be pre-programmed parameters to provide concurrent control for heating cables used for pipe freeze protection, and roof and gutter de-icing, applications.
 3. All programming shall be done through the central User Interface Terminal.
 4. The UIT shall be a color LCD touch-screen display with password protection to prevent unauthorized access to the system.
 5. The UIT shall communicate with up to twenty (20) Power Control Panels where each panel can control up to five (5) circuits and accept up to five (5) temperature inputs. System shall have individual controllers for single circuit extensions.
 6. Digital control system shall be capable of assigning up to four (4) temperature inputs per heat-tracing circuit.
 7. The UIT shall communicate with up to sixteen (16) Remote Monitoring Modules , where each module can accept up to eight (8) temperature inputs.

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8. The UIT shall have a USB port to allow for quick and easy software update.
9. The UIT shall have three (3) programmable alarm contacts including an alarm light on the enclosure cover.
10. A separate offline software tool shall be made available to allow users to pre-program the digital control system and transfer program via a USB drive or Ethernet.
11. The UIT enclosure shall be NEMA 4 for indoor or outdoor locations.
12. The Power Control Module (PCM) panel shall be in a NEMA 4/12 enclosure approved for nonhazardous indoor and outdoor locations.
13. The PCM panel shall provide ground-fault and line current sensing alarming, switching and temperature inputs for five (5) heat tracing circuits.
14. Each PCM panel shall have five (5) 3-pole, 30-A contactors (EMR type).
15. The PCM panel shall be capable of operating at 120 V to 277 V.
16. The PCM shall have an alarm contact including an alarm light on the panel cover.
17. Digital controller shall have an integrated adjustable GFPD (10 - 200 mA).
18. Digital control system can be configured for On/Off, ambient sensing, PASC and timed duty cycle control modes based on the application. PASC control proportionally energizes the power to the heating cable to minimize energy based on ambient sensed conditions.
19. Upon communication loss with the user interface terminal (UIT), the PCM panels shall control with the last downloaded set point.
20. Digital control system will have a built-in self-test feature to verify proper functionality of heating cable system.
21. Digital control system will also be able to communicate with facility SCADA by one of the following protocols. [Select one]
 - a. Modbus®
 - b. BACnet®
22. The following variables will be monitored by the digital controller and reported back to the BMS:
 - a. Temperature

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- b. Ground fault
 - c. Current draw
 - d. Power consumption
 - e. Associated alarms
23. The UIT shall be c-CSA-us Certified. The PCM panel shall be c-UL-us Listed.
6. Thermal Pipe Insulation
- a. Pipes must be thermally insulated in accordance with the Manufacturer's Design Guide requirements.
 - b. Thermal insulation must be a type that is flame retardant (closed-cell or fiberglass) with waterproof covering.
7. Approval
- a. The complete heat trace system (heating cable, connection kits, and controller) shall be listed by a shall be listed by a Nationally Recognized Testing Laboratory (NRTL), and marked for intended use of:
 - 1) Freeze protection of above ground water piping
 - 2) Freeze protection of below ground water / drain piping
 - 3) Freeze protection of roof drains and downspouts.

PART 3 EXECUTION

3.1. EXAMINATION

- A. Verification of Conditions
 - 1. Prior to installation of heating cable system, verify that all piping which will be heat traced has passed all hydrostatic/pressure test and is signed off by plumbing inspector.
- B. Preinstalling Testing
 - 1. Prior to installing heating cable on the piping an insulation resistance test shall be performed by the installing contractor to ensure integrity of heating cable as describe in the installation and maintenance manual.

3.2. PREPARATION

- A. Protection of In-Place Conditions
 - 1. All heating cable ends shall be protected from moisture ingress until cable is terminated.
 - 2. Acceptable methods are installing end seals.

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3.3. INSTALLATION

- A. Comply with the manufacturer's recommendations contained in their heating cable system installation and operation manual.
- B. All heat tracing components including power connections, splices, tees, crosses or end seal must be installed above grade and protected from abuse or damage. By NEC and CEC, electrical connections are not permitted to be installed below grade.
- C. Branch circuit conductors feeding existing heat trace systems shall be replaced from heat trace connection back to power source.
- D. Existing raceway maybe reused where applicable to the new layout, when raceway is in good condition or raceway is routed through inaccessible space.
- E. In all cases Raceway MUST be replaced from in roadway manholes to accessible space (supply plenums, adjacent rooms, behind access panels . . . etc). Raceway shall be PVC coated RGS or PVC coated steel FMC. No raceway allowed in exhaust plenums.
- F. All new heat trace connection points shall have new raceway and conductors.
- G. Contractor to furnish & install a 1" PVC coated rigid galvanized steel conduit to manhole for each circuit on the below ground water / drain piping as a raceway for the heating cable to the below grade piping.
- H. Contractor to provide a heat trace circuit disconnecting means with red LED pilot light, that is within Line-of-Site to the heat trace connection point. Disconnect shall be rated for environment installed in, labelled and accessible without interrupting traffic movement.
- I. Temperature sensor shall be installed in exterior space inside of ¾" plastic conduit and pushed all the way to the closed end. Contractor to wire temperature sensor to controller and be responsible for extended temperature sensor wiring as required by the site conditions.
- J. Install electric heating cable accordance with the manufacturer's instructions. The installer shall be responsible for providing a complete functional system, installed in accordance with applicable national and local requirements.
- K. Interface with Other Work
 - 1. Connection of all electrical wiring shall be according to Section 26 05 19 "Low-Voltage Electrical Power Conductors and Cables."
 - 2. Grounding of controller shall be according to Section 26 05 26 "Grounding and Bonding for Electrical Systems."
- L. Existing Insulated pipes to be heat traced.
 - 1. Remove existing insulation and properly dispose of.

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SECTION 22 05 33
HEAT TRACING FOR PLUMBING PIPING
HEAT TRACE PIPE FREEZE PROTECTION AND FLOW MAINTENANCE SYSTEM

2. Install heat trace cable and associated equipment per manufacturer's requirement.
3. Install new insulation on entire length of pipe affected.

3.4. FIELD QUALITY CONTROL

A. Field Tests and Inspections

1. The system shall be commissioned in accordance with the Manufacturer's Installation and Operation manual.
2. The following test shall be performed after the heat cable has been installed but before the insulation and after insulating the piping. The results of both sets of tests shall be recorded and included in submittals to owner:
 - a. Continuity Test
 - b. Insulation Resistance - 2500 VDC
 - c. Capacitance Check - Circuit Length Verification
 - d. Power Check
 - e. Ground-fault Test
3. The technician shall verify the insulation schedule is in compliance with the Installation and Operation manual.
4. The technician shall verify that the control parameters are set to the application requirements.
5. The technician shall verify that the alarm contacts are correctly connected to the Facility SCADA System.
6. The technician shall verify that the Heat Trace Control System are configured correctly with the Facility SCADA System.

B. Non-Conforming Work

1. Any heat tracing circuit which fails any of the above tests must be corrected prior to commissioning or startup of the system.

C. Retain the services of the Manufacturer's Engineering and Technical Department to provide factory design build and inspection services to prepare submittals for complete design layouts, wiring diagrams, installation details for all heat trace equipment including power distribution panels, power control modules, heating cable, connection kits, controllers, and sensors. Supply 11"x17" isometric drawings for every circuit for a complete heat tracing system.

D. Provide factory inspection report as part of a complete manufacturer approved installation that is compliant to Code.

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**SECTION 22 05 33
HEAT TRACING FOR PLUMBING PIPING
HEAT TRACE PIPE FREEZE PROTECTION AND FLOW MAINTENANCE SYSTEM**

3.5. SYSTEM STARTUP

1. Provide a factory-certified technician or manufacturer's representative for startup and commissioning of the heat tracing system and controller.
2. Coordinate all controller settings prior to programming the controller with owner Maintenance & Operations.
3. Provide commissioning report in submittals package to owner.

END OF SECTION 22 05 33

**REVISION OF SECTION 202
REMOVAL OF ELECTRICAL EQUIPMENT**

Section 202 of the Standard Specifications is hereby revised for this project to include the following: Subsection 202.01 shall include the following:

The work shall include the demolition and removal of:

The existing heat trace systems including but not limited to heat trace cable associated control devices, contactors, sensors, panels, circuiting and conduit. Refer to Specification Section 22 05 33 Heat Trace Pipe Freeze Protection.

Existing branch circuits that feed equipment to remain shall be recircuited to a new panelboard located in east and west portal electric rooms. Contractor shall confirm with Tunnel M&O which existing circuiting is still utilized and shall remain.

Contractor shall dispose of all equipment, materials, and liquids to be removed.

Subsection 202.02 shall include the following:

CDOT personnel will operate and disable all switchgear and power switching equipment as necessary for work. At no time shall the Contractor operate any of the above equipment themselves. Any safety critical work where power will or has the potential to be interrupted shall only occur during specific outage periods as identified by CDOT. All complete outages shall be scheduled with CDOT 48 prior to the requested time.

Subsection 202.11 shall include the following:

Removal of Electrical Equipment will not be measured but shall be paid for as a single lump sum basis for all work, materials, and equipment required for removal of all electrical and associated equipment required for the removal.

Removal of Electrical Equipment shall include systems as described in 202.01. This payment will include the removal, hauling and, disposal of all abandoned or non-used electrical items which in any way hinders or obstructs the installation of the new electrical equipment indicated on the plans and contract documents. Included in the term "associated items" is all equipment required to perform the complete demolition of the electrical items as required for the tunnel facility. This payment will also include the relocation or rearrangement of all electrical items that are presently in use or energized which in any way hinders or obstructs the installation of the new electrical equipment indicated on the plans. All materials and equipment removed shall become the property of the Contractor.

Subsection 202.12 shall include the following:

The accepted quantities will be paid for at the contract unit price for each of the pay items listed below that appear in the bid schedule.

**REVISION OF SECTION 210
SCADA SYSTEM INTEGRATION AND INTEGRATOR REQUIREMENTS**

Section 210 of the Standard Specifications is hereby revised for this project to include the following: Subsection 210.01 shall include the following:

Subsection 210.02 shall include the following:

Modifications to Existing SCADA System and Power Control Board shall be made in accordance with the requirements of Section 260533 - Heat Trace for Plumbing Piping. Final Control, Monitoring and Alarm points to be coordinated with CDOT.

Project Summary

The SCADA system at the EJMT controls and monitors the north and south tunnel fans, 24.9kV switchgear and 480V switchgear on the west side. Additionally, the SCADA system will be configured to monitor the status and provide alarms for the new freeze protection system.

Integrator Scope of Work

The systems integrator shall provide all labor to complete the work described herein.

1. Attend project meetings.
2. Develop startup plans detailing work schedule and impact to operations.
3. Modify existing schematics, layout drawings, panel drawings, and network drawings to include the freeze protection system.
4. Attend and facilitate a programming workshop with the engineer and owner to establish the sequence of operations for freeze protection alarms.
8. Submit new and modified graphics pages to be reviewed and approved by the engineer and customer.
9. Prepare on-site testing documentation including I/O Checkout, Loop Checks and Performance Testing sheets.
10. Provide Operations and Maintenance training for provided system. This includes Software Overview, Maintenance, Troubleshooting, and Operation.
11. Revise Operation and Maintenance Manuals to include added functionality for this project.

Integrator Supplied Documentation

The systems integrator shall provide the following documentation:

1. Network, Panel, and Schematic Drawings.
2. SCADA screen submittals.
3. Startup Plan documents.
4. On-Site testing documentation.
5. Operation and Maintenance Manuals.

System I/O

The following describes the I/O to be included in the SCADA system:

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REVISION OF SECTION 210
SCADA SYSTEM INTEGRATION AND INTEGRATOR REQUIREMENTS

Heat Trace/ Freeze Protection System

Network I/O points to be included on SCADA:

Refer to Section 260533 - Heat Trace for Plumbing Piping

1. Inputs
 - a. Circuit Temperature (per circuit)
2. Alarms
 - a. The following alarms from the heat trace/ freeze protection system per circuit. Required alarms to be brought across to SCADA will be established during programming workshop.
 - i. Comm Alarm
 - ii. Fail Safe Alarm
 - iii. Ground Fault Alarm
 - iv. Ground-Fault Trip
 - v. High Temp
 - vi. High Temp Cut-Out
 - vii. Low Temp
 - viii. Relay Failure Alarm
 - ix. RTD Failure
 - b. Heat Trace/ Freeze Protection Alarm Relay Output

System Operation

The following describes the operation to be included in the SCADA system:

Heat Trace

Section 260533 - Heat Trace for Plumbing Piping

1. Temperature and alarm status of the heat trace system displayed on SCADA.

**REVISION OF SECTION 613
ELECTRICAL CONDUIT AND RACEWAYS**

Section 613 of the Standard Specifications is hereby revised for this project as follows:
Subsection 613.01 shall include the following:

The work shall also include furnishing, handling, storing, and installing all conduit, wireway, hanger system, conduit fittings, sealing boots, wall penetrations, ceiling/roof penetrations, mounting hardware, and anchors, fasteners and supports for fastening conduit and equipment to the building structure.

Subsection 613.02(c) shall include the following:

(c) Conduit. Unless otherwise noted in these specifications or shown on the plans, all interior and exposed exterior conduits shall be metal Galvanized Rigid Conduit (GRC). GRC shall be mild steel, hot-dip galvanized conduit complying with ANSI C80.1 and FS WW-C-581 and shall be UL listed. All conduit material shall comply with the applicable standards of ASTM, NEMA, ICEA, and where applicable shall be UL listed. All below grade conduit shall be Schedule 40 PVC, conduits penetrating concrete equipment pads shall be PVC coated Rigid Galvanized Steel (RGS).

PVC conduit is not allowed on interior or exterior of building.

Below grade conduits shall be consolidated when possible into ductbanks.

Ductbanks with medium voltage feeders shall be concrete encased. The encasement shall extend to 3" beyond ductbank on all sides. Concrete shall be minimum of 2500 PSI and be red in color.

Conduit shall be ¾ inch trade size or larger or as indicated on the plans, and shall be manufactured by National Electrical Products Company, Youngstown Steel and Tube Company, Republic Steel, Allied Steel Tube and Conduit Company, or approved equal.

Liquid tight flexible metal conduit shall be minimum 3/4-inch trade size and shall comply with UL-1 Listed, standard weight, flexible, galvanized steel conduit with a heavy wall neoprene or polyurethane jacket. Fittings shall be galvanized steel designed for use with liquid tight flexible metal conduit and comply with UL Standard 514.

Elbows, bends, and similar offsets shall be made of full weight materials complying with the above and shall be coated and threaded the same as conduit. Threads for conduit, couplings, and fittings shall be full depth and clean cut.

Material for Fittings shall comply with ANSI/NEMA FB-1.

Conduit Expansion Fittings shall be O-Z./Gedney type AX, EX, EXDS, TX, or EXE; Crouse Hinds type XJ; Appleton expansion fitting or approved equal.

Factory fabricated metal connectors of the size, rating material type, and class required for each service shall be provided.

Lubricants for assisting in the pulling of jacketed cables shall be those specifically recommended by the cable manufacturer.

The finish shall consist of a wash and phosphate undercoat and an ANSI 61 gray polyester powder finish. Hardware and latches are zinc plated with a yellow chromate finish.

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**REVISION OF SECTION 613
ELECTRICAL CONDUIT AND RACEWAYS**

- (j) A hanger system for the support of conduits and wireways shall be provided. Support shall be provided for conduits at 10 foot intervals and within 18 inches of terminations, in accordance with the requirements of the National Electrical Code. The materials for the hanger system shall conform to the following:
- (1) Conduit Clamps shall be one hole or two-hole, cadmium plated or galvanized heavy gauge steel, or galvanized malleable iron.
 - (2) Hanger Rod: Galvanized Steel or electro-galvanized and zinc chromate coated steel, 3/8-inch minimum.
 - (3) Channels, Fittings, Hangers, Clamps, and Accessories: Unless otherwise indicated, all surface mounted supporting channels and associated fittings, clamps and accessories shall be galvanized steel. Channels shall be constructed of 12-gauge minimum, 1-5/8-inch deep by 1-5/8-inch wide minimum. Hangers shall be steel which is hot-dip galvanized after fabrication.
 - (4) Nuts, bolts, and washers shall be Type 316 stainless steel.

Subsection 613.03 shall include the following:

All equipment and materials that are damaged during transport, and which the Engineer deems to be non-functional or unfit for use, will be repaired or replaced at the Contractor's expense.

Equipment shall be stored in a clean, dry space and protected from dirt, fumes, water, construction debris, and any physical damage.

Auxiliary heaters shall be provided for all equipment that would be damaged by moisture condensation.

The Contractor shall examine the areas and conditions under which electrical equipment is to be installed and notify the Engineer in writing of conditions detrimental to the proper and timely completion of the Work. Work shall not proceed until unsatisfactory conditions have been corrected in a manner acceptable to the Engineer.

Supporting devices shall be installed as follows:

- (1) Provide anchors with sufficient strength to support four times the load imposed by the combined conduit and conductor weight. Anchors shall be seismic rated for Zone 3 requirements.
- (2) Hollow Masonry: Toggle bolt type expansion anchors.
- (3) Solid Masonry: Expansion anchors or preset inserts.
- (4) Metal Surfaces: Machine screws, bolts, or welded studs.
- (5) Wood Surfaces: Wood screws.
- (6) Concrete Surfaces: Concrete screw anchors, wedge anchors, or sleeve anchors or approved equal. Power driven (powder actuated) studs shall not be used.

Subsection 613.07 shall be deleted in its entirety and replaced with the following:

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**REVISION OF SECTION 613
ELECTRICAL CONDUIT AND RACEWAYS**

613.07 Conduit. Electrical conduit shall be installed in accordance with the applicable requirements described in the Department of Transportation's, A Policy on the Accommodation of Utilities on Colorado Highways Rights-of-Way, as amended, and the following:

Conduit runs in structures are shown on the plans only for information. Locations will be established during construction by the Contractor with approval of the Engineer. Conduit and cable shall be so located as to avoid any interference with known present or known future construction installations. Existing conduit to be reused shall be cleaned with a mandrel 1/2 inch smaller than conduit's inside diameter (ID) and a cylindrical wire brush of diameter equal to conduit's ID, followed by a swab of the same size as the conduit's ID.

The ends of all conduits, whether shop or field cut, shall be reamed to remove burrs and rough edges. Cuts shall be made square and true so that the ends will butt or come together for the full circumference thereof. Slip joints or running threads will not be permitted for coupling conduit. When a standard coupling cannot be used for coupling metal type conduit, an approved threaded union coupling shall be used. All threads on all ferrous metal conduit, not previously treated with a corrosion preventative, shall be painted with conducting rust preventive paint before couplings are made up. All couplings for metal type conduit shall be tightened until the ends of the conduit are brought together, providing a continuous electrical connection throughout the entire length of the conduit run. Where the coating on ferrous metal conduit has been damaged in handling or installing, such damaged places shall be painted with rust preventive paint.

All metal type conduit ends shall be threaded and shall be capped until wiring is started. When caps are removed, the threaded ends shall be provided with conduit bushings or transition fittings as applicable.

Liquid tight flexible metal conduit shall be used only when necessary as the final conduit connection to electrical equipment and other utilization devices. Connections to equipment subject to vibration, calibration, periodic removal, or where specifically indicated or noted on the plans shall be made with between 18 and 24 inches of Liquid tight flexible metal conduit.

It shall be the option of the Contractor, at no expense to the Department, to install pull boxes to facilitate the work.

The Contractor shall route exposed conduit parallel and perpendicular to walls and adjacent piping.

The Contractor shall maintain a minimum 6-inch clearance between conduit and piping.

The Contractor shall arrange conduit supports to prevent distortion of alignment by wire pulling operations.

The Contractor shall group conduit in parallel runs where practical, and use conduit supports constructed of galvanized steel channel with conduit clamps, designed to provide the proper separation between the conduits.

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**REVISION OF SECTION 613
ELECTRICAL CONDUIT AND RACEWAYS**

The Contractor shall fasten conduit with approved malleable iron clamps before conductors are pulled. Do not use spring steel clips for conduit clamps. The Contractor shall remove all wire used for temporary conduit support during construction.

The Contractor shall support conduit at a maximum of 10 feet on center.

The Contractor shall install no more than the equivalent of three 90-degree bends between end points of any conduit run. Adequately sized boxes shall be installed to meet this requirement whether specifically shown or not in the Plans.

Conduit bodies shall not be used to make sharp changes in direction, as around beams or corners. All bends shall be via standard radius sweeps. LB fittings shall be a mogul cast fitting with a gasket and cover.

The Contractor shall use hydraulic one-shot conduit bender or factory elbows for bends in conduit.

The Contractor shall avoid moisture traps where possible; where unavoidable, provide conduit body with drain fitting at conduit low point.

Conduit offsets shall be properly made and installed where required. Where two or more conduit offsets or bends are installed in parallel, they shall be symmetrically formed and arranged.

Conduit shall be supported on each side of conduit bends or fittings and not more than 2 feet away from any junction box or pull box, if utilized.

Conduit shall not be fastened to other conduits or pipes for support.

Conduits and conduit boxes shall be of such sizes and numbers and shall be so installed that the required number of conductors may be drawn in without injury or excessive strain. The Contractor will be permitted to increase the size of conduits and number of boxes, if he so desires, to facilitate a speedier and less complicated installation, however, such changes shall be at his expense.

Where fasteners are required in concrete floors, walls or ceilings, expansion anchors shall be used unless noted otherwise

- (1) The minimum allowable anchor working load for existing concrete strength $f'c = 3,000$ psi, shall be certified in writing for Tension = 6,800 lbs and Shear = 5,000 lbs.
- (2) The corresponding ultimate anchor capacity shall be certified in writing for Tension = 22,000 lbs and Shear = 18,000 lbs.
- (3) The concrete anchors and the Type 316 stainless steel bolts, nuts, and washers shall be supplied by one of the following manufacturer or an approved equal:
 - a. HILTI Corporation
 - b. Williams
 - c. Marine Fasteners
- (4) All anchors supplied shall be from one manufacturer.

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**REVISION OF SECTION 613
ELECTRICAL CONDUIT AND RACEWAYS**

- (5) The bolts shall be installed by first drilling holes into existing concrete and effectively cleaning any loose material from the drilled holes. The Contractor shall exercise care in locating and drilling the holes so as to avoid damage to existing reinforcing steel bars and concrete.
- (6) The Contractor shall follow the installation procedures recommended by the manufacturer, including, but not limited to, the size and depth of hole for the required bolt size, the type of drilling tools preferred, surface preparation.

Inserting wooden plugs in concrete or masonry will not be accepted as a base for conduit fastenings, nor will conduit or pipe straps be welded to steel structures.

Openings in floors, walls, ceilings or roofs required for the installation of the conduit shall be sealed and patched to match the existing area after the installation is complete.

Rigid metallic conduits shall have expansion fittings installed at every expansion joint and as specified in the NEC. The expansion fittings shall provide for 4-inch conduit movement, 2-inches in either direction. A 14-inch bonding jumper, designed for use in conjunction with the expansion fitting shall be installed around every expansion fitting.

All raceways shall be provided with a green equipment grounding conductor.

613.08 Wiring. The material shall comply with the applicable standards of ASTM, NEMA, ICEA, and where applicable shall be UL listed.

600-volt wire and cable shall be copper, not less than 98% conductivity. Aluminum is not allowed. Cables installed shall be Low Smoke Zero Halogen (LSZH) cables.

Insulation shall be type XHHW. Wire shall be stranded. All wire sizes shown are in American Wire Gauge sizes. All power wire shall be color coded as follows:

<u>Conductor</u>	<u>120 Volt</u>	<u>120/208 Volt</u>	<u>277/480 Volt</u>
Ungrounded	Black Red	Black (ΦA) Red (ΦB) Blue (ΦC)	Brown (ΦA) Orange (ΦB) Yellow (ΦC)
Grounded Grounding	White Green	White Green	Gray Green

Factory fabricated metal connectors of the size, rating material type, and class required for each service shall be provided.

35kV cable shall be shielded, with a semi-conducting strand shield, ethylene propylene rubber insulation, semi-conducting insulation shield, copper tape shield, and polyvinyl chloride jacket. The insulation level shall be 100 percent. Terminations shall be made using stress cones, and the shields shall be grounded at the switchgear. The other end of the shield shall not be grounded.

Lubricants for assisting in the pulling of jacketed cables shall be those specifically recommended by the cable manufacturer.

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**REVISION OF SECTION 613
ELECTRICAL CONDUIT AND RACEWAYS**

Subsection 613.10 shall be deleted in its entirety and replaced with the following:

613.10 Testing. Prior to final acceptance, the Contractor shall demonstrate to the Engineer's satisfaction that electrical installations are in proper working condition, provide all instrumentation and labor required to perform all inspection and tests as described herein.

All tests shall be performed in the presence of the Department personnel or Department's authorized Engineer. All test results shall be documented and submitted to the Engineer for approval.

Subsection 613.11 shall include the following:

Electrical Conduit of the specified diameter will not be measured and paid for separately but shall be included in the lump sum item, Conduit.

Conduit clamps, channels, associated accessories, hardware and hanger system described herein and the installation thereof shall not be measured separately, but shall be incidental to the work.

**REVISION OF SECTION 613
ELECTRICAL IDENTIFICATION**

Section 613 of the Standard Specifications is hereby revised for this project as follows:
Subsection 613.01 shall include the following:

This work shall also consist of furnishing and installing nameplates and labels on new equipment and markers on wire and cable installed in the tunnel and as indicated herein and on the Contract Drawings. Color coding requirements are included in this Section.

References. The most recent version of the following laws, codes, regulations, guides, and standards form a part of this Section and Contractor shall comply therewith.

1. American National Standards Institute (ANSI):
 - a. A13.1 - Scheme for Identification of Piping Systems.
 - b. Z535.1-2002 - Safety Color Code.
 - c. Z535.2-2002 - Environment and Facility Safety Signs.
 - d. Z535.3-2002 - Criteria for Safety Symbols.
 - e. Z535.4-2002 - Product Safety Signs and Labels.
 - f. Z535.5-2002 - Safety Tags and Barricades (for Temporary Hazards).
2. Code of Federal Regulations (CFR):
 - a. 29 CFR 1910.145 - Occupation Safety and Health Standards (OSHA) Specification for Accident Prevention Signs and Tags.
 - b. 29 CFR 1910.144 - Occupation Safety and Health Standards (OSHA) Safety Color Code for Marking Physical Hazards.
3. National Fire Protection Association (NFPA):
 - a. 70 - National Electrical Code (NEC) 2011 Edition.
4. Underwriters Laboratories (UL):
 - a. UL 969 - Marking and Labeling Systems.

Subsection 613.02 shall include the following:

Identification Devices. A single type of identification product for each of the following applications. Use colors prescribed by ANSI A13.1, NEC.

1. Colored Adhesive Marking Tape for phase identification of Wires, and Cables: Self-adhesive vinyl tape, not less than 1 inch wide by 3 mils thick. Tape shall be electrical grade.
2. Tape Markers for Wire: Vinyl or vinyl-cloth, self-adhesive, wraparound type with preprinted numbers and letters.

Conduit Markers. Conduit markers shall be brass tags, 1 ¼ inch in diameter, attached to the conduits using stainless steel wire with a non-removable crimp type connection. Conduit markers shall be marked with the identification number of the conduit as listed in the conduit and wire schedules on the Drawings. Where a conduit contains only a single circuit, the circuit number shall also be marked on the conduit tag.

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**REVISION OF SECTION 613
ELECTRICAL IDENTIFICATION**

Color-Coding Cable Ties. Nylon, self-locking type. Colors to suit coding scheme.

Engraved-Plastic Labels, Signs, and Instruction Plates. Engraving stock, melamine plastic laminate punched or drilled for mechanical fasteners 1/16-inch minimum thickness for signs up to 20 sq. in. and 1/8-inch minimum thickness for larger sizes. Engraved legend in black letters on white background. Self-adhesive signs and labels shall be provided on electrical enclosures.

Fasteners for Nameplates and Signs. Self-tapping, stainless-steel screws or No. 10/32 stainless-steel machine screws with nuts and flat and lock washers.

Subsection 613.11 shall include the following:

Nameplates, labels, cable markers, and associated components described herein and the installation thereof will not be measured and paid for separately, but shall be incidental to the equipment that they identify.

**REVISION OF SECTION 622
ELECTRICAL MODIFICATIONS**

Section 622 of the Standard Specifications is hereby revised for this project as follows:
Subsection 622.01 shall include the following:

This work is Electrical Modifications in accordance with these specifications and in conformity with the details shown on the Contract Drawings or herein.

The Contractor shall furnish all labor, materials, tools, and equipment necessary for electrical work as indicated on the Contract Drawings and Specifications. The work shall include but not be limited to the following:

1. The maintenance of all existing electrical feeders, circuits, and equipment disturbed during the process of construction that will not be removed, relocated or replaced.
2. Making all changes, additions, and connections as indicated or required for a completed electrical system.
3. The furnishing and installation of all material and equipment necessary for a complete electrical system including but not limited to the following:
 - D. Heat Trace System
 - E. Conduit, Boxes, Fittings and Supports.
 - F. Conductors - less the 600 Volts.
 - G. Conductors - Medium Voltage
 - H. Demolition
 - I. Electrical to support Water Treatment System
 - J. Electrical to support New Water Mainline
 - K. Equipment Concrete Pads, Grading, Trenching, Backfill . . . etc.
 - L. SCADA Integration, Control, and testing.
 - M. Commissioning, Startup, Testing and Training
 - N. Any other electrical work indicated or specified.

The electrical work to be performed under this section of the specifications is related but not limited to the following 2017 sections:

- Revision of Section 622 - Testing.
- Revision of Section 622 - Boxes and Fittings (Revision of Section 622),
- Revision of Section 622 - Wires, Cables, Splices, Terminations (600 Volts or Less), and
- Revision of Section 622 - Wires, Cables, Splices, Terminations (Medium Voltage: 601 Volts to 34,500 Volts, Inclusive).

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REVISION OF SECTION 622
ELECTRICAL MODIFICATIONS

CONSTRUCTION REQUIREMENTS

General.

1. Existing Circuits: Where the Contractor disturbs existing circuits, all wires shall be disconnected in the boxes and the exposed ends taped and tagged.
2. Existing Conditions: The Contractor, before submitting his proposal, shall visit the site and be responsible for having ascertained local conditions such as but not limited to the location, accessibility, and general character of the site, the character and extent of any existing work within or adjacent to the site, and any other work being performed on the site at the time of submitting his proposal. The Contractor shall fully examine all drawings relating to the work and become completely informed as to the extent and character of the work required and prevailing existing conditions. No allowances shall be made for the Contractor's failure to avail himself of information.
 - A. When working with existing equipment or wiring systems, care shall be taken to avoid damage to equipment. Prior to working in an area, the Contractor shall examine existing conditions. Any defects caused by the Contractor shall result in the Contractor being held liable for damage to existing equipment.
 - B. Where new construction involves connecting to or using existing equipment, the Contractor shall include all work and materials required to adapt, extend, or re-work the prevailing existing "As Is" condition, to the new work. Should an existing condition prove to be grossly deteriorated or inadequate for modification, that condition shall be reported to the Engineer for a remedy.
3. Locations - Approximate: The locations of equipment, conduit, boxes, switches, outlets, and similar objects as shown on the Contract Drawings are approximate only, and exact locations shall be determined in the field. In case of interference with other work or of erroneous locations with respect to equipment or structures, the Contractor shall furnish all labor and materials to complete the work in an approved manner, at no additional cost to CDOT.
4. Drawings - Diagrammatic: Equipment, conduits and wiring are shown diagrammatically only. The Contractor shall furnish, install, and place in satisfactory condition ready for operation, all equipment, conduits, cables, and other material needed for installation and operation of the electrical systems shown or indicated in the Contract Documents. Additional conduits and required wiring shall be installed by the Contractor where necessary to complete the installation of the equipment furnished and to meet NEC requirements at no additional cost to CDOT.
5. Painting: All shop painting shall be accomplished at the manufacturer's facilities meeting ANSI standards and shall be included in the bid price for equipment and materials furnished under this division. All scratched or base surfaces of factory-painted equipment shall be touched up with the same color and type of paints as used originally.
6. Close out Procedures: General coordination is required. Close out procedures shall be sequenced properly such that work shall not be endangered or damaged, and every required performance shall be fully tested and demonstrated.

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**REVISION OF SECTION 622
ELECTRICAL MODIFICATIONS**

- A. System performance test runs are required. Test runs of electrical systems shall be coordinated with test runs of equipment served.
 - B. During test runs, the Contractor shall make final corrections or adjustments of systems to refine and improve performances where possible, including noise and vibration reductions, elimination of hazards, better response of controls, signals and alarms, and similar system performance improvements.
 - C. Cleaning and lubrication is required. After final performance test run of each electrical system, the Contractor shall clean systems both externally and internally and comply with manufacturer's instructions for lubrication. The Contractor shall remove excess lubrication and touch up minor damage to factory-painted finishes.
7. Documentation Procedures: Signed commitments are required. The transfer of electrical system to CDOT for operation shall not proceed until guarantees, warranties, performance certifications, maintenance agreements, and similar commitments to be signed by the Contractor and other entities have been executed and transmitted to the Engineer for placement in records.
 8. The Contractor shall furnish and install all electrical equipment, materials and labor, machinery, tools, transportation, procurement of all necessary permits, certificates, and other incidental services, whether described in these specifications and drawings or not, to provide a satisfactory operating and complete electrical installation.
 9. The Contractor shall perform all operations necessary to install, adjust, and put into satisfactory operation all electrical equipment.
 10. The Contractor shall provide and install conduits, cable and electrical connections, adjustments, and test of mechanical equipment which requires electrical power.
 11. The Contractor shall provide and install all required systems and equipment grounding as required to properly ground all systems and equipment in conformance with the latest requirements of NEC and best modern practice using the existing grounding system.
 12. The specifications and Contract Drawings are complementary; items shown in one, but not in the other shall be as binding as if included in both. Where a discrepancy exists between specifications and drawings and/or drawings and drawings, the Contractor shall assume the most expensive material or method of installation for bidding purposes and shall refer the discrepancy to the Engineer for a decision.
 13. Before cutting or removing any existing cable, the Contractor shall ensure the cable has been properly identified, de-energized, grounded, or otherwise made safe.
 14. All electrical equipment enclosures shall have no knockouts, nor shall they be drilled for more than the actual conduits entering them. All electrical equipment shall be made to minimize equipment size.
 15. For existing electrical equipment shown on drawings as relocated and reused, the Contractor shall extend the existing raceways or conduits and wire of the same size, type, and number where required to reach the new location of the equipment.

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**REVISION OF SECTION 622
ELECTRICAL MODIFICATIONS**

16. All floor-mounted electrical equipment shall be installed on a concrete pad as indicated on the Contract Drawings. The pad shall be extended four inches beyond the base plan of the equipment or as shown on the Contract Drawings.
17. All electrical equipment shall be installed on hot dipped galvanized steel channel 1½" X 1½" 12 gauge thick with holes on the web. All channels installed for mounting lighting fixtures, troughs and conduits shall be 1½" X 1½" 12 gauge thick with rod, fitted with a metallic shroud and painted (color to match fixture, trough and steel channel) with lock washer, and hexagonal nuts.
18. Branch circuit conduits and/or lights shall have to be rerouted, extended, relocated, or temporarily removed and replaced to permit the installation or removal of equipment. The Contractor shall allow for and accomplish these re-work items to suit field requirements and conditions.
19. All exposed conduit shall run in a neat, inconspicuous, and workmanlike manner. This work shall be performed to the satisfaction of the Engineer.
20. All feeders shall be in one continuous length without a splice or joint.
The Contractor shall prepare the following shop drawings (scale 1/4" = 1' and size 24" x 36"), based on the one-line diagram and electrical distribution and room layouts, and shall submit to the Engineer for approval:
 - A. Detailed plan view showing all electrical equipment, ceiling mounted conduits 2" and larger, pull boxes 12"x12"x4" and larger, etc.
 - B. Elevation of all walls showing equipment height, clearance between them, pull boxes, and conduit routing.
21. All electrical equipment shall be installed to permit easy access for inspection, operation, maintenance, and repair in accordance with manufacturer's recommendations and as directed by the Engineer.
22. The approval of shop drawings will be general and will not relieve the Contractor of responsibility for the accuracy of the drawings, nor for the proper fitting and construction of the work, nor of the furnishing of materials or work required by the Contract and not indicated on the shop drawings. Approval of shop drawings shall not be construed as approving departures from the Contract Drawings, supplementary drawings, or specifications.

Surface Raceway and Wireway Installations. The surface raceway system shall be installed in an approved and workmanlike manner to make the system as inconspicuous as possible. Where standard lengths are required to be cut or mitered to suit the field conditions, proper tools as recommended by the manufacturer shall be used to attain smooth edges, accurate bends, and offsets. Runs shall be parallel or at right angles to walls and partitions. Each surface raceway section shall be independently and securely supported to the structure in an approved manner.

1. Connections shall be made to other types of raceways in an approved manner with fittings manufactured for the purpose and application. Flat tees, crosses, or utility boxes

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**REVISION OF SECTION 622
ELECTRICAL MODIFICATIONS**

shall be installed where required to accommodate branch circuits. Bushings shall be installed where a raceway enters a terminal fitting. Where the surface raceway systems enters the rigid conduit system, conduit connectors as manufactured by the Wiremold Company, or approved equal, together with all necessary fittings shall be installed.

2. Detail drawings, showing the various proposed methods of installation of the surface raceways, shall be submitted for the approval of the Engineer. The Contractor shall not proceed with the installation of any surface raceways before approval is obtained.

Clean Up. The Contractor shall be responsible for cleaning of the worksite during progress of the work, including periods when work is suspended, and at completion of the work.

1. Requirements of Regulatory Agencies: In addition to the requirements herein, the Contractor shall maintain the cleanliness of the work and surrounding premises within the work limits to comply with federal and local fire and safety laws, ordinances, codes and regulations. Comply with all federal and local anti-pollution laws, ordinances, codes and regulations when disposing of waste materials, debris, and rubbish.
2. Protection of Painted Surfaces: The Contractor shall schedule cleaning and disposal operations so that dust, wash water, or other contaminants generated during such operations do not damage or mar painted or finished surfaces and to prevent accumulation of dust, dirt, debris, rubbish, and waste materials on or within the work or on the premises surrounding the work.
3. Waste Material Disposal: The Contractor shall dispose of all waste materials, surplus materials, debris and rubbish from the project site. Do not burn or bury rubbish and waste materials on the project site, nor dispose of volatile or hazardous wastes such as mineral spirits, oil, or paint thinner in storm or sanitary drains.
4. Cleaning Materials: The Contractor shall use only cleaning materials recommended by manufacturer of surface to be cleaned. Use each type of cleaning material on only those surfaces recommended by the cleaning material manufacturer. Use only materials which shall not create hazards to health or property.
5. During Construction: The Contractor shall keep the work and surrounding premises within work limits free of accumulations of dirt, dust, waste materials, debris, and rubbish. Keep dust-generating areas wetted down. Provide suitable containers for storage of waste materials, debris and rubbish until time of disposal. Dispose of waste, debris and rubbish off site at legal disposal areas.
6. Upon Completion: The Contractor shall remove and dispose of all excess or waste materials, debris, rubbish, and temporary facilities from the site, structures, and all facilities. Repair all areas affected by the construction and restore them to original condition or to minimum condition specified in the Contract Documents. Remove spatter, grease, stains, fingerprints, dirt, dust, labels, tags, packing materials, and other foreign items or substances from interior and exterior surfaces, equipment, signs, and lettering. Repair, patch and touch-up chipped, scratched, dented, or otherwise marred surfaces to match specified finish. Remove paint, clean, and restore all equipment and material

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**REVISION OF SECTION 622
ELECTRICAL MODIFICATIONS**

nameplates, labels, and other identification markings. Clean all walls, floors, slabs, pavements, and ground surfaces, and maintain cleaning until substantial completion.

Testing. The Engineer reserves the right to require such tests, after installation, as in his opinion may seem adequate and reasonable to demonstrate that the work has been properly performed. All apparatus, labor, and other facilities necessary to perform tests shall be provided by the Contractor. Any work deemed by the Engineer to be defective shall be replaced. The Contractor is required to submit documents and perform tests as requested by the Engineer. Proper documentation includes but is not limited to: A (certifications), B (visual inspection & mechanical tests), and C (electrical tests) for the systems and system components.

**REVISION OF SECTION 622
BOXES AND FITTINGS**

Section 622 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work is installation of electrical boxes and fittings in accordance with these specifications and in conformity with the details shown on the plans or established.

MATERIALS

General.

1. Locations, types and sizes of boxes and fittings as specified here within, as required to provide a complete electrical system and as shown on the Contract Drawings
2. Boxes and fittings shall be metallic, unless otherwise shown shall conform to NEMA OS1, NEMA 250, UL 50, UL 514A, UL 514B, and National Fire Protections Association (NFPA) 70.
3. Nonmetallic boxes and fittings shall conform to NEMA OS2, NEMA 250, UL 50, UL 514C, and NFPA 70.
4. Boxes and fittings to be located in hazardous (classified) areas shall conform to UL 886 and NFPA 70.
5. All electrical materials and equipment for which there are established UL standards shall bear the UL label.
6. Where the sizes or dimensions of a box whether for use on power, communications, signaling, control, telephone, or other purposes, shall be sized as follows:
 - A. In straight pulls, the length of the box shall not be less than eight times the trade diameter (nominal inside diameter) of the largest raceway.
 - B. Where angle or "U" pulls are made, the distance between each raceway entry inside the box and the opposite wall of the box shall not be less than six times the trade diameter of the largest raceway. The distance shall be increased for additional entries by the amount of the sum of the diameters of all other raceway entries in any row on the same wall of the box. The distance between raceway entries enclosing the same conductor shall not be less than six times the trade diameter of the larger raceway.
 - C. Where a conduit entry is in the wall of a box opposite a removable cover, the minimum distance between the entry and the cover shall be as follows:

Conduit Size	Distance Between Entry and Cover
Up to 1-1/4 inch	4 inches
1-1/4 inch and 1-1/2 inches	6 inches
2 inches and 2-1/2 inches	8 inches
3 inches and larger	12 inches

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**REVISION OF SECTION 622
BOXES AND FITTINGS**

The minimum depth of a box shall be not less than two times the trade diameter of the conduit entries in a single row and not less than 1-1/2 times the sum of the trade diameter of the largest raceway in each row for multiple rows.

7. Weatherproof cast boxes shall be used for exterior or damp locations. Weatherproof boxes shall be hot-dipped galvanized cast-steel or cast-aluminum. Cast boxes shall be threaded conduit entrance type provided with mounting lugs. Materials shall match the type of conduit i.e., galvanized steel or aluminum, used in the conduit run.
8. Covers for boxes located in public spaces or where shown on the Contract Drawings shall be furnished with tamper-resistant hardware.
9. Cover plates for outlet boxes shall be stainless steel grade 302.

Interior Outlet and Device Boxes. Provide galvanized, flat-rolled, sheet-steel interior outlet wiring boxes, of types, shapes and sizes, including box depths, to suit each respective location and installation; construct boxes with stamped knockouts in back and sides and with threaded screw holes with corrosion-resistant screws for securing box covers and wiring devices.

Outlet boxes shall be of proper sizes and shapes for conduits and wires entering them, and equipped with plaster ring or cover as necessary for the wiring devices to be installed. Boxes for switches and receptacles shall be 4-inch square, minimum 2 1/8-inch deep, for up to two devices; solid, ganged boxes for over two devices; and installed so that device covers shall be tight and plumb with wall finish. Provide suitable barrier in boxes where two or more 277-volt switches are to be installed, to isolate each on its own phase. Boxes for lighting fixture installation shall be 4-inch square, minimum 2 1/8-inch deep, and provided with 3/8-inch studs.

Boxes to be installed in ceilings, plenums, or spaces used for supply or return of environmental air shall be UL-listed for such use, without holes, openings or penetrations, and complete with gasketed cover plates. Provide all sheet-steel boxes with suitable knockouts.

Junction and Pull Boxes

1. General
 - A. Unless otherwise shown on the Contract Drawings, the Contractor shall provide galvanized, code-gauge, sheet-steel junction and pull boxes and covers for interior locations and cast-metal boxes and covers for exterior locations of types, shapes and sizes to suit each respective location and installation, and equipped with stainless steel hinges, nuts, bolts, screws and washers.
 - B. Junction or pull boxes having any dimension larger than 36 inches shall contain racks or supports for all cables or conductors.
 - C. The Contractor shall provide pull boxes with suitable insulating barriers where shown on the Contract Drawings or required by code. Vertical-offset pull boxes shall contain cable supports at turns to prevent cables from resting on corners.

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**REVISION OF SECTION 622
BOXES AND FITTINGS**

- D. Where shown on the Contract Drawings, the Contractor shall provide boxes with provisions for padlocking.
 - E. Special boxes shall be as shown on the Contract Drawings.
 - F. Where shown on the Contract Drawings, catches or vault handles shall be lockable. Locks shall be keyed alike for the same service, such as power, communications, signal or telephone. Each service type shall be keyed differently.
 - G. All covers in exposed exterior locations, or other areas as shown on the Contract Drawings, shall be gasketed.
 - H. For covers heavier than 20 pounds or more than 24 inches in any dimension, the Contractor shall provide two replaceable studs, located on each side of the box flange, to support the cover during installation.
 - I. Boxes containing, or designated for, conductors operating at greater than 600 volts (phase-to-phase) shall be constructed of minimum 12-gauge steel.
2. Interior Junction and Pull Boxes
- A. Finished Areas
 - (1) Junction and pull boxes, located in finished areas and having any dimension larger than 12 inches, shall be furnished with flush-mounting, lockable, hinged covers, similar to adjacent panelboard cabinets. Locks shall be keyed alike for the same service, such as power, communications, signal or telephone. Each service type shall be keyed differently. Hinged covers shall contain catches to keep covers closed. Covers having any dimension larger than 36 inches and all multiple-section doors shall contain three-point vault handles. Covers shall be furnished shop-primed for field painting, and shall be finished with a color as selected by the Engineer.
 - (2) Boxes having any cover dimension 12 inches or less shall be furnished with flush-mounting, screw- on covers, unless otherwise shown on the Contract Drawings.
 - B. Unfinished Areas
 - (1) Junction and pull boxes, located in electrical or telephone closets or rooms, in mechanical equipment rooms, in areas above hung or accessible ceilings, or in areas shown on the Contract Drawings as "unfinished," shall be furnished with screw-on covers for boxes having any cover dimension 24 inches or less, and with either single or multiple-section hinged covers for boxes having any cover dimension larger than 24 inches.

Conduit Bodies. The Contractor shall provide galvanized, cast-metal, conduit bodies, of types, shapes and sizes to suit each respective location and installation; construct with threaded-conduit entrance hubs, removable covers, and stainless steel or brass screws.

Bushings, Locknuts and Knockout Closures. The Contractor shall provide corrosion-resistant knockout closures and conduit locknuts, and insulated, malleable iron, conduit bushings and offset connectors, of types and sizes to suit each respective use and installation.

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**REVISION OF SECTION 622
BOXES AND FITTINGS**

Supporting Devices. The Contractor shall provide inserts, expansion shield lugs, bolts with nuts and washers, shims, or any other type of fastening devices required to secure boxes, in accordance with Supporting Devices (Revision of Section 622). Unless otherwise shown on the Contract Drawings, all fasteners shall be hot-dipped galvanized and of sizes and types recommended by the equipment manufacturer and as approved by the Engineer.

CONSTRUCTION REQUIREMENTS

General. Installation of boxes and fittings shall meet the following requirements:

1. Install boxes and conduit bodies at the locations shown on the Contract Drawings and as required by NFPA 70 at any other location where they are required to facilitate the pulling, supporting or connection of wires and cables.
2. Securely mount all boxes in a manner approved by the Engineer and support the boxes independently of conduits entering them.
3. Install boxes and conduit bodies in classified (hazardous) locations in accordance with their listing or label requirements. Conduit seal fittings shall be packed and filled only after proper operation of equipment and systems has been demonstrated and approved by the Engineer.
4. Paint exteriors of boxes exposed in mechanical equipment rooms or in electrical rooms or closets or spaces shown as "unfinished" on the Contract Drawings, and the exteriors of boxes installed above hung or accessible ceilings, as follows:
 - A. Emergency: Orange
 - B. Fire Alarm: Red
 - C. High Voltage: Red with 1-inch, white block letters reading "HIGH VOLTAGE" on each exposed face and cover.
5. All installations shall conform to NFPA 70.
6. Dissimilar Metals
 - A. "Dissimilar metals" shall mean those metals which are incompatible with one another in the presence of moisture, as determined from their relative positions in the Electrochemical Series, or from test data.
 - B. Where dissimilar metals come in contact, paint the joint both inside and out with approved coating to exclude moisture from the joint, or provide a suitable insulating barrier separating the metals.

METHOD OF MEASUREMENT

Boxes and Fittings will not be measured and paid for separately, but shall be included in the lump sum price for Electrical Modifications.

**REVISION OF SECTION 622
GROUNDING AND BONDING**

Section 622 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work is installation of grounding in accordance with these specifications and in conformity with the details shown on the plans or established.

MATERIALS

General. The Contractor shall furnish grounding elements for cabinets, starters, and miscellaneous electrical equipment for all non-current-carrying metallic portions of the entire electrical system and for exposed non-electrical systems located in electrical substations or switchgear rooms as required by ANSI C2, National Fire Protection Association (NFPA) 70 and building codes which would be applicable if CDOT were a private corporation. All receptacles, switches, disconnects, individual motor controllers, etc., shall be provided with a grounding terminal connected to the device frame or enclosure.

Refer to each individual equipment Specification section for additional grounding requirements. All conduit, cable tray, raceways, junction boxes, pull boxes, etc., shall be made electrically continuous by means of grounding conductors, bonding jumpers, grounding brushings, couplings, fittings, etc., as required by the NEC and the authority having jurisdiction.

Grounding Conductors. The Contractor shall provide grounding conductors in accordance with the requirements of NFPA 70, this Revision of Section 622 as applicable, and as specified on the Contract Drawings. Equipment grounding conductors shall be green insulated. Isolated grounding conductors shall be green insulated with yellow striping. All bonding conductors shall be flexible copper bonding jumpers sized in accordance with the NEC for grounding electrode conductors.

Above Grade Connections. Connectors to piping, fencing, and conduit systems shall be listed and labeled as grounding connectors for the materials used.

Grounding Bushings. Grounding bushing shall be insulated type.

CONSTRUCTION REQUIREMENTS

Installation. The Contractor shall install grounding elements for cabinets, panelboards, starters, and miscellaneous electrical equipment, for all metallic non-current carrying portions of the entire electrical system and for exposed non-electrical systems located in electrical substations or switchgear rooms as required by ANSI C2, NFPA 70 and building codes which would be applicable if CDOT were a private corporation.

1. Each system or electrically continuous metallic piping and ductwork shall be electrically grounded in accordance with the requirements of NFPA for “bonding” as they apply to the “bonding of piping systems.” Isolated metallic piping and duct systems shall be bonded to the building equipment grounding system.
2. Bonding and grounding conductors shall be sized, run in conduit and connected to various services in accordance with the requirements of NEC and NFPA70.

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**REVISION OF SECTION 622
GROUNDING AND BONDING**

3. Grounding shall be done in accordance with the requirements of and subject to the approval of the Engineer. Approved materials, devices and workmanship shall be utilized. All conductor terminations shall be in accordance with Revision of Section 622 - Wires, Cables, Splices, Terminations.
4. All ground connectors, shall be protected from mechanical injury by rigid conduit to which the conductor shall be bonded at each end.
 - A. All exposed non-current-carrying metal parts of permanently mounted electrical equipment, all terminal devices, and the conduit system shall be effectively grounded and securely bonded to the reference ground point of its separately derived service ground. The equipment ground path from conduit, equipment, and metal enclosures shall be continuous and permanent, and shall have the capacity to safely conduct any fault currents imposed on it with sufficiently low impedance to facilitate the operation of the circuit protective devices.
 - B. All conduits 2 inches and larger entering distribution switchboards and distribution or power panels shall be provided with grounding bushings and connected to the respective equipment ground bus by means of bare copper wire.
 - C. Flexible metal conduit and liquid-tight flexible metal conduit, where permitted by other sections of this Specification, shall be provided with a separate, copper equipment grounding conductor. The equipment grounding conductor shall be sized in accordance with NFPA70, and if insulated, the color of the insulation shall be green for the conductor's entire length. The equipment grounding conductor shall be bonded at both ends of the flexible conduit using an approved fitting or bonding screw.
 - D. Motor frames that are not directly clamped to the supply conduit shall be bonded and grounded to the conduit by means of a suitably-sized ground conductor and ground clamp. No soldered connections shall be used in leads. All connections shall be made with an approved solderless connector.
 - E. A separate insulated (green) equipment grounding conductor shall be installed in all branch circuits.
 - F. When a separate insulated equipment grounding conductor is provided with a branch circuit, it shall be connected to a ground bus in the panelboard from which it is served. The panelboard ground bus shall be of sufficient size to accommodate all devices served, including space for future expansion, as well as lugs of appropriate size for connection of an equipment grounding conductor to the grounding electrode of the derived source.
5. Flexible Bonds
 - A. All expansion joints, points of electrical discontinuity, or connections in conduit where firm mechanical bond is not possible shall be bonded with OZ-Gedney Type "BJ" or approved equal bonding jumper.

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**REVISION OF SECTION 622
GROUNDING AND BONDING**

- B. A flexible bonding jumper shall be provided around isolating couplings and isolating nipples, and shall be similar and approved equal to OZ-Gedney Type "BJ." All mechanical piping requires isolating couplings or isolating nipples when the piping material is changed.
- 2. Grounding shall be installed as shown on the Contract Drawings.
- 3. Grounding and bonding equipment for use in connection with interior wiring systems shall conform to UL 467.
- 4. Separate insulated equipment grounding conductors shall be installed with circuit conductors to maintain grounding system at equipotential. Raceway system shall not be utilized as the equipment ground.
- 5. All non-current-carrying metallic enclosures of electrical conductors, or exposed non-current-carrying metallic parts of electrical equipment, or of power apparatus shall be grounded.
- 6. Connections:
 - A. General
 - (1) Make connections in such a matter as to minimize possibility of galvanic action or electrolysis. Select connectors, connection hardware, conductors, and connection methods so metals in direct contact will be galvanically compatible.
 - (2) Use electroplated or hot-tin-coated materials to assure high conductivity and make contact points closer in order of galvanic series.
 - B. Make connections with clean bare metal at points of contact.
 - C. Make all connections of grounding connector cables to ground rods by exothermic welding method. Welds that are puffed up or that show convex surfaces indicating improper cleaning are not acceptable.
 - D. Terminate insulated equipment grounding conductors for feeders and branch circuits with pressure-type grounding lugs. Where metallic raceways terminate at metallic housings without mechanical and electrical connection to the housing, terminate each conduit with a grounding bushing. Connect grounding bushings with a bare grounding conductor to the ground bus in the housing. Bond electrically non-continuous conduits at both entrances and exits with grounding bushings and bare grounding conductors.
 - E. Tighten grounding and bonding conductors and terminals, including screws and bolts, in accordance with manufacturer's published torque-tightening values for connectors and bolts.
 - F. Where insulated grounding conductors are connected to ground rods or ground buses, insulate the entire area of the connection and seal against moisture penetration of the insulation and cable.

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**REVISION OF SECTION 622
GROUNDING AND BONDING**

Field Tests. Upon completion of the electrical system, including all grounding, the Electrical Contractor shall test the system for stray currents, ground shorts, etc. These tests shall be performed in a manner acceptable to the Engineer. Approved instruments, apparatus, services and qualified personnel shall be utilized. If stray currents, shorts, etc., are detected, eliminate or correct as required. The test procedure shall be as follows:

1. All main disconnects shall be opened for the system being tested.
2. A DC ohmmeter shall be connected across the system neutral and equipment ground.
3. An ohmmeter reading in excess of 100 ohms shall indicate that the system neutral and equipment ground are properly isolated.
4. An ohmmeter reading less than 100 ohms shall indicate that the system contains ground shorts (stray currents) at some point along the system neutral.
5. Grounded neutrals may be identified by disconnecting individual neutral conductors from the system one at a time while monitoring the ohmmeter.
6. The systems shall be retested after correction of all ground shorts is complete. Final readings shall be tabulated for review by the Engineer.

**REVISION OF SECTION 622
SUPPORTING DEVICES**

Section 622 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work is installation of hangers and supports, sleeves, and fasteners used to support electrical raceways and equipment in accordance with these specifications and in conformity with the details shown on the plans or established, except as specified within this section.

Supporting devices, furnished as part of factory-fabricated equipment, are specified as part of equipment assembly in other Sections of the Specifications.

MATERIALS

Manufacturers. Subject to compliance with requirements of this Section, the Contractor shall provide supporting devices of the acceptable manufacturers as shown on Contract Drawings.

(b) General Hangers and Supports. Unless otherwise shown on the Contract Drawings, the Contractor shall provide hangers and supports as specified in this Section. Where more than one type of hanger or support is suitable for the intended use, selection is at the Contractor's option, subject to approval by the Engineer. Hangers and supports for which there are established Underwriters Laboratories Inc. (UL) standards shall bear the UL label.

(c) Raceway Support.

1. Clevis hangers for supporting horizontal conduit shall be of galvanized steel with hole provided for a threaded steel rod.
2. Riser clamps for supporting vertical conduits shall be of galvanized steel with two or three bolts and nuts and 4-inch ears.
3. Steel rod reducing couplings shall be sized as required and constructed of galvanized or plated steel.
4. C-Clamps shall be of black malleable iron, galvanized, or plated steel with a hole for threaded rod.
5. I-Beam clamps shall be galvanized or plated steel out of 1-1/4-inch by 3/16-inch stock with a 3/8-inch cross bolt and a 2-inch flange width.
6. Right-angle and parallel beam clamps shall be constructed of galvanized steel clamps for supporting or fastening conduit up to 2-inch trade size.
7. One-hole conduit straps for supporting up to 1-inch conduit or electrical metallic tubing (EMT) shall be of galvanized steel.
8. Two-hole conduit straps for supporting conduit or EMT larger than 1-inch shall be $\frac{3}{4}$ - inch in width and of galvanized steel.
9. Hexagon nuts shall be of galvanized steel
10. Round steel rod shall be of galvanized or plated steel.

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**REVISION OF SECTION 622
SUPPORTING DEVICES**

11. Threaded trapeze hangers shall be the same as specified in this section. The following types of hangers and supports shall not be used: perforated metal strapping, slotted/perforated angles, spring pressure or torsion clips, hangers or supports.

Equipment Supports. U-channel strut system shall be 12-gauge, hot-dipped galvanized steel. Provide with drilled or slotted holes as required for the application and with the following fittings which mate and match with U-channel:

1. Fixture hangers
2. Channel hangers
3. End caps
4. Beam clamps
5. Wiring stud
6. Thin wall conduit clamps
7. Rigid conduit clamps
8. Conduit hangers
9. U-bolts

(e) Supporting Steel Sections and Channels. Supporting steel sections and channels shall be fabricated of ASTM A36 steel in accordance with the appropriate requirements of the AISC, AISI, and AWS publications specified in this Section, and shall be hot-dip galvanized after fabrication.

(f) Cable Supports. The Contractor shall provide cable supports with insulating wedging plug for non-armored type electrical cables in risers. Assembly shall include body of galvanized malleable iron with insulating wedging plug. Provide cable supports for armored type electrical cables in risers. Assembly shall include body and pressure plates of galvanized steel.

(g) General Sleeves and Seals. Unless otherwise shown on the Contract Drawings, the Contractor shall provide sleeves and seals as specified below. Where more than one type of sleeve or seal is suitable for the intended use, selection is at the Contractor's option, subject to approval by the Engineer. Sleeves and seals for which there are established UL standards shall bear the UL label.

(h) Pipe Sleeves. Pipe sleeves for conduits penetrating concrete or masonry floor and walls shall be provided as follows:

1. Steel Pipe: Fabricate from schedule 40 galvanized steel pipe; remove burrs.
2. Iron Pipe: Fabricate from cast iron or ductile iron pipe; remove burrs.
3. Plastic Pipe: Fabricate from either fiberglass or schedule 40 PVC plastic pipe; remove burrs. Fiberglass sleeves may be utilized for interior or exterior usages, but PVC sleeves shall be utilized for exterior usage only.

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REVISION OF SECTION 622
SUPPORTING DEVICES

4. Sleeves shall have a minimum inside diameter as shown, based on the installed raceway diameter.

Raceway Diameter (inches)	Sleeve Inside Diameter (inches)
1 or less	2
1-1/4 to 2	3
2-1/2 to 3	4
3-1/2 to 4	5
5	6
6	7

5. Where sleeve encloses only one conductor, phase or polarity, or ground wire or cable, the sleeve shall be non-ferrous.

Interlocking Modular Seals. Provide interlocking modular type seals for conduit access located in exterior foundation and pit walls. The seals shall be multi-link, stainless steel bolted connection, high-temperature fittings.

(j) Sealing Bushings. Provide sealing bushings for conduit access core-drilled through foundation walls or floors. The bushings shall be molded, one-piece neoprene sealing rings with PVC-coated steel or uncoated aluminum pressure plates, stainless steel hex socket head cap screws, and flat washers.

(k) Fire Seals. Provide UL-listed, three-hour rated, silicone-based foam, fire-resistive, waterproof joint sealing system to prevent the passage of hot gases and fire.

(l) Wall and Floor Seals. Provide watertight and pressure-tight wall and floor seals suitable for sealing around conduit passing through exterior concrete floors and walls. Assembly shall include steel sleeves, galvanized malleable iron body, neoprene sealing grommets and rings, metal pressure rings, membrane clamp where required by foundation design, and pressure clamps with Type 316 stainless steel hex head cap screws. Seal sizes shall be maximum published size for conduit to be installed therein.

(m) General Fasteners. Unless otherwise shown on the Contract Drawings, provide fasteners as specified below. Where more than one type of fasteners is suitable for the intended use, selection is at the Contractor's option, subject to approval by the Engineer.

(n) Toggle Bolts. Toggle bolts shall be spring head, galvanized or plated steel, 1/4-inch to 1/2-inch sizes, and of length as required.

(o) Expansion Anchors. Expansion anchors shall be metallic expansion anchors or shields, including drop-in anchors, wedge and sleeve anchors, and two-piece and three-piece shields for lag screws or machine screws or bolts.

(p) Powder Activated Fasteners. Powder-activated fasteners shall be steel-, pin-, or stud-type, selected for proper length and penetration for the equipment, clamp or strap to be installed, and the base material.

Bolts, Nuts, Lockwashers and Washers. All hardware shall be galvanized or plated steel, unless otherwise shown on the Contract Drawings. Bolts and nuts, 1/4-inch trade size and

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**REVISION OF SECTION 622
SUPPORTING DEVICES**

larger, shall be hex head or hex socket type, standard American sizes. Lockwashers shall match the finish of the furnished bolts and nuts, and generally be installed one-per-bolt, at the nut end of the assembly. Washers shall be standard-or fender-type, as required, and sized to match the installed bolts or screws. The following types of fasteners shall not be used:

1. Lead anchors or studs;
2. Wooden plugs or anchors;
3. Plastic anchors;
4. "Nail-in" anchors, either of plastic or metal type.

CONSTRUCTION REQUIREMENTS

Examination. The Contractor shall verify that electrical installations, structural, mechanical and other related Work satisfy the requirements for performance of the Work of this Section in accordance with the Contract Documents. Report immediately to the Engineer any electrical, structural or related construction defects in areas where supporting devices are to be installed, and do not attempt to rectify any defect unless specifically instructed to do so by the Engineer.

(b) Installation. Before installation the supporting devices, the Contractor shall investigate the site condition to determine what preparatory work, if any, is needed.

1. Install hangers and supports, sleeves, and fasteners in accordance with approved printed manufacturer's installation procedures and as specified.
2. Coordinate all affected trades and all aspects of the electrical work, including installation of raceways and wiring as necessary to interface installation of supporting devices with other work.
3. Install hangers, supports, and attachments to properly support raceways, equipment, and accessories from building structure. Arrange for grouping of parallel runs of horizontal conduits to be supported together on trapeze hangers where possible. Install hangers and supports with maximum spacing not to exceed that permitted by NFPA 70 and NECA Standard of Installation, as applicable, unless otherwise shown on the Contract Drawings.
4. Secure threaded rod couplings, trapeze hangers, supports, or similar horizontal elements using lock washers and jam nuts to prevent loosening.

Conduit and Raceway Supports. Raceways shall not be supported from hung ceiling supports or members or metal roof deck. Do not support raceways from mechanical ductwork, ductwork supports, piping, or piping supports. Threaded rod used for the support of conduits, raceways, or trapeze hangers of the given size, shall be not less than the following:

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REVISION OF SECTION 622
SUPPORTING DEVICES

Conduit, Raceway, Hanger Size (inches)	Threaded Rod Size (inches)
2 or less	3/8
2-1/2 to 3-1/2	1/2
4 to 5	5/8
6	3/4

1. Where trapeze hangers are used, bolt or clamp the raceways in place to at least every third hanger and to the first hanger on each side of a bend, fitting, junction or pull box, or change in direction.

(d) *Sleeves.* Unless otherwise shown on the Contract Drawings, sleeves for raceways and risers shall be extended one inch beyond top of finished floor, curb, or building element being penetrated. Install sleeves level and plumb, accurately located, and positioned to conform to the requirements of the equipment and in accordance with the approved layout drawings. Interlock modular seals in tandem, one at the interior and one at the exterior face of the pipe sleeve. Tighten sleeve seal nuts until sealing grommets have expanded to form watertight seal.

(e) *Fasteners.* Wood screws, lag screws, carriage bolts, or machine screws shall be utilized for wood or materials of similar fibrous nature. Welded or blazed threaded studs, bolts or machine screws, or clamps shall be utilized for structural and miscellaneous steel, iron, or other metals. Metallic expansion shields, wedge anchors, or drop-in anchors with lag screws, bolts, or machine screws shall be utilized for solid masonry or concrete. Sleeve anchors, drop-in anchors, or toggle bolts shall be utilized for concrete masonry units (CMU). Do not use powder-activated fasteners in CMU.

(f) *Dissimilar Metals.* "Dissimilar metals" shall mean those metals which are incompatible with one another in the presence of moisture, as determined from their relative positions in the Electrochemical Series, or from test data. Where dissimilar metals come in contact, paint the joint both inside and out with approved coating to exclude moisture from the joint, or provide a suitable insulating barrier separating the metals.

**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

Section 622 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work is installation of wires, cables, splices, terminations, and appurtenances for electrical systems of 600 volts or less in accordance with these specifications and in conformity with the details shown on the plans or established in the Contract Documents.

MATERIALS

Manufacturers. Subject to compliance with requirements of this Section, the Contractor shall provide wires, cables, wire and cable splicing, terminating, and arcproofing materials of manufacturers as shown on the Contract Drawings.

(b) Wires and Cables.

1. Wire shall be defined as a solid or stranded conductor smaller than No. 6 AWG with or without insulation. Cable shall be defined as a single conductor No. 6 AWG or larger, or two or more conductors of any size wire under a common covering.
2. Locations, types, sizes and numbers of wires and cables are shown on the Contract Drawings. Where not indicated, provide proper wire and cable selection to comply with this section and National Fire Protection Association (NFPA) 70 Standards.
3. The wires and cables must be suitable for use in wet and dry locations, as applicable for the installation, with temperature ratings that correspond to the conditions of application. Wires and cables shall be suitable for installation indoors or outdoors, in conduits, trays, and underground ducts or direct burial in earth, as applicable for the installation shown on the Contract Drawings and as allowed by applicable codes and this Section.
4. Unless otherwise indicated on the Contract Drawings, cable insulation shall be rated for conductor temperatures not exceeding 90 degrees C for normal operation, 130 degrees C for emergency overload conditions and 250 degrees C for short circuit conditions in accordance with Insulated Cable Engineers Association (ICEA) standards S-95-658 and S-73-532. Temperature ratings shall be for both wet and dry locations.
5. Unless otherwise shown on the Contract Drawings, solid conductors shall be soft or annealed copper, conforming to ASTM B33 (tinned) or ASTM B3 (uncoated). Unless otherwise specified in this Section or unless otherwise shown on the Contract Drawings, stranded copper conductors shall be concentric stranding conforming to ASTM B8.
6. Polyvinyl Chloride (PVC): PVC-insulated power wiring and items containing PVC shall not be installed in subway areas, railroad or vehicular tunnels, railroad stations, and areas defined on the Contract Drawings as subject to NFPA 130 or NFPA 502 jurisdiction.
7. 35kV cable shall be shielded, with a semi-conducting strand shield, ethylene propylene rubber insulation, semi-conducting insulation shield, copper tape shield, and polyvinyl chloride jacket. The insulation level shall be 100 percent. Terminations shall be made using stress cones, and the shields shall be grounded at the switchgear. The other end of the shield shall not be grounded.

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

8. Unless otherwise shown on the Contract Drawings, cable insulations and jackets designated as Low-Smoke, Zero-Halogen (LSZH) shall be thermoset, low-smoke, low-toxicity, non-halogen, flame retardant type and shall meet the following performance characteristics:
 - A. Cables shall pass the flame propagatory and smoke release criteria according to the test method of UL 1685.
 - B. The halogen content of cable jackets shall not exceed 0.2 percent according to the test method of MIL- DTL-24643.
 - C. The toxicity index of cable jackets shall not exceed 2.0 according to the test method of Naval Engineering Standard NES 713.
 - D. The cable jackets shall comply with ICEA T-33-655 for smoke generation.
 - E. The acid gas content of cable jackets shall not exceed a maximum of 3.0 percent according to the test method of MIL-DTL-24643.
9. The following additional performance characteristics shall be used for wires and cables that will be installed in subway areas, railroad or vehicular tunnels, railroad stations, and areas defined on the Contract Drawings as being under the jurisdiction of NFPA 130 or NFPA 502, where stringent flame retardant, low-smoke, low-toxicity, zero-halogen, and good circuit integrity during a fire are required.
 - A. All insulated conductors shall be UL listed as type XHHW-2, in accordance with UL 44. In addition, all one-conductor cables shall be listed for and marked with the following UL designations: "VW-1," "LS" or "ST1" (limited smoke), "Oil and Gas Resistant," and for 1/0 and larger, "CT USE."
 - B. Single conductor wire and cable shall utilize thermoset Low-Smoke, Zero-Halogen, Cross-Linked Polyolefin insulation conforming to ICEA S-73-532 and S-95-658. The insulation shall be comprised of a single layer of homogeneous material. Jackets or other additional coverings shall not be allowed for single conductors because of the increase in cable size. All single conductor wires and cables shall follow the dimensional requirements of NFPA 70, Table 5.
 - C. Wires shall pass the flame propagatory criteria according to the test method of UL 1581 (VW-1).
 - D. The halogen content of both the wire and cable insulation and cable jacket(s) shall not exceed 0.2 percent according to the test method of MIL-DTL-24643.
 - E. The toxicity index of both the wire and cable insulation and cable jacket(s) shall not exceed 2.0 according to the test method of Defence Standard DEF STAN 02-713.
 - F. The acid gas content of both wire and cable insulation and cable jacket(s) shall not exceed a maximum of 2.0 percent according to the test method of MIL-DTL-24643.
 - G. The wire and cable insulation materials shall pass the smoke generation test in accordance with ASTM E662. All wires and cables shall pass the smoke release criteria according to the test method in UL 1685 for "LS" or "ST1" classification as

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

“limited smoke.” Wire and cable insulation when tested on a specimen of 80 mils thick slab shall not exceed the following values:

- (1) Flaming Avg. Ds (4 minutes) 50
 - (2) Flaming Avg. Dm (20 Minutes) 200
 - (3) Non-Flaming Avg. Ds (4 minutes) 50
 - (4) Non-Flaming Avg. Dm (20 minutes) 200
- H. All single conductor wires shall provide a minimum of 15-minute circuit integrity when tested in accordance with UL 2196. UL qualification is required and shall be predicated upon a No. 12 AWG sample in conduit without the water spray.
- I. Wires and cables shall pass the following flame propagation requirements:
- (1) All single conductor wires and cables shall pass the “UL VW-1” vertical flame test, according to UL 1581.
 - (2) All single conductor wires and cables shall pass the vertical flame test stated in AAR RP583, paragraph 5.9.4.
- J. Water Resistance
- (1) All wires and cables shall be rated for wet applications at 90 degrees C as defined by the requirements for type “XHHW-2” stated in UL 44 when tested in accordance with UL 1581.
 - (2) The mechanical water absorption of the insulation shall not be greater than 4 mg/sq. in. when tested in accordance with UL 1581.
- K. All wires shall be suitable for prolonged exposure to water by evidence of long term insulation resistance qualification testing in 90 degree C water. Testing shall be in accordance with UL 44 and UL 1581. After a minimum of one year exposure to 90 degree C water, the insulation resistance measurements must exceed an insulation resistance reading of 4.0 megohms/1000 ft. sample used for testing shall be either 14 or 12 AWG with a nominal 30 mils of LSZH insulation.
- L. Overload Stability: To ensure overload stability, all wires and cables shall pass the following tests defined in AAR Standard RP585:
- (1) Electrical Overload - Single Conductor (paragraph 5.9)
 - (2) Bundle Overload (paragraph 5.9.1)
 - (3) 125 degrees C Penetration Test (paragraph 5.9.2)
- M. The insulation shall demonstrate heat stability by retaining 95 percent of its original tensile strength and elongation values after aging seven days at 158 degrees C, as per AAR Standard RP585.
- N. Multi-Conductor Cables: Where multi-conductor cables are utilized, use the following additional criteria:

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- (1) Multi-conductor control cables shall utilize stranded class “B” or “C” conductors in accordance with ASTM B8. All conductors shall utilize thermoset low-smoke, zero-halogen cross-linked polyolefin insulation, conforming to ICEA standard S-95-658 and S-73-532, and be listed as type “XHHW-2.” Insulated conductors shall be cabled with a suitable binder tape and covered with a low-smoke, zero-halogen cross-linked polyolefin jacket. All cables shall be UL-listed Type TC in accordance with UL 1277. All individual insulated conductors utilized in multi-conductor cables shall meet all of the requirements set forth in this Section for single conductor cables for subway areas, railroad or vehicular tunnels, railway stations and areas defined on the Contract Drawings as under the jurisdiction of NFPA 130 or NFPA 502, except that UL print is not required on the individual conductor insulation.
 - (2) The halogen content of the cable jacket(s) shall comply with this Section.
 - (3) The toxicity index of the cable jacket(s) shall comply with this Section.
 - (4) The acid gas content of the cable jacket(s) shall comply with this Section.
 - (5) The cable jacket materials shall pass the smoke generation test in accordance with ASTM E662. Cable jacket when tested on a specimen of 80 mils thick slab shall not exceed the following values:
 - Flaming avg. DS (4 minutes): 50
 - Flaming avg. DM (20 minutes): 150
 - Non-Flaming avg. DS (4 minutes): 50
 - Non-Flaming avg. DM (20 minutes): 250
 - (6) All multi-conductor wire and cables shall provide a minimum of 15-minute circuit integrity when tested in accordance with International Electrotechnical Commission (IEC) IEC-331. Qualifications shall be predicated on a 2/C No.14 AWG sample tested at 240 Volts.
 - (7) All multi-conductor cables shall pass the UL vertical flame test criteria according to the test methods stated in UL 1685 for IEEE 1202 type of flame exposure. Test sample used shall be 2/c No.14 AWG.
 - (8) All multi-conductor wires and cable shall be listed for, and be marked with, the following UL designations on the cable jacket: “Type TC” (Tray Cable), “LS” or “ST1” (Limited Smoke), “Sun Res” (Sun Resistant) or “XHHW-2”/“90 degrees C Wet and Dry,” “IEEE 1202.”
10. Color-Coding for Power and Lighting Conductors
- A. Insulation or covering of wires and cables shall be factory color-coded by the use of colored compounds or coatings. The color-code shall be followed consistently throughout the performance of the Work.

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- B. Circuit identification for multi-conductor cable shall be accomplished by either Method 1 (colored compounds) or Method 3 (printed color designations) per ICEA with a K2 scheme, unless otherwise stated on the Contract Drawings.
- C. Upon written request of the Contractor, the Engineer may permit the use of the following methods in lieu of the wire or cable manufacturer's color-coding, when limited quantities of wire and cable are involved, for sizes No. 8 AWG and larger.
 - (1) For dry locations only, spiral application of 3/4 inch wide, colored, pressure-sensitive plastic tape, half-lapped for a distance of not less than six inches may be used. To prevent unwinding, the last two wraps of tape shall be applied with no tension.
 - (2) For wet or dry locations, application of three, 3/16 inch wide, colored, fungus-inert, self-extinguishing, self-locking, nylon cable ties spaced 3 inches apart may be used. The ties shall be snugly applied with a special tool or pliers, and any excess removed.
 - (3) Each wire and cable shall be color-coded at all terminal points, in all manholes, boxes, or other similar enclosures.
 - (4) Color markings shall be applied so as not to obliterate the manufacturer's identification markings.
- D. Color code chart shall be as follows:

System Voltage	Conductor	
	208Y/120V	480Y/277V
Phase A	Black	Brown
Phase B	Red	Orange
Phase C	Blue	Yellow
Neutral	White	Gray
Ground	Green	Green

General-Purpose Wires and Cables. Unless otherwise shown on the Contract Drawings, general-purpose wires and cables shall be as follows:

- 1. General-purpose wires and cables shall be single conductor, ASTM B8, Class B stranded for all sizes AWG.
- 2. Select from the following list of UL wire and cable types:
 - A. Type XHHW: Flame retarding, Cross-linked-polyolefin insulation, conforming to UL 44, for dry locations only.
 - B. Type XHHW-2: Flame retardant, Cross-linked-polyolefin insulation, conforming to UL 44, 90 degrees C wet and dry.
 - C. Type THWN: Flame retardant, moisture and heat-resistant thermoplastic insulation with a nylon jacket or equivalent; double-rated THHN-THWN gasoline-oil resistant II;

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

conforming to UL 83. The use of this cable shall be in accordance with the requirements of this Section.

3. Type USE: Unless otherwise indicated, Type USE shall be the only wire and cable used for underground installations. Select from one of the following:
 - A. Heat- and moisture-resistant ethylene-propylene-rubber insulation with jacket of either cross-linked polyolefin or heavy duty thermosetting chlorosulphanated polyethylene or heavy-duty neoprene; multiple rated "USE-RHH-RHW"; conforming to ASTM D2802, ICEA S-95-658, UL 44 and UL 854.
 - B. One layer of low-smoke, zero-halogen thermosetting cross-linked polyolefin, Type RHW-2, 90 degrees C wet and dry.

(d) Lighting Fixture Wires. Unless otherwise shown on the Contract Drawings, lighting fixture wires shall be stranded only, and shall be Type SF-2, silicone rubber insulated conforming to UL 62.

(e) Grounding Wires and Cables. Unless otherwise shown on the Contract Drawings, grounding wires and cables shall be as follows:

1. Insulated
 - A. ASTM B8, Class B stranded for all sizes; and of the same insulation type as the power conductors.
 - B. Covering shall be a continuous green color and conforming to ASTM B 33 and UL 44.
2. Uninsulated
 - A. General: ASTM B8, Class B stranded for all sizes AWG.
 - B. In raceways soft-drawn and conforming to ASTM B3.
 - C. Direct buried or encased in concrete
3. Soft-drawn, medium-hard-drawn, or hard-drawn and conforming to ASTM B1, B2 or B3, respectively.

Control Wires and Cables. Unless otherwise shown on the Contract Drawings, control wires and cables shall be as follows:

1. Single conductor wires and cables shall be ASTM B8, Class B stranded, type XHHW or XHHW-2 flame retardant, cross-linked-polyolefin insulation. Both shall conform to UL 44 and ICEA S-73-532.
2. Multiconductor cables shall be ASTM B8, Class B or Class C stranded, Control Cable Type B, conforming to ICEA S-73-532. Color-coded as per ICEA S-73-532. Method No. 1 for NFPA 70 applications (with white and green) or ICEA S-73-532 for paired conductor cables. Select from the following list of cable types.
 - A. Individual ethylene-propylene rubber insulation with overall flame retardant, cross-linked-polyolefin jacket; conforming to ICEA S-73-532, UL 44 and UL 1581.

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- B. Individual flame retardant, cross-linked-polyolefin insulation with overall flame retardant, cross-linked- polyolefin jacket; conforming to ICEA S-73-532.
- 3. Single conductor wires and cables shall be ASTM B3 stranded soft drawn bare copper conductor, Type MTW (machine tool wire), resistant to acids, alkalis, grease, chemicals, abrasion, and moisture. Wire shall be UL-recognized as AVM, and shall meet or exceed all applicable requirements of VW-1 flame test per UL44, UL 1015, CSA FT-1 flame test, NEC Article 30, and NFPA Standard 79.

(g) Switchboard Wires and Cables. Unless otherwise shown on the Contract Drawings, switchboard wires and cables shall be as follows:

- 1. Switchboard wires and cables shall be single conductor, ASTM B8, Class B stranded, except that for wires and cables crossing hinged joints and swinging panels and where "Extra Flexible" wire or cable is shown on the Contract Drawings, conductors shall be ASTM B174, Class K stranded.
- 2. Wires and cables shall be Type SIS, cross-linked-thermosetting-polyethylene insulation, conforming to ICEA S-73-532 or ICEA S-95-658, IEEE 383 and UL 44.

(h) Cable Tags.

- 1. Dry Locations
 - A. Fiberglass tags, 1/16 inch thick and 3/4 inch wide, indented with letters and numbers 5/16 inch high, with No. 14 AWG copper or nylon, weather-resistant cable ties.
 - B. Lighting branch circuit wiring and single conductor signal and control wiring may be identified with "Quik" labels manufactured by W. H. Brady Company, or approved equal.
- 2. Wet Locations
 - A. Brass or stainless steel metal tags, No. 28 gauge and 3/4 inch wide, embossed with letters and numbers 5/16 inch high, with No. 14 AWG copper or nylon, weather-resistant cable ties, or stainless steel cable ties.

Splicing, Terminating and Arcproofing Materials. All splicing, terminating and arcproofing materials shall be compatible so that no one material will adversely affect the physical or electrical properties of any other or of the wire or cable itself. All materials for making splices and terminations shall be specifically designed for use with the type of wire or cable, insulation, installation, and operating conditions of the specific application.

- 1. Connectors
 - A. Subject to compliance with requirements of this Section, provide connectors of the following types:
 - (1) Solderless, uninsulated, high conductivity, corrosion-resistant, compression connectors conforming to UL 467 and IEEE 837;
 - (2) Insulated, indenter type compression butt connectors;

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- (3) Insulated, integral self-locking flexible shell, expandable spring connectors;
 - (4) Uninsulated, indenter type compression pigtail connectors;
 - (5) Welded type connectors.
- B. For installations in subway areas, railroad stations, railroad or vehicular tunnels, or areas defined as subject to NFPA 130 or NFPA 502 jurisdiction, use flame-retardant type connectors.
2. Terminals
- A. Subject to compliance with requirements of this Section, provide terminals of the following types:
- (1) Solderless, uninsulated, high conductivity, corrosion-resistant, compression terminals conforming to UL 467 and IEEE 837;
 - (2) Insulated, compression terminals;
 - (3) Solderless, high conductivity, corrosion-resistant, hex screw type, bolted terminals;
 - (4) Welded type terminals.
3. Shrinkable Tubing
- A. Subject to compliance with requirements of this Section, provide shrinkable tubing of the following types:
- (1) Either irradiated modified polyvinyl chloride or irradiated modified polyolefin heat shrinkable tubing;
 - (2) Cold shrinkable tubing.
4. Tapes and Sealers
- A. Vinyl Tapes:
- (1) Flame-retardant, cold- and weather-resistant, 3/4 inch or 1-1/2 inches wide, as required, and conforming to UL 510 and ASTM D3005.

For interior, dry locations, provide 7 mil, conforming to ASTM D3005 (Type I); Scotch (3M) No. 33, or approved equal.

For exterior or damp and wet locations, provide 8.5 mil, conforming to ASTM D3005 (Type II); Scotch (3M) No. 88, or approved equal.
- B. Rubber Tapes:
- (1) Ethylene-propylene, rubber-based, 30-mil splicing tape, rated for 130 degrees C operation; 3/4 inch and wider (1, 1-1/2, 2 inches) as shown on the Contract Drawings or approved by the Engineer, conforming to (Grade A); Scotch (3M) No. 130C, or approved equal.
- C. Insulating Putty

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- (1) Rubber-based, 125-mil elastic filler putty; 1-1/2 inches wide; Scotch (3M) Scotchfil, or approved equal.
- D. Silicone Rubber Tapes
 - (1) Inorganic silicone rubber, 12 mil, 130 degrees C rated, anti-tracking, self-fusing tape; 1 inch wide; Scotch (3M) No. 70, or approved equal.
- E. Sealer
 - (1) Liquid applied fast-drying sealant; Scotch (3M) Scotchkote, or approved equal.
5. Resin Filled Splices
 - A. Epoxy Molded Type
 - (1) Two-piece, snap-together molded bodies, sized for wire or cable, with two-part low viscosity polyurethane insulating and sealing compound, rated for 600 volts, using crimp-type wire connector; Scotch (3M) No. 82-A1, 82-A2 or 82-A3 compound, or approved equal.
 - B. Re-Enterable Type
 - (1) Transparent, molded bodies clamped with stainless steel strain-relief bar and shield continuity connectors, sized for wire or cable, with loosely woven polyester spacer web and jelly-like urethane formulation for permanent re-entry capability; Scotch (3M) Nos. 78-R1 through 78-R5, with No. 2114 compound, or approved equal.
6. Fireproofing Materials
 - A. Fire-resistant tapes shall be Scotch (3M) No. 77, or approved equal.
 - B. Glass cloth binding tapes shall be Scotch (3M) No. 69, or approved equal.
7. Special splicing materials and methods shall be as shown on the Contract Drawings.

Factory Tests.

1. For quantities as shown on the Contract Drawings, regular dielectric-withstand and insulation-resistance in water tests for wires and cables shall be performed in accordance with UL44.
2. Flame tests for wires and cables shall be performed in accordance with UL 1685, UL 2196, and AAR RP- 585.
3. The test results shall be certified for each reel/coil/box of wire or cable.
4. Factory inspection and witnessing of tests by the Engineer shall be required for all wires and cables furnished under this Contract. The Engineer reserves the right to require additional testing, or to waive factory inspection or witnessing of tests. The Contractor shall notify the Engineer 14 days in advance of the scheduling of such factory tests.

CONSTRUCTION REQUIREMENTS

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

Preparation. Prior to pulling wires and cables, raceway systems shall be cleaned of all foreign matter and all operations necessary shall be performed so as not to cause damage to wires and cables while pulling. Prior to pulling wires and cables into underground conduit systems, place a feeding tube approved by the Engineer at the entrance end of such systems.

(b) Wire and Cable Installation.

1. General
 - A. Keep wires and cables dry at all times.
 - B. Seal wire and cable ends with water tight end seals if splicing or terminating does not follow at once.
 - C. Before splicing or terminating wires and cables, make a thorough inspection to determine that water has not entered the wires and cables or that the wires and cables have not been damaged.
 - D. Use adequate lubrication when installing cables in conduits or raceways. Any pulling compounds shall be compatible with the finish of the wires and cables furnished.
2. General Purpose Wires and Cables
 - A. Minimum wire or cable size shall be No. 12 AWG for light and power service.
 - B. Wires or cables shall be at least No.10 AWG for the entire length of branch circuits, where distances to first outlets are as follows:
 - (1) 100 feet or more on 480Y/277 Volt systems.
 - (2) 70 feet or more on 208Y/120 Volt systems.
3. Lighting Fixture Wires
 - A. For wiring within lighting fixtures only, where sizes No. 14 AWG or smaller are required, use Type SF- 2 fixture hookup wire. Type SF-2 wire shall not be used for wiring end-to-end connected fluorescent fixtures.
 - B. For connecting lighting fixtures to branch circuit conductors, use low-smoke, zero-halogen XHHW for dry and XHHW-2 90 degrees C wet and dry for indoor applications. For outdoor applications, use RHW-2 or RHH-RHW-2, VW-1, 90 degrees C wet and dry.

Splicing and Terminating.

1. General
 - A. Splices shall be permitted with the Engineer's approval. Splicing and terminating shall be as specified in this Section. Details of special splicing and terminating shall be as shown on the Contract Drawings. Any splicing or terminating methods other than those specified below, for which the components are in accordance with the requirements of this Section, shall be submitted to the Engineer for approval.
2. General Purpose Wires and Cables

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- A. Splices in dry locations for sizes No. 10 AWG and smaller: Splicing shall be completed using one of the following:
 - (1) Insulated, integral, self-locking flexible shell, expandable spring connectors shall be applied to the twisted conductors. Two, half-lapped layers of vinyl tape, extending to a distance of not less than one inch from the connector, shall be applied.
 - (2) Compression type, insulated butt connectors shall be applied to the butted conductors by means of an appropriate crimping tool, providing controlled indentation. Two, half-lapped layers of vinyl tape, extending to a distance of not less than one inch from the connector, shall be applied.
 - (3) Compression type, pigtail connectors shall be applied to the conductors by means of an appropriate crimping tool, providing controlled indentation. The connector shall be covered with a polyamide cap and two, half-lapped layers of vinyl tape, extending to a distance of not less than one inch from the connector, shall be applied.
- B. Splices in dry locations for sizes No. 8 AWG and larger, splicing shall be completed using all of the following:
 - (1) Connectors shall be split sleeve solderless type or solderless compression type.
 - (2) Fill indents of connectors with Scotchfil insulation putty.
 - (3) Apply rubber splicing tape equal to the original insulation rating.
 - (4) Apply two, half-lapped layers of vinyl tape, or a shrinkable tubing.
- C. Splices in wet locations
 - (1) Same as dry locations specified in this Section, except that after vinyl tape is applied, cover with two coats of sealer or shrinkable tubing.
 - (2) Resin-filled splice shall be covered with two, half-lapped layers of vinyl tape and two coats of sealer or shrinkable tubing.
- D. Terminations in dry locations for sizes No. 10 AWG and smaller:
 - (1) Terminations shall be compression terminals, insulated or uninsulated.
- E. Terminations in dry locations for sizes No. 8 AWG through No. 3/0 AWG.
 - (1) Ring tongue terminals shall be solderless, uninsulated compression crimp-type.
 - (2) Ring tongue lugs shall be bolted hex screw type.
- F. Terminations in dry locations for sizes No. 4/0 AWG and larger:
 - (1) Ring tongue terminals shall be solderless, uninsulated compression crimp-type.
- G. Terminations in wet locations:

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

- (1) In addition to the dry location terminations specified in this Section, cover the entire termination area with two, half-lapped layers of vinyl tape and apply two coats of sealer over the tape.
3. Overhead Service Cables
 - A. Splices and terminations in overhead service cables shall be the same as specified in this Section, as appropriate for overhead service conductor size.
4. Portable Cords
 - A. Splices shall not be made in portable cords.
 - B. Terminations shall be made only at apparatus to be served or at branch circuit connection by means of any of the following:
 - (1) Insulated, integral, self-locking flexible shell, expandable spring, or crimp-type connectors;
 - (2) Insulated, crimp-type, compression connectors;
 - (3) Uninsulated, ring tongue terminals for connection to wire terminal strip block.
5. Lighting Fixture Wires
 - A. Connections to branch circuit and to fixture wiring shall be made by either insulated, integral, self- locking flexible shell, expandable spring, or crimp-type connectors.
6. Grounding Wires and Cables
 - A. Splices and terminations shall be installed in accordance with the manufacturer's recommendations.
 - B. In hazardous or classified locations, splices and terminations shall be solderless high conductivity, corrosion-resistant, compression type connectors and terminations shall be clamp-type pressure connectors, suitable for such use.
 - C. All underground connections shall be covered with two coats of asphalt base paint.
7. Control Wires and Cables
 - A. Splices shall be made in accordance with the requirements specified in this Section, and shall be enclosed in a re-enterable splicing case. Where shielded cable is shown on the Contract Drawings, the shielding shall be continued through the splice. Shields shall be grounded at one location only unless otherwise shown on the Contract Drawings.
 - B. Terminations shall be insulated, indenter-type ring tongue terminals.
8. Switchboard Wires
 - A. No splices are permitted.
 - B. Terminations shall be insulated, indenter-type ring tongue terminals.

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**REVISION OF SECTION 622
WIRES, CABLES, SPLICES, TERMINATIONS (600 VOLTS OR LESS)**

Arcproofing.

1. Arcproofing shall be applied where shown on the Contract Drawings.
2. Arcproofing, which has been disturbed for any reason, shall be reinstalled as soon as possible after the disturbance.
3. Arcproofing shall be installed as follows:
 - A. Wires and cables shall be grouped by circuit and arcproofing applied over the group of wires and cables comprising one circuit. Splices shall be arcproofed individually and the taping shall join with and be overlapped by the group taping.
 - B. Arcproofing shall be applied in two wrappings of half-lapped tape, bound with glass cloth tape applied at the ends of the fire-resistant tape, and at intervals not to exceed 24 inches along the entire length of the cables. The two wrappings shall be applied with opposing lays.
 - C. Arcproofing shall be extended into the conduit opening or end bell of the raceway entering a handhole, manhole, or box.
 - D. Arcproofing tape shall be 1-1/2 inches wide where the diameter of the individual cable, or of the circumscribed circle for the circuit group, is less than 1-3/4 inches. For larger diameters, the tape shall be 3 inches wide.

(e) Identification of Wires and Cables.

1. Each wire and cable shall be identified by its circuit in all cabinets, boxes, manholes, handholes, wireways, other enclosures and access locations, and at all terminal points.
2. The circuit designations shall be as shown on the Contract Drawings. Tags shall be attached to wires and cables in such a manner as to be readily visible.
3. The tag ties shall be wrapped around all conductors comprising the circuit or feeder to be identified.
4. Wires and cables that are arcproofed shall also be identified outside the applied arcproofing.

(f) Field Tests. Test all wires and cables up to equipment installed under this Contract with a 1000-volt Megohmmeter. Furnish the Engineer with a copy of the "Megger" readings together with an outline of the method used. If, in the opinion of the Engineer, any reading is lower than that required by applicable codes, the Contractor shall promptly replace the materials involved, at his expense, and retest.

METHOD OF MEASUREMENT

Wires, Cables, Splices and Terminations (600 volts or less) will not be measured and paid for separately, but shall be included in the lump sum price for Electrical Modifications.

**REVISION OF SECTION 622
OVER-CURRENT PROTECTIVE DEVICES (600 VOLTS OR LESS)**

Section 622 of the Standard Specifications is hereby revised for this project to include the following:

DESCRIPTION

This work is installation of Over-current Protective Devices (6000 Volts or Less) in accordance with these specifications and in conformity with the details shown on the plans or established. The types of over-current protective devices specified in this Revision of Section 622 are: Low Voltage Power Air Circuit Breakers, Molded Case Circuit Breakers, Safety Switches, and Fuses.

MATERIALS

Manufacturers. Subject to compliance with the requirements of this Section, the Contractor shall provide low voltage power circuit breakers, molded case circuit breakers, safety switches and fuses of one of the manufacturers specified herein.

1. Circuit Breakers and Safety Switches
 - A. Square D Company
 - B. General Electric Company
 - C. Siemens Energy Automation, Inc.
 - D. Cutler - Hammer
2. Fuses
 - A. Commercial Enclosed Fuse Company (CEFCO)
 - B. Cooper Industries Inc./Bussman Division
 - C. Gould Incorporated/Circuit Protection Division
 - D. Ferraz/Shawmut

(b) General. Location, types, sizes, ratings and enclosures for over-current protective devices are shown on the Contract Drawings. Over-current protective devices mounted in their own enclosures as shown on the Contract Drawings shall conform to the requirements of NEMA, UL, and National Fire Protection Association (NFPA). Over-current protective devices to be installed as part of an assembly unit shall be installed in accordance with the manufacturer's requirements for the specified assembly or as shown on the Contract Drawings. Over-current protective devices and enclosures for which there are established UL standards, shall bear the UL label.

(c) Molded Case Circuit Breakers.

1. Molded case circuit breakers for panel or individual mounting shall be molded-case type, quick-make and quick-break on manual or automatic operation. The handle mechanism shall be trip-free to prevent holding contacts closed on a fault. Tripping shall be indicated by the handle automatically assuming a position between the manual "off" and "on" positions.

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**REVISION OF SECTION 622
OVER-CURRENT PROTECTIVE DEVICES (600 VOLTS OR LESS)**

2. Molded case circuit breaker contacts shall be of the high-pressure type and shall be made of a silver composition material. Arc shields shall be provided to confine, cool, and quench the arc drawn at interruption.
3. Continuous ampere ratings and number of poles shall be as shown on the Contract Drawings.
4. Molded case circuit breakers shall be bolt-on type. Unless otherwise shown on the Contract Drawings or as required by the system interrupting rating, all 120V or 208V circuit breakers shall have a minimum short circuit interrupting rating of not less than 10,000 amperes (RMS symmetrical) and all 277V or 480V breakers shall have a minimum short circuit interrupting rating of not less than 18,000 amperes (RMS symmetrical).
5. All molded case circuit breakers feeding 120V or 277V lighting circuits that are not controlled by local wall switches shall be UL approved type "SWD" circuit breakers.
6. Each molded case circuit breaker shall be suitable for the circuit on which it is applied and the load that it controls.
7. Accessories including, but not limited to, auxiliary switches, shunt trips, under-voltage trips, ground fault sensing and tripping shall be as shown on the Contract Drawings.

Thermal-Magnetic Circuit Breakers

1. Circuit breakers up to, but not including 400 amperes shall be thermal magnetic trip. Electronic trip circuit breakers rated 100 amperes or higher may be provided in lieu of thermal magnetic type.
2. Automatic operation of the molded case circuit breaker shall be obtained by means of calibrated thermal and magnetic tripping devices for each pole of the breaker. The thermal device shall provide time-delay tripping on overloads, and the magnetic device shall provide instantaneous tripping on short circuits. The instantaneous magnetic trip shall be adjustable and accessible from the front of the breaker on frame sizes above 100 amperes.

(e) Safety Switches. Safety switches shall conform to NEMA KS-1, UL 98 and Federal Specifications (FS) FSW- S-865. Safety switches shall conform to the NEMA classification and shall be rated, as shown on the Contract Drawings. Safety switches shall be of the quick-make, quick-break type with terminals suitable for copper conductors, shall be padlock-able in the "off" position and shall be equipped with defeatable door interlocks.

(f) Fuses. Fuses shall be of the class, size and ratings (current, voltage, interrupting capacity, type, NEMA class) as shown on the Contract Drawings. Fuses shall conform to ANSI C97.1 for low voltage fuses. Unless otherwise shown on the Contract Drawings, fuses used in conjunction with motor protection shall be current limiting, dual element, time-delay type.

CONSTRUCTION REQUIREMENTS

General. Unless otherwise shown on the Contract Drawings, over-current protective devices shall be installed in conformance with NFPA 70, and UL 98, in accordance with the manufacturer's instructions and in accordance with the requirements of this Section.

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**REVISION OF SECTION 622
OVER-CURRENT PROTECTIVE DEVICES (600 VOLTS OR LESS)**

(b) Fuses. All fuses rendered inoperative during the Work shall be replaced before the issuance of the Certificate of Final Completion. All replacement fuses shall be provided in addition to the spare fuses specified in Section Spare Parts herein.

(c) *Spare Parts*. Furnish a minimum of three but not less than 10 percent spare of the number of fuses of each type and rating required and shown on the Contract Drawings.

Delivery, Storage and Handling. Over-current protective devices to be installed in an assembly, as shown on the Contract Drawings, shall be mounted in the assembly and delivered in accordance with the manufacturer's specifications for such assembly. Over-current protective devices to be installed in their own enclosures, as shown on the Contract Drawings, shall conform to the following requirements:

1. Enclosures shall be packaged with material to prevent damage to components due to vibration or jarring during transportation and handling.
2. Enclosures shall be delivered in the manufacturer's original, unopened, protective packaging and shall be identified with suitable non-corrosive tags.
3. Where possible, maintain protective coverings until installation is complete and remove such coverings as part of the final cleanup.