# 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 Heat Trace System, Emergency Generator, 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 coordinate with the electrical utility company, Xcel Energy, to determine electric power requirements for the Project and to develop the Project electrical design and construction requirements. The contractor shall refer to Book 1 Section 2.3.5.6 for all Permitting responsibility.

The Contractor shall design and construct all electrical incidental elements required to provide 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: Lighting/Electrical Standards**

| | Author | Title |
|---|---|---|
| 1 | CDOT | *Standard Specifications for Road and Bridge Construction Section 613* |
| 2 | NFPA | *70 – National Electrical Code* |
| 3 | NFPA | *502 – Road Tunnels, Bridges, and other Limited Access Highways* |

### 14.1.2 Heat Trace

#### 14.1.2.1 Heat Trace Design Requirements

The Contractor shall design, procure, install, and test complete heat trace 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 exterior roof drains. The design shall include replacing the existing heat trace cables, heat trace controls and associated components with new. The plans shall include any existing heat tape demolition, new heat tape routing, new heat tape controls, electrical rooms equipment and elevations, electrical connections, and all necessary guide, warning, supplemental, and regulatory labels. 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.

Heat tape 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 heat trace distances required in pipes listed below. Refer to the Heat Trace block diagram 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: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - Existing Seep Main South: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - Existing 18’’ Ductile Iron Sewer: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - Existing 6’’ Ductile Iron Storm: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - New 4” Galvanized Steel Water Main: Entire length of pipe. 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 cable within the Water Main. Distance between each manhole is approximately 300 feet.
- Heat Trace Cable
    - Existing Roof Drains
    - Existing Seep Main North: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - Existing Seep Main South: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - Existing 12’’ Ductile Iron Sewer: Minimum of 990’ from each side. Maximum circuit lengths of 419’.
    - Existing 6’’ Ductile Iron Storm: Minimum of 990’ from each side. 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.

Currently there are existing conduits, junction boxes, and other infrastructure already in place that shall be used if possible after conducting site verification. Associated electrical panels and equipment "past it's 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 tape circuits currently fed from existing LCPs in East and West Main Electric Rooms shall be re-fed to new heat tape panels. Heat tape 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 tape connections for maintenance and operations purposes.

New monitoring and alarming of the entire new heat tape system shall be added to be able to remotely monitor the new system(s) and / or circuits for power failure. Add to the existing SCADA system ability to monitor Heat Trace status and provide alarms for the new Heat Trace System. Refer to Special Provisions Revisions to Section 210 – SCADA System Integration and Integrator Requirements.

## 14.1.3 Emergency Generator

### 14.1.3.1 Emergency Generator System Design Requirements

The Contractor shall design, procure, install, and test the new Emergency Generator System and components along with the replacement of the existing (2) 500kW Generator System. Required plans shall include electrical connection points, routing, details of system components, and all necessary guide, warning, supplemental, and regulatory labels. Emergency Generator to be designed at Project elevation of 11,160 feet. New generator enclosure shall meet the mountain corridor aesthetic guidelines along with outdoor rating guidelines.

Emergency Generator design shall comply with the requirements of the most current publications of the Standard Specifications, and the National Electric Code.

### 14.1.3.2 Emergency Generator Design Criteria

Provide a new Emergency Generator System consisting of a Diesel Generator sized to handle existing peak demands and emergency demands in the event of a failure of both electrical supplies. New Emergency Generator shall be in a Sound Attenuated Weatherproof Enclosure located at the west portal along with supporting infrastructure and electrical distribution equipment that shall replace the current emergency backup generators. Proposed equipment locations provided in Reference Documents, but exact location shall be decided upon by Design Build team and placed on the southwest side of the West portal. Additional components

of design include a Fuel Tank to withstand a runtime of 10 hours and a Step-up Transformer to step-up 13.8kV to 24.9kV. Emergency Generator shall have a separate feeder to 24.9kV switchgear in West central Electrical Room. New 24.9kV switchgear sections shall be added to tie into Emergency Generator. Main switchgear shall be configured with interlocking automatic transfer switch(es) to allow for Emergency standby generator installation to be connected to serve all essential services.

Refer to Section 263213 – Packaged Engine Generators for properly sizing the new Generator System. East and West Portal XCEL Peak history reports included in Reference Documents. The Emergency Generator System shall serve the entire facility and a maximum of (4) Fans and Fan Motors in an Emergency situation.

Refer to Special Provisions Revision of Section 202 – Removal of Electrical Equipment for demolition requirements of the existing Generator System. Refer to Special Provisions Revision of Section 613 - 24.9 kV Switchgear Assemblies, Book 2 Section 10 – Geotechnical Roadway Pavements, and Book 2 Section 11 – Earthwork for new Generator System pad requirements.

Add to the existing SCADA system ability to control and monitor the new Emergency Generator System and provide alarms for the new Emergency Generator and its associated Siemens protection relay on the 24.9kV Switchgear lineup. Refer to Special Provisions Revisions to Section 210 – SCADA System Integration and Integrator Requirements.

# 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 must utilize Licensed Journeymen Electricians, Licensed Master Electricians, or Registered and Property Supervised 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 Jet Fan Motor Rewinding

The Contractor shall perform the rewinding of (16) sixteen 480Volt, 3 Phase, 600H.P. fan (exhaust or supply) motors located on fan deck of East and West Portals for the North Tunnel. Motor Repair Shop / Contractor is responsible for ALL work associated with disassembly, reassembly, transportation, coordination, and scheduling with CDOT Tunnel Maintenance. Only (1) one exhaust fan motor and (1) one supply fan motor will be allowed off-line at a time per Portal side. Total of 4 motors at a time. In the event CDOT Maintenance has a fan motor off-line for other repairs the contractor shall make it a priority to rewind it concurrently. This work shall be performed in accordance with the Book 2 Section 14 Exhibit A Specification.

## 14.3 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 |
| Heat Trace Product Data and Design Guide | Acceptance | Within 90 days of contract award |
| Heat Trace Circuit Layouts, Plans, and Details | Acceptance | Within 90 days of contract award |
| Heat Trace SCADA Integration Report | Approval | Within 90 days prior to integration |
| Heat Trace Testing Plan | Approval | 30 days prior to testing |
| Heat Trace Testing Report | Approval | 30 days after testing |
| Emergency Backup Generator System Product Data and Design Guide | Acceptance | Within 90 days of contract award |
| Emergency Backup Generator Connection and Interconnection Plans and Details | Acceptance | Within 90 days of contract award |
| Emergency Backup Generator SCADA Integration Report | Approval | Within 90 days prior to integration |
| Emergency Backup Generator Testing Plan | Approval | 30 days prior to testing |
| Emergency Backup Generator Testing Report | Approval | 30 days after testing |
| Emergency Backup Generator Field Report | Approval | 20 days after inspection |
| Project Special Provisions Required Submittal Material | Acceptance | Within 90 days of contract award |
| Maintenance and Operations Training Plan and Syllabus | Review | 30 days prior to beginning training |
| Annual Maintenance Plan | Approval | 30 days prior to the start of the Short-Term year |

| Deliverable | Review, Acceptance, or Approval | Schedule |
|---|---|---|
| Annual Maintenance Report | Review | 30th day of the new Short-Term year |
| Motor Rewinding Test Report | Acceptance | Completion of Repairs |

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

# 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. 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.

B. Related Requirements

1. Section 26 05 19 – Low-Voltage Electrical Power Conductors and Cables
2. Section 26 05 26 – Grounding and Bonding for Electrical Systems

### 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, mineral 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 have a Polyolefin (-CR) jacket for above ground piping & internally traced lines. 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.

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
    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.

## 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 construction of the self-regulating heating cable shall consist of a continuous core of conductive polymer that is radiation crosslinked, extruded between two (2) 16 AWG nickel-plated copper bus wires that varies its power output in response to pipe temperature changes.

b. The heating cable shall have a modified polyolefin inner jacket for dielectric integrity and long-life expectancy.

c. The heating cable shall have a thicker gauge (5/24) tinned copper braid with minimum 70% coverage for ground path and mechanical ruggedness.

d. 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.

e. The heating cable shall have an outer jacket that is approved and clearly marked for the install conditions.

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).

a) Heating cables shall be self-regulating heating cables specifically designed for the intended application, tested and approved to UL 515, CSA 22.2 No 130-03 and IEEE 515.1 requirements.

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).

f. The heating cable shall be included in a UL Listed, CSA Certified, or FM Approved system.

g. 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.

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.
        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
    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.

### 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 stell 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 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."

**3.4. FIELD QUALITY CONTROL**

A. Initial start-up and field testing (commissioning) of the system shall be performed by factory technician or factory certified representative.

B. 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.

C. 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.

D. 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.

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

F. Start-up – Start-up of system shall be performed by factory technician or factory representative per the owner’s requirements.

**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**

## SECTION 26 12 00
## OUTDOOR PAD MOUNTED TRANSFORMERS

### PART 1 – GENERAL

### 1.1 RELATED SECTIONS

A. Drawings and general provisions of the Contract, Including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this section.

### 1.2 DESCRIPTION OF WORK

A. When output voltage of generator does not match utility service voltage of 24.9/14.4 kV, 3 phase, 3 wire, solidly grounded neutral provide outdoor type pad-mounted stepup transformer sized to match kW/kVA of generator.

### 1.2 SUBMITTALS

A. Shop Drawings shall include all technical and descriptive data to include:

1. Physical layout and dimension.
2. Measured impedance percent efficiency.
3. Wiring and connection diagrams showing top configuration.
4. Sound ratings.
5. Fuse coordination curves.
6. Switch and radial feed configuration if applicable.
7. Load break terminations and bushing wells if applicable.
8. Test Reports.

### 1.3 STANDARDS

A. All characteristics, definitions, and terminology, except as specifically covered in this specification, shall be in accordance with the latest revision of the following ANSI and NEMA standards.

C57.12.00 - IEEE Standard General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers.

C57.12.26 - IEEE Standard for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers for Use with Separable Insulated High-Voltage Connectors (34500GrdY/19920 Volts and Below; 2500 kVA and Smaller).

C57.12.28 - Pad-Mounted Equipment - Enclosure Integrity.

C57.12.34 - IEEE Standard Requirements for Pad-Mounted, Compartmental-Type, Self-Cooled, Three-Phase Distribution Transformers (2500 kVA and Smaller) - High Voltage: 34500GrdY/19920 Volts and Below; Low-Voltage: 480 Volt 2500 kVA and Smaller. *(Issued in March 2005 - combines C57.12.22 and C57.12.26)*

C57.12.90 - IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and IEEE Guide for Short-Circuit Testing of Distribution and Power Transformers.

C57.91 - Guide for Loading Mineral-Oil-Immersed Transformers.

## PART 2 - PRODUCTS

### 2.1 PRODUCTS

The transformer shall have efficiency compliant with the U.S Department of Energy final rule for the distribution.

A. Transformers Energy Conservation Standard Rulemaking, 72 FR 58190 (Oct.12, 2007).

B. The transformer shall be designed in accordance with this specification and the kVA rating shall be per the plans. Transformer shall be TP-1 or Energy Star rated.

C. The primary voltage, configuration, and the basic lightning impulse insulation level (BIL) shall be match output of the generator..

D. The secondary voltage, configuration, and the basic insulation level (BIL) of the secondary voltage shall be 24.9/14.4 kV, 3 phase, 3 wire, solidly grounded neutral, 150 BIL.

E. The transformer shall be furnished with full capacity high-voltage taps. The taps shall be +/- 2 - 2½% above and below nominal voltage. The tap changer switch shall be an externally operated switch with a hotstick-operable handle. The tap changer shall be clearly labeled to reflect that the transformer must be de-energized before operating the tap changer as required in Section 3.3 of ANSI C57.12.26. Taps shall be provided on the higher voltage of dual voltage primary units.

F. The Kilovolt-ampere (kVA) ratings are continuous and are based on not exceeding either a 65° C average winding temperature rise or an 80° C hot-spot conductor temperature rise. The temperature rise of the insulating oil shall not exceed 65° C when measured near the top of the tank.

G. The percent impedance voltage, as measured on the rated voltage connection, shall be per Table 2. For target impedances, the tolerance on the impedance shall be +/- 7.5% of nominal value for impedance values greater than 2.5%. The tolerance on the impedance shall be +/- 10.0% for impedance values less than or equal to 2.5%.

- **Table 2 - Percent Impedance Voltage**

| KVA Rating (Low voltage < 700 V) | Impedance |
|---|---|
| 75 | 1.10 - 5.75 |
| 112.5-300 | 1.40 - 5.75 |
| 500 | 1.70 - 5.75 |
| 750-3750 | 5.75% |

| KVA Rating | Low voltage > 700 V (all nominal values) | | |
|---|---|---|---|
| | ≤150 kV BIL | 200 kV BIL | 250 kV BIL |
| 1000 - 5000 | 5.75 | 7.00 | 7.50 |
| 7500 - 10000 | 6.50 | 7.00 | 7.50 |

### 2.2 HIGH VOLTAGE BUSHINGS AND TERMINALS

A. Bushing style:

FOR 25 KV DEADFRONT, FOR CURRENTS BELOW 200 AMPS: The high voltage bushings shall be 25 kV 200A bushing wells with bushing well inserts installed. The bushings shall be externally removable and be supplied with a removable stud.

B. Bushing configuration:

25 KV RADIAL FEED DEADFRONT: The transformer shall be provided with three (3) high voltage bushings in accordance with ANSI C57.12.34 for radial feed configurations. The bushing heights shall be in accordance with ANSI C57.12.34.

## 2.3 SECONDARY VOLTAGE BUSHINGS AND TERMINALS

A. Bushing style:

FOR 25 KV DEADFRONT, FOR CURRENTS BELOW 200 AMPS: The high voltage bushings shall be 25 kV 200A bushing wells with bushing well inserts installed. The bushings shall be externally removable and be supplied with a removable stud.

B. Bushing configuration:

25 KV RADIAL FEED DEADFRONT: The transformer shall be provided with three (3) high voltage bushings in accordance with ANSI C57.12.34 for radial feed configurations. The bushing heights shall be in accordance with ANSI C57.12.34.

## 2.4 TRANSFORMER PROTECTION AND SWITCHING

A. Overcurrent protection:

1. Bayonet with current limiting fuses: The high-voltage overcurrent protection scheme provided with the transformer shall be an externally removable loadbreak expulsion Bay-O-Net fuse assembly with a flapper valve to minimize oil spillage. The bayonet fuses shall be in series with ELSP under-oil partial-range current-limiting back-up fuses with an interrupting rating of 50,000 A.
2. An interlock shall be required between the load-break switch scheme specified and the bayonet fuses, such that the fuses may not be removed unless the transformer has been de-energized via the load-break switch scheme.

B. Overvoltage protection:

1. The overvoltage protection scheme provided with the transformer shall protect the high-voltage winding.
2. With DEADFRONT bushings: Externally mounted, Distribution Class M.O.V.E. Deadfront elbow arresters shall be supplied.

C. Switching:

1. The primary switching scheme provided with the transformer shall be two on/off loadbreak switches on the radial feed.

## 2.5 GENERAL DESIGN

A. Core and coil

The core and coil shall be vacuum processed to ensure maximum penetration of insulating fluid into the coil insulation system. While under vacuum, the windings will be energized to heat the coils and drive out moisture, and the transformer will be filled with preheated filtered degassed insulating fluid. The core shall be manufactured from

burr-free, grain-oriented silicon steel and shall be precisely stacked to eliminate gaps in the corner joints. The coil shall be insulated with B-stage, epoxy coated, diamond pattern, insulating paper, which shall be thermally cured under pressure to ensure proper bonding of conductor and paper. Windings shall be copper.

B. Dielectric fluid

The dielectric coolant shall be listed less-flammable fluid meeting the requirements of National Electrical Code® Section 450-23 and the requirements of the National Electrical Safety Code (IEEE C2-1997), Section 15. The dielectric coolant shall be readily and completely biodegradable per EPA OPPTS 835.3100. The base fluid shall be 100% derived from edible seed oils with performance enhancing additives. The fluid shall result in zero mortality when tested on trout fry per OECD G.L. 203 and be non-bioaccumulating. The fluid shall be published under US EPA Environmental Technology Verification (ETV) requirements, and tested for compatibility with transformer components. The fluid shall be Factory Mutual Approved, UL® Classified Dielectric Medium (UL-EOUV) and UL Classified Transformer Fluid (UL-EOVK), Envirotemp® FR3® fluid.

C. TANK AND CABINET ENCLOSURE

1. The high-voltage and low-voltage compartments, separated by a metal barrier, shall be located side-by-side on one side of the transformer tank. When viewed from the front, the low-voltage compartment shall be on the right. Each compartment shall have a door that is constructed so as to provide access to the high-voltage compartment only after the door to the low-voltage compartment has been opened. There shall be one or more additional fastening devices that must be removed before the high-voltage door can be opened. Where the low-voltage compartment door is of a flat panel design, the compartment door shall have three-point latching with a handle provided for a locking device. Hinge pins and associated barrels shall be constructed of corrosion-resistant material, passivated AISI Type 304 or the equivalent.

2. A recessed, captive, penta-head bolt that meets the dimensions per ANSI C57.12.28 shall secure all access doors.

3. The enclosure integrity of the tank and cabinet shall meet the requirements for tamper resistance set forth in ANSI C57.12.28 including but not limited to the pry test, pull test, and wire probe test.

4. The compartment depth shall be in accordance with C57.12.34, unless additional depth is specified.

5. The tank base must be designed to allow skidding or rolling in any direction. Lifting provisions shall consist of four lifting lugs welded to the tank.

6. The tank shall be constructed to withstand 7 psi without permanent deformation, and 15 psi without rupture. The tank shall include a 15 psig pressure relief valve with a minimum flow rate of 35 SCFM.

7. The tank and cabinet coating shall meet all the requirements of ANSI C57.12.28 including:

    a. Salt Spray Test

b. Crosshatch Adhesion Test

c. Humidity Test

d. Impact Test

e. Oil Resistance Test

f. Ultraviolet Accelerated Weathering Test

g. Abrasion Resistance - Taber Abraser

8. The exterior of the unit shall be painted Munsell 7GY3.29/1.5 brown, in color. The cabinet interior and tank face shall be painted gray for ease of viewing the inside the compartment.

9. The tank shall be complete with an anodized aluminum laser engraved nameplate. This nameplate shall meet Nameplate B per ANSI C57.12.00.

**2.6 FEATURES AND ACCESSORIES**

A. The following features and accessories shall be provided:

1. Welded main tank cover with bolted handhole (1500 kVA & above)
2. 1.0” upper fill plug
3. 1.0” drain valve w/ sampling device on exterior of LV compartment with weather-proof cover.
4. Automatic pressure relief valve
5. Metal drip shield (when bayonets specified)
6. 20” deep cabinet (2500 kVA & below)
7. Ground provisions per C57.12.34 section 9.11.
8. Meet NEMA TR-1 sound levels
9. Liquid level gauge
10. Dial-type thermometer gauge
11. Pressure vacuum gauge
12. Ground connectors
13. Seismic 4 tank anchoring
14. Dial-type thermometer gauge with auxiliary contacts
15. Current or potential transformers

**PART 3 – EXECUTION**

3.1 Units 1500 kVA and larger shall be loaded and unloaded with overhead cranes, so a pallet is not to be provided for these transformers.

**3.2 INSTALLATION**

A. Install transformer in accordance with manufacturer’s Instruction/Installation Manual.

B. Provide structural concrete pad designed per Manufacturer's recommendations to suit site conditions and equipment requirements. Pad shall extend a minimum of 12" beyond equipment enclosure.

C. Prepare level site for structural pad. Remove and repair asphalt as needed, grade, remove and backfill site as needed. Provide drainage to eliminate low spots and puddling areas.

D. Provide traffic protection bollards per CDOT requirements around all equipment.

Install on existing concrete pad.

E. Grounding should be per Project Drawings and in accordance with local codes and standards and in compliance with the NEC.

**3.3 ADJUSTMENTS AND CLEANING**

A. Remove debris from job site and wipe dust and dirt from all components.

B. Repaint marred and scratched surfaces with touch up paint to match original finish.

**3.4 TESTING & TOLERANCES**

A. ALL UNITS SHALL BE FACTORY TESTED FOR THE FOLLOWING:

No-Load (20°C) losses at rated current

Total (85°C) losses at rated current

Percent Impedance (85°C) at rated current

Excitation current (100% voltage) test

Winding resistance measurement tests

Ratio tests using all tap settings

Polarity and phase relation tests

Induced potential tests

Full wave and reduced wave impulse test

B. In addition, the manufacturer shall provide certification upon request for all design and other tests listed in C57.12.00, including verification that the design has passed short circuit criteria per ANSI C57.12.00 and C57.12.90.

C. Transformer efficiency shall meet the requirements of NEMA TP-1 2002.

**END OF SECTION 26 12 00**

## SECTION 26 14 00
## CONDUCTORS MEDIUM VOLTAGE

### PART 1 - GENERAL

### 1.1 RELATED SECTIONS

A. Drawings and general provisions of the Contract, Including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this section.

### 1.1 DESCRIPTION OF WORK

A. This Section covers single conductor EPR (Ethylene Propylene Rubber) insulated, thermoplastic jacketed power cable for use in conduit and underground duct installations. This cable capable of operating continuously at a conductor temperature not in excess of 90-degree C for normal operation, 130-degree C for emergency overload conditions, and 250-degree C for short circuit conditions; cable rated 25,000 Volts, 133% insulation level, and shall be designed to withstand UL horizontal and vertical flame tests. Submit minimum 16" sample of each type of cable specified.

B. 25kV rated cable shall be used for the 13.8kV and 25kV electrical systems.

### 1.2 RELATED WORK

A. Section 26 60 00 Electrical Systems Testing.

### 1.3 STANDARDS

A. IPCEA Pub. NO. S-68-516 (NEMA Pub. WC8-1976) "Ethylene Propylene Rubber Insulated Cable and Wire".

B. Underwriters Laboratories Standard 1072 for Medium Voltage Solid Dielectric Cable (MV90).

C. AEIC No. 6, latest issue.

### PART 2 - PRODUCTS

### 2.1 CONDUCTOR

A. Use new Class B, stranded compressed soft or annealed copper per ASTM Specs B3 and B8 and IPCEA, Part 2, Section 2.1 and 2.5.

### 2.2 CONDUCTOR SHIELDING

A. Use extruded semi-conducting layer over conductor, applied in tandem with and firmly bonded to insulation.

### 2.3 INSULATION

A. EPR (Ethylene Propylene Rubber) per referenced standards. Average thickness of 115 mils-5,000V **(minimum) or 320 mils-25,000V (minimum)** and minimum spot thickness not less than 90% of average thickness.

## 2.4 SHIELDING

A. Insulation covered with a helically applied, lapped, printed semi-conducting tape. Over this layer apply helically lapped, 5 mils (minimum) bare copper tape with minimum 12.5% overlap.

## 2.5 CABLE JACKET

A. Black polyvinyl chloride compound per requirements specified for sun-light resistant polyvinyl chloride jackets in IPCEA. Average thickness of 80 mils and minimum spot thickness not less than 80% of average thickness.

B. IDENTIFY cable with surface printing on jacket indicating manufacturer size, insulation type, voltage rating, and U.L. designations.

C. Color Code as follows and/or per local ordinances. Apply minimum 2" of tape to each individual phase or neutral conductor in half lapped pattern. Conductors shall be identified with color coded tape at all locations accessible including all splices and terminations. The equipment ground conductor shall be taped green for its entire exposed length. Color-code as follows:

| | | |
|---|---|---|
| PART 2 -<br>PART 3 - Phase<br>PART 4 - | PART 5 - 13.800<br>PART 6 - Volts<br>PART 7 - | PART 8 - 25,000<br>PART 9 - Volts<br>PART 10 - |
| PART 11 - A | PART 12 - Red | PART 13 - Red |
| PART 14 - B | PART 15 - Yellow | PART 16 - Yellow |
| PART 17 - C | PART 18 - Blue | PART 19 - Blue |
| PART 20 - Neutral | PART 21 - White | PART 22 - White |
| PART 23 - Equip. Ground | PART 24 - Green | PART 25 - Green |

## 2.6 TESTS

A. Manufacturing tests shall be made in accordance with:

1. IPCEA No. S-68-516 (NEMA WC8-1976).
2. Underwriter's Laboratories Standard 1072 for Medium Voltage Solid Dielectric Cable (MV90).

B. Acceptable Cable Manufacturers:

1. Okonite
2. Kerite
3. Southwire
4. Cablec
5. Pirelli
6. Or equal.

## PART 3 - EXECUTION

### 3.1 INSTALLATION

A. Install new conductors without splicing.

B. Carefully pull cable into raceways to prevent insulation damage. Allow an extra 36” of cable length so that distorted or damaged ends of cables maybe trimmed off. Installation shall be in accordance with manufacturer’s recommendations and IEEE 576.

C. Terminate all medium voltage cable with load break/ Dead break terminations.

D. Clean underground ducts before cable is installed. Provide “Buried Cable” warning tape 12” above conduit or duct.

E. After cables are installed with load break/ Dead break terminals made up, test each conductor with a non-destructive, very low frequency (VLF) high potential tester. Each test to last 15 minutes with readings at one minute intervals. Furnish graph of readings relating microampere leakage to time.

F. Pull conductors simultaneously where more than one cable is indicated in the same raceway.

G. Use UL listed and manufacturer approved pulling compound or lubricant. Do not exceed manufacturer’s recommended maximum pulling tensions, jamming ratio and sidewall pressure values. Protect and seal ends of cable to prevent entrance of entrained moisture during storage and installation until terminations are made.

H. Use pulling means including, fish tape, cable, rope and basket weave wire/cable grips that will not damage cables or raceways. Do not use rope hitches for pulling attachment to cable.

I. When cables are to be installed in cold weather, they shall be kept in heated storage for at least 24 hours before installation.

J. In manholes, train cables around walls utilizing the longest route from entry to exit and support cables at intervals adequate to prevent sag.

K. Arc proofing: Arc proof medium-voltage cable at transformer, vaults, manholes, and pullboxes where cables are not protected by conduit or termination material. Apply as follows and as recommended by the manufacturer of the arc-proofing tape.

1. Clean cable sheath.
2. Wrap metallic cable components with 10-mil pipe wrapping tape.
3. Smooth surface contours with electrical insulation putty.
4. Apply arc-proofing tape in one half-lapped layer with the coated size toward the cable.
5. Each cable shall be arc proofed individually.
6. Band the arc-proofing tape with 1-inch wide bands or half-lapped adhesive glass-cloth tape 2 inches on center.

a. Acceptable arc proof tapes

1) 3M Scotch #77

2) Plymouth "plyarc"

3) Or equal.

**END OF SECTION 26 14 00**

## SECTION 26 15 00
## SPLICING AND TERMINATING MEDIUM VOLTAGE CABLE

### PART 1 - GENERAL

### 1.1 RELATED SECTIONS

A. Drawings and general provisions of the Contract, Including General and Supplementary Conditions and other Division 1 Specification Sections, apply to this section.

### 1.2 DESCRIPTION OF WORK

A. Furnish and install materials for terminating medium voltage cable specified in Section 26 14 00. This section consists of all primary terminating devices, and accessories as required for the project.

B. Installer qualifications: All primary cable terminations shall be made by a cable splicer having not less than five (5) years experience in splicing cables and making terminations of the type specified herein on system with rated voltage not less than the primary system specified. Name and experience, record of cable splicer shall be submitted for approval with shop drawings, including reference from past objects.

### 1.2 STANDARDS

A. ANSI/IEEE Standard 386.

B. IEEE Standard No.48 (Class 1 Terminations).

C. IEEE Standard 404 (Connectors)

D. IEEE Standard 386 (Separable Connectors)

### PART 2 - PRODUCTS

### 2.1 SPLICES

A. Cables shall be installed without splices.

### 2.2 LOAD BREAK SEPARABLE CONNECTORS

A. Furnish modular load break separable connectors hereinafter referred to "LBSC" as shown on drawings and specified in equipment covered in other Sections.

B. LBSC fittings to include following components

1. Arc follower to quench break-make arc.
2. Plated copper main male contact.
3. Dead front molded 90 degrees elbow connector housing.
4. Rubber locking ring to provide reliable seal and to assist quick break action.
5. AL/CU plated cable connector, ring or compression type.
6. One (1) phase identification band.
7. Voltage test point.

8. Molded stress relief to terminate cable insulation.
9. Grounding eye to ground connector shield.
10. Molded conductive inner shield or approved equivalent.
11. Molded conductive outer shield or approved equivalent.
12. Molded insulating medium to provide required creepage length and waterseal.
13. Hotstick eye.

C. LBSC fittings to be submersible rated with electrical ratings as follows

1. Voltage: 25 KV line to line (grounded or ungrounded).
2. B I L: 125 KV, 1.2 x 50 microsec. wave.
3. Withstand: 35 KV, 60 Hz., 1 minute. 55 KV, D.C., 15 minutes.
4. Corona: 11 KV
5. Current: 200 amperes RMS - continuous. 10000 amperes short time, (10 cycles).
6. Switching Operation
   a) A 200 amp: 14.4 KV, 10 load make or break at 200 amperes, 70-100% PF (lag). One (1) fault close operation.
   b) A 600 amp: Dead break.
7. Production Tests: 100% of product withstand 35 KV, 60 Hz., 1 minute. Corona: 11 KV. Test Point operation verified.

D. Furnish T-Body LSBC dead-break terminations for 600A parallel feeders.

E. Furnish LBSC with all necessary accessories to make complete terminations.

F. Furnish modular female load break bushing inserts with configuration as required to mate to equipment specified in other Sections. Bushing inserts shall have same ratings as LBSC listed above. Provide necessary mounting and interface hardware.

G. Acceptable LBSC Manufacturers

1. Elastimold
2. ITT Blackburn
3. Cooper/RTE

H. Operating kit not required to be furnished for this project.

## 2.3 LOAD BREAK SEPARABLE CONNECTORS

A. Furnish modular load break separable connectors hereinafter referred to "LBSC" as shown on drawings and specified in equipment covered in other Sections.

B. LBSC fittings to include following components

1. Arc follower to quench break-make arc.
2. Plated copper main male contact.

3. Dead front molded 90 degrees elbow connector housing.
4. Rubber locking ring to provide reliable seal and to assist quick break action.
5. AL/CU plated cable connector, ring or compression type.
6. One (1) phase identification band.
7. Voltage test point.
8. Molded stress relief to terminate cable insulation.
9. Grounding eye to ground connector shield.
10. Molded conductive inner shield or approved equivalent.
11. Molded conductive outer shield or approved equivalent.
12. Molded insulating medium to provide required creepage length and waterseal.
13. Hotstick eye.

C. LBSC fittings to be submersible rated with electrical ratings as follows

1. Voltage: 25 KV line to line (grounded or ungrounded).
2. B I L: 125 KV, 1.2 x 50 microsec. wave.
3. Withstand: 35 KV, 60 Hz., 1 minute. 55 KV, D.C., 15 minutes.
4. Corona: 11 KV
5. Current: 200 amperes RMS - continuous. 10000 amperes short time, (10 cycles).
6. Switching Operation
   a) A 200 amp: 14.4 KV, 10 load make or break at 200 amperes, 70-100% PF (lag). One (1) fault close operation.
   b) A 600 amp: Dead break.
7. Production Tests: 100% of product withstand 35 KV, 60 Hz., 1 minute. Corona: 11 KV. Test Point operation verified.

D. Furnish LBSC with all necessary accessories to make complete terminations.

E. Furnish modular female load break bushing inserts with configuration as required to mate to equipment specified in other Sections. Bushing inserts shall have same ratings as LBSC listed above. Provide necessary mounting and interface hardware.

F. Acceptable LBSC Manufacturers

1. Elastimold
2. ITT Blackburn
3. Cooper/RTE

G. Operating kit not required to be furnished for this project.

## PART 3 - EXECUTION

### 3.1 INSTALLATION

A. Install all splicing and terminating equipment in strict compliance with manufacturer's recommended procedures.

B. Mount all porcelain terminators to steel channel on poles or within switchgear.

C. Each termination shall have attached an engraved plastic tag bearing feeder designation.

D. Test all splices and terminations. All test shall be performed before electrical circuitry has been energized.

**END OF SECTION 26 15 00**

# SECTION 26 32 13
# PACKAGE ENGINE GENERATOR SET

## PART 1 - GENERAL

### 1.1 RELATED DOCUMENTS

A. Drawings and general provisions of the Contract, including General and Supplementary Conditions, Controls and Instrumentation and System Commissioning apply to this section.

### 1.2 SUMMARY

A. This section includes packaged engine-generator sets for emergency power, and standby power with the following features:

1. Diesel engine
2. Unit mounted cooling system
3. Remote mounted control and monitoring with connections to facility SCADA.
4. Performance requirements for sensitive loads
5. Fuel system
6. Outdoor Enclosure
7. Exhaust
8. Mounting and Structural equipment pad

B. Related Sections include the following:

1. Section 26 05 26 - Grounding and Bonding for Electrical Systems.
2. Section 26 05 53 - Identification for Electrical Systems.

### 1.3 DEFINITIONS

A. CDOT – Colorado Department of Transportation

B. EJMT – Eisenhower Johnson Memorial Tunnel

### 1.4 REFERENCES

A. National Electrical Manufacturers Association:

1. NEMA ICS 10 - Industrial Control and Systems: AC Transfer Switch Equipment.
2. NEMA MG 1 - Motors and Generators.

B. International Electrical Testing Association:

1. NETA ATS - Acceptance Testing Specifications for Electrical Power Distribution Equipment and Systems.

C. National Fire Protection Association:

1. NFPA 30 - Flammable and Combustible Liquids Code.

2. NFPA 110 - Standard for Emergency and Standby Power Systems.

3. NFPA 502 – Standard for Road Tunnels, Bridges, and Other Limited Access Highways

A. The generator set and all components shall be designed, manufactured, installed and tested in accordance with the latest applicable standards and codes as follows:

1. National Electric Code (NEC)

2. National Fire Protection Association (NFPA) 70

3. National Fire Protection Association (NFPA) 110

4. American National Standards Institute (ANSI)

5. Underwriters Laboratories (UL)

6. Institute of Electrical and Electronics Engineers (IEEE)

**1.5 ACTION SUBMITTALS**

A. Bill of Materials: A listing shall include all panels, racks, instruments, components, and devices provided under this section

B. Product Data: Drawings and descriptive (catalog) data and brochures of each item of equipment including technical data sheets for the engine, generator, control panel, battery, battery charger, exhaust, exhaust silencer, vibration isolators, base fuel tank, and outdoor enclosure.

1. Diesel engine data

a. Manufacturer

b. Model

c. Revolutions per minute (RPM)

d. Rated capacity brake horsepower (bhp)

e. Make and model of governor

f. Piston displacement (cubic inches)

g. Fuel consumption rate in gallons per hour at:

1) Full load

2) 3/4 load

3) 1/2 load

2. Generator data

a. Manufacturer

b. Model

c. Rated kVA

d. Rated kW

e. Voltage

f. Temperature rise above 40°C ambient at rated output with 0.8 power factor

g. Motor starting capability (skVA) at 30% instantaneous voltage dip (motor starting at 90% rated voltage will not be accepted)

h. Generator efficiency including excitation losses at:

1) Full load

2) 3/4 load

3) 1/2 load

3. Package data

a. Overall length, width, and height

b. Weight of complete skid mounted unit with full fuel tank

c. Exhaust pipe size

d. Air flow (in cubic feet per minute) of air required for combustion and ventilation

e. Heat rejection to the atmosphere of the engine and generator in BTU/hr

f. Cooling air volume required

g. Emissions certification

h. Sound data

4. Engine-generator unit and accessories to include:

a. Enclosure

b. Accessory sub-panel, transformer, misc. electrical.

c. Control panels

d. Voltage regulator

e. Fuel system

f. Exhaust system

g. Batteries

h. Battery charger

i. Jacket water heater

5. Generator circuit breaker

a. Catalog data

b. Recommended trip settings for all adjustable settings

c. Short circuit interrupt ratings

C. Shop Drawings: Detail equipment assemblies and indicate dimensions, weights, loads, required clearances, method of field assembly, components, and location and size of each field connection.

1. Dimensioned outline plan and elevation drawings of engine-generator set and other components specified.

2. Design Calculations: Signed and sealed by a qualified professional engineer. Calculate requirements for selecting vibration isolators, vibration isolation bases and structural concrete pad.

3. Vibration Isolation Base Details: Signed and sealed by a qualified professional engineer. Detail fabrication, including anchorages and attachments to structural pad and to supported equipment. Include base weights.

4. Wiring Diagrams: Power, signal, and control wiring.

## 1.6 INFORMATIONAL SUBMITTALS

A. Sizing calculation: Generator supplier to submit a project specific sizing calculation for engineering review and approval. Loading as noted. Manufacturer's calculation showing maximum expected transient voltage and frequency dips, and recovery time during operation of the generator set at the specified site conditions with the specified loads

B. Manufacturer Seismic Qualification Certification: Submit IBC certification that engine-generator set, batteries, battery racks, accessories, and components will withstand seismic forces. Include the following:

1. Basis for Certification: Indicate whether withstand certification is based on actual test of assembled components or on calculation.

a. The term “withstand” means “the unit will remain in place without separation of any parts from the device when subjected to the seismic forces specified and the unit will be fully operational after the seismic event.”

2. Dimensioned Outline Drawings of Equipment Unit: Identify center of gravity and locate and describe mounting and anchorage provisions.

3. Detailed description of equipment anchorage devices on which the certification is based and their installation requirements

C. Qualification Data: For installer, manufacturer, and testing agency

D. Source quality-control test reports

1. Certified summary of prototype-unit test report.

2. Certified Test Reports: For components and accessories that are equivalent, but not identical, to those tested on prototype unit.

3. Report of factory test on units to be shipped for this Project, showing evidence of compliance with specified requirements.

4. Report of sound generation.

5. Factory EPA Certificate showing compliance with applicable federal regulations.
6. Certified Torsional Vibration Compatibility: Comply with NFPA 110.

E. Field quality control test report

F. Warranty: Special warranty specified in this Section

G. Operation and Maintenance Data: For packaged engine generator to include in emergency, operation, and maintenance manuals. Include the following:

1. List of tools and replacement items recommended to be stored at Project for ready access. Include part and drawing numbers, current unit prices, and source of supply.

## 1.7 MAINTENANCE MATERIAL

A. Furnish extra materials that match products installed and that are packaged with protective covering for storage and identified with labels describing contents

1. Fuses: One for every ten of each type and rating, minimum one fuse of each type.
2. Filters: One set each of lubricating oil, fuel, and combustion air filters

## 1.8 QUALITY ASSURANCE

A. Installer Qualifications: Manufacturer's authorized representative who is trained and approved for installation of units required for this Project.

1. Maintenance Proximity: Not more than two (2) hours' normal travel time from Installer's place of business to Project site.
2. Engineering Responsibility: Preparation of data for vibration isolators and seismic restraints of engine skid and base fuel tank mounts, including Shop Drawings, based on testing and engineering analysis of manufacturer's standard units in assemblies similar to those indicated for this Project.

B. Manufacturer Qualifications: A qualified manufacturer with a minimum of 20 years' experience building the specified products. The manufacture shall maintain, 100 miles of Project site, a factory authorized and trained service center capable of providing training, parts, and emergency maintenance repairs.

C. Source Limitations: Obtain packaged generator set and auxiliary components through one source from a single manufacturer.

D. Electrical Components, Devices, and Accessories: Listed and labeled as defined in NFPA 70, Article 100, by a testing agency acceptable to authorities having jurisdiction, and marked for intended use.

E. Comply with ASME B15.1.

F. Comply with NFPA 37.

G. Comply with NFPA 70.

I. Comply with NFPA 110 requirements for Level 1 and Level 2 emergency / legally required power supply systems.

K. Exhaust Emissions: Comply with applicable federal, state, and local emissions requirements at the time of installation and commissioning.

L. Sound emissions: Comply with applicable local sound requirements

## 1.9 PROJECT CONDITIONS

A. Environmental Conditions: Engine-generator system shall withstand the following environmental conditions without mechanical or electrical damage or degradation of performance capability:

1. Ambient Temperature: Minus 30°C to plus 50 °C.

2. Altitude: 11,160 ft.

## 1.10 WARRANTY

A. Two Year Standby / Mission Critical Generator Set Warranty

1. The manufacturer's standard warranty shall in no event be for a period of less than two (2) years from date of initial start-up of the system and shall include repair parts, labor, reasonable travel expense necessary for repairs at the job site, and expendables (lubricating oil, filters, antifreeze, and other service items made unusable by the defect) used during the course of repair. Running hours shall be limited to 500 hours annually for the system warranty by both the manufacturer and servicing distributor. Submittals received without written warranties as specified will be rejected in their entirety.

2. Warranty shall include a temporary generator set in the event a warrantable repair will take more than 48 hours. Selling dealer must have a minimum of 10 units in its rental fleet to assure a temporary unit is available if needed. Provide documentation as such.

## 1.11 MAINTENANCE SERVICE

A. The engine generator supplier shall maintain 24-hour parts and service capability within 100 miles of the project site. The distributor shall stock parts as needed to support the generator set package for this specific project. The distributor shall carry sufficient inventory to cover no less than 80% of the parts service within 24 hours and 95% within 48 hours.

B. Initial Maintenance Service: Beginning at Acceptance, provide 12 months' full maintenance by certified employees of manufacturer's designated service organization. Include bi-monthly exercising (6 test) to check for proper starting, load transfer, and running under facility load. Include routine preventive maintenance as recommended by manufacturer and adjusting as required for proper operation. Provide parts and supplies same as those used in the manufacture and installation of original equipment. Fuel for 12-month maintenance period provided by CDOT.

## PART 2 – PRODUCTS

### 2.1 MANUFACTURERS

A. Manufacturers: Subject to compliance with product, performance, and project requirements.

B. Basis-of-Design Product: Subject to compliance with requirements, provide a diesel generator set. The power system has been designed to the specified manufacturer's electrical and physical characteristics. The equipment sizing, spacing, amounts, electrical wiring, ventilation equipment, fuel, and exhaust components shall all be sized and designed to meet performance and project requirements.

### 2.2 ENGINE-GENERATOR SET

A. New, 2018-2021 manufactured, factory assembled and tested engine-generator set.

B. The electric power generating system shall consist of 24,940skVA or 12987.0 skVA @ 30% instantaneous voltage dip, 0.8 power factor, 13,800 volts, when connected, 3-Phase, 4 wire, 60 hertz generator systems. Motor starting at 90% rated sustained voltage will not be accepted. Generator set shall be rated for Standby applications with typical usage of 500 hours per year.

1. For Generator system with a maximum output voltage of 13,800 Volts provide a step-up 13,800 Volt / 24,940 Volt transformer to match XCEL service voltage. Transformer shall be located adjacent to the generator.

2. The generating system shall be sized to operate the following load and start-up sequence noted below.

| GENERATOR SIZING REQUIREMENTS | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Step 1 | BASE LOAD (LIGHTS, MISC POWER, HVAC. . . ETC) 26.97 Amps at 24.9 KV, 3PH, (1,163 KVA) within 10 Seconds | | | | | | | | | |
| | | | | | | | | | | |
| Priority | South Tunnel Fan Loads | Intermediate 1 - (100 H.P.) | | | Intermediate 2 - (200 H.P.) | | | High - (600 H.P.) | | |
| | | Step | Start Sequence in Seconds | Motor Nameplate Amps at 2300 V, 3PH | Step | Start Sequence in Seconds | Motor Nameplate Amps at 2300 V, 3PH | Step | Start Sequence in Seconds | Motor Nameplate Amps at 2300 V, 3PH |
| 1 | East Exhaust-7 | 2 | :20 | 31 | 6 | :60 | 47 | 10 | 1:40 | 135 |
| | West Supply-5 | 3 | :30 | 31 | 7 | 1:10 | 47 | 11 | 1:50 | 135 |
| 2 | East Exhaust-6 | 4 | :40 | 31 | 8 | 1:20 | 47 | 12 | 2:00 | 135 |
| | West Supply-7 | 5 | :50 | 31 | 9 | 1:30 | 47 | 13 | 2:10 | 135 |
| | | | | | | | | | | |
| NOTE: South Tunnel Supply and Exhaust Fans are (2) Stage (2) Winding Across-the-Line Starting | | | | | | | | | | |

C. Engine power shall be capable of powering load at 77°F (25°C) at altitude of 11,160 feet.

D. Mounting Frame: Maintain alignment of mounted components without depending on concrete foundation, with provisions for lifting attachments.

1. Rigging diagram shall be permanently attached to the generator set package to indicate location and lifting capacity of each lifting attachment and generator-set center of gravity

E. Capacities and Characteristics:

1. Power Output Ratings: To operate load.
2. Output Connections: 24,940 volt or 13,800 volt three-phase, four wire. See 2.2 (B) 1

F. Nameplates: For each major system component, identify manufacturer's name, model, and serial number of components.

G. Generator set performance:

1. Steady-State Voltage Operational Bandwidth: 3 percent of rated output voltage from no load to full load.
2. Transient Voltage Performance: Not more than 20 percent variation for 50 percent step-load increase or decrease. Voltage shall recover and remain within the steady-state operating band within three seconds.
3. Steady-State Frequency Operational Bandwidth: 0.5 percent of rated frequency from no load to full load.
4. Steady-State Frequency Stability: When system is operating at any constant load within the rated load, there shall be no random speed variations outside the steady-state operational band and no hunting or surging of speed.
5. Transient Frequency Performance: Less than 5 percent variation for 50 percent step-load increase or decrease. Frequency shall recover and remain within the steady-state operating band within five seconds.
6. Output Waveform: At no load, harmonic content measured line to line or line to neutral shall not exceed 5 percent total and 3 percent for single harmonics. Telephone influence factor, determined according to NEMA MG 1, shall not exceed 50 percent.
7. Sustained Short-Circuit Current: For a 3-phase, bolted short circuit at system output terminals, system shall supply a minimum of 250 percent of rated full-load current for not less than 10 seconds and then clear the fault automatically, without damage to generator system components.
8. Start Time: Comply with NFPA 110, Type 10, system requirements.

## 2.3 ENGINE

A. Fuel: Fuel oil, Grade DF-2 ULS type

B. Rated engine speed: 1800 RPM

C. Lubrication system: The following items are mounted on engine or base rails:

1. Filter and strainer: Oil filters rated to remove 90% of particles 5 micrometers and smaller while passing full flow
2. Lube oil pump
3. Oil level regulator

4. Crankcase Drain: Arranged for complete gravity drainage to an easily removable container with no disassemble and without use of pumps, siphons, special tools, or appliances

D. Engine Fuel System:

1. Main Fuel Pump: Mounted on engine. Pump ensures adequate primary fuel flow under starting and load conditions.

2. Relief-Bypass Valve: Automatically regulates pressure in fuel line and returns excess fuel to source.

3. Provide water separator and fuel filters. Fuel filters shall have isolation valve for changing of filters during engine operation.

E. Coolant Jacket Heater: Electric-immersion type, factory installed in coolant jacket system. Comply with NFPA 110 requirements for Level 1 equipment for heater capacity. Heater shall include a circulation pump. Provide isolation valves that allow for change out of the heater without having to drain the entire system.

F. Governor: Shall provide isochronous control, with provisions to interface with load share modules and / or remote switchgear. The engine governor shall be an electronic Engine Control Module (ECM) with 24-volt DC Electric Actuator. The ECM shall be enclosed in an environmentally sealed, die-cast aluminum housing which isolates and protects electronic components from moisture and dirt contamination. The ECM shall adjust fuel delivery per exhaust smoke, altitude and cold mode limits. In the event of a DC power loss, the forward acting actuator will move to the minimum fuel position.

G. Cooling System: Closed loop, liquid cooled, with radiator factory mounted on engine-generator-set mounting frame, radiator duct flange and integral engine-driven coolant pump.

1. Coolant: Solution of 50 percent ethylene-glycol-based antifreeze and 50 percent water, with anticorrosion additives as recommended by engine manufacturer for specified in Part 1 “Project Conditions”

2. Size of Radiator: Adequate to contain expansion of total system coolant from cold start to 100 percent load condition to an ambient temperature of 104°F / 40°C ambient. Radiator shall be capable of providing cooling for an external restriction of 1.0 inch of water column.

3. Expansion Tank: Constructed of welded steel plate and rated to withstand maximum closed-loop coolant system pressure for engine used. Equip with gage glass and petcock.

4. Temperature Control: Self-contained, thermostatic-control valve modulates coolant flow automatically to maintain optimum constant coolant temperature as recommended by engine manufacturer.

5. Coolant Hose: Flexible assembly with inside surface of nonporous rubber and outer covering of aging-, ultraviolet-, and abrasion-resistant fabric.

6. Rating: 50-psig (345-kPa) maximum working pressure with coolant at 180°F (82°C), and non-collapsible under vacuum.

7. End Fittings: Flanges or steel pipe nipples with clamps to suit piping and equipment connections.

8. Integral fuel oil cooler shall be provided as required by the OEM.

H. Muffler / Silencer:

1. Provide a minimum critical grade exhaust silencer with valved condensate drain that extends beyond the depth of the insulation, and of the appropriate size for use with the engine. The silencer shall have inlet and outlets configured as required to meet the project exhaust system design with a 12-inch water column maximum pressure drop. Flexible, full-length stainless-steel connector/wye shall be furnished as required between the silencer and the engine exhaust outlet(s). The generator set manufacturer shall furnish all appropriate fittings, flanges, etc., as required between the engine and the silencer.

2. For outdoor enclosed applications, the exhaust silencer shall be mounted and insulated within the enclosure and pre-piped to the generator and exhaust stack.

I. Air Intake Filter: Heavy duty dual element, engine mounted air cleaners with replaceable dry-filter elements, “blocked filter” visual indicator

J. Starting System: 24 VDC electric with negative ground

1. Dual cranking motor: Dual electric starters that automatically engage and release from engine flywheel without binding.

2. Cranking cycle: as required by NFPA 110 for system level Type 1

3. Battery: Oversize (20%) capacity to accommodate starting within ambient temperature range specified in Part 1 “Project Conditions” Article to provide specified cranking cycle at least three times without recharging.

4. Battery Cable: Size as recommended by engine manufacturer for cable length required as per site conditions to be field verified by manufacturer’s representative prior to order. Include required interconnecting conductors and connection accessories.

5. Battery-Charging Alternator: Factory mounted on engine with solid-state voltage regulation and 35-A minimum continuous rating.

6. Battery Charger: Current-limiting, automatic-equalizing and float-charging type. Unit shall comply with UL 1236 and include the following features:

a. Operation: Equalizing-charging rate of 10 A shall be initiated automatically after battery has lost charge until an adjustable equalizing voltage is achieved at battery terminals. Unit shall then be automatically switched to a lower float-charging mode and shall continue to operate in that mode until battery is discharged again.

b. Automatic Temperature Compensation: Adjust float and equalize voltages for variations in ambient temperature from -40°C to +60°C to prevent overcharging at high temperatures and undercharging at low temperatures.

c. Automatic Voltage Regulation: Maintain constant output voltage regardless of input voltage variations up to ±10%.

d. Amp meter and Voltmeter: Flush mounted in door. Meters shall indicate charging rates.

e. Safety Functions: Sense abnormally low battery voltage and close contacts providing low battery voltage indication on control and monitoring panel. Sense high battery voltage and loss of ac input or dc output of battery charger. Either condition shall close contacts that provide a battery-charger malfunction indication at system control and monitoring panel.

f. Enclosure and Mounting: NEMA 250, Type 1, wall-mounted cabinet in genset enclosure

## 2.4 FUEL OIL STORAGE / SUB BASE TANK

A. Double walled base fuel tank constructed to meet all local codes and requirements as an integral part of the enclosure. Sized to provide 10 hours of run time at 50% load. Sub base tank shall be contained in a rupture basin with 110% capacity. Tank shall meet IL142 standards. Tank to include dual integral pumps, level control, leak detection, locking fill cap, a mechanical reading fuel level gauge. Provide with main vent and emergency vent.

B. Furnish flexible fuel line connections, fuel gauge, check valve, high and low fuel level alarm contacts and indicating lights. All alarm points shall be integrated into existing facility SCADA system.

C. Provide a fully automated, stand-alone self- contained fuel maintenance system for the fuel tank. System shall clean and recondition stored fuel when stored over time. Controller shall periodically circulate stored fuel through a Racor fuel/water separator to remove water and particulate contaminants

D. Mounting – Base mounted under generator

E. Conform to NFPA 30.

## 2.5 CONTROLS AND MONITORING

A. Provide a fully solid-state, microprocessor based, generator set controller. The control panel shall be designed and built by the engine manufacturer. The controller shall provide all operating, monitoring, and control functions for the generator set. The control panel shall provide real time digital communications to all engine and regulator controls via secure communication network.

B. Mounting

1. The control panel shall include all interconnecting cables and harnesses to allow it to be mounted within genset enclosure.

C. Environmental

1. The generator set controller shall be tested and certified to the following environmental conditions:

   a. -40°C to +70°C Operating Range

   b. 100% condensing humidity, 30°C to 60°C

   c. IP22 protection for rear of controller; IP55 when installed in control panel

   d. 5% salt spray, 48 hours, +38°C, 36.8V system voltage

   e. Sinusoidal vibration 4.3G's RMS, 24-1000Hz

   f. Electromagnetic Capability (89/336/EEC, 91/368/EEC, 93/44/EEC, 93/68/EEC, BS EN 50081-2, 50082-2)

   g. Shock: withstand 15G

D. Functional Requirements: The following functionality shall be integral to the control panel.

1. The control shall include a minimum 5.5-inch, 480 x 320 pixel, white backlit graphical display with text based alarm/event descriptions.
2. The control shall include a minimum of 6-line data display
3. Generator set overview screen displaying critical generator set mechanical and electrical data on a single screen.
4. Audible horn for alarm and shutdown with horn silence switch
5. Standard ISO labeling
6. Multiple language capability
7. Remote start/stop control
8. Local run/off/auto control integral to system microprocessor
9. Cooldown timer
10. Speed adjust
11. Lamp test
12. Emergency stop push button
13. Voltage adjust
14. Voltage regulator V/Hz slope - adjustable
15. Password protected system programming

E. Digital Monitoring Capability: The controls shall provide the following digital readouts for the engine and generator. All readings shall be indicated in either metric or English units.

1. Engine

a. Engine oil pressure

b. Engine oil temperature

c. Engine coolant temperature

d. Engine RPM

e. Battery volts

f. Engine hours

g. Engine crank attempt counter

h. Engine successful start counter

i. Service maintenance interval

j. Real time clock

k. Engine exhaust stack temperature

l. Engine main bearing temperature

2. Generator

a. Generator AC volts (Line to Line, Line to Neutral and Average.

b. Generator AC current (Avg and Per Phase.

c. Generator AC Frequency

d. Generator kW (Total and Per Phase.

e. Generator kVA (Total and Per Phase.

f. Generator kVAR (Total and Per Phase.

g. Power Factor (Avg and Per Phase.

h. Total kW-hr

i. Total kVAR-hr

j. % kW

k. % kVA

l. % kVAR

m. Generator bearing temperature

n. Generator stator winding temperature

o. Real (kW. Load Histogram – which tracks time that the generator kW is within predefined ranges

F. Alarms and Shutdowns: The control shall monitor and provide alarm indication and subsequent shutdown for the following conditions. All alarms and shutdowns are accompanied by a time, date, and engine hour stamp that are stored by the control panel for first and last occurrence:

1. Engine Alarm/Shutdown
   a. Low oil pressure alarm/shutdown
   b. High coolant temperature alarm/shutdown
   c. Loss of coolant shutdown
   d. Overspeed shutdown
   e. Overcrank shutdown
   f. Emergency stop shutdown
   g. Low coolant temperature alarm
   h. Low battery voltage alarm
   i. High battery voltage alarm
   j. Control switch not in auto position alarm
   k. Battery charger failure alarm
   l. ATS remote start wiring failure
2. Generator Alarm/Shutdown
   a. Generator phase sequence
   b. Generator over voltage
   c. Generator under voltage
   d. Generator over frequency
   e. Generator under frequency
   f. Generator reverse power (real and reactive.
   g. Generator overcurrent (including inverse definite minimum time. for Normally Inverse, Very Inverse, Extremely Inverse conditions as well as those based on Thermal Damage Curve configurations
   h. Generator current balance
3. Voltage Regulator Alarm/Shutdown
   a. Loss of excitation alarm/shutdown
   b. Instantaneous over excitation alarm/shutdown
   c. Time over excitation alarm/shutdown
   d. Rotating diode failure
   e. Loss of sensing
   f. Loss of PMG

G. Inputs and Outputs

1. Programmable Digital Inputs. The Controller shall include the ability to accept programmable digital input signals. The signals may be programmed for either high or low activation using programmable Normally Open or Normally Closed contacts.
2. Programmable Discrete Outputs. The control shall include the ability to operate sixteen (16) discrete outputs, integral to the controller, which are capable of sourcing up to 200mA per input.
3. Integrated PLC Functionality. The panel shall allow the operator to create custom logic functions to provide additional user defined control of the generator set operation.

H. Accessibility and Maintenance

1. All engine, voltage regulator, control panel and accessory units shall be accessible through a single electronic service tool. The following maintenance functionality shall be integral to the generator set control:
   a. Engine running hours display
   b. Service maintenance interval (running hours or calendar days)
   c. Engine crank attempt counter
   d. Engine successful starts counter
   e. 40 events are stored in control panel memory
   f. Chronological status event log capable of displaying a sequence of event leading up to a generator set shutdown
   g. Programmable cycle timer that starts and runs the generator for a predetermined time. The timer shall use 7 user-programmable sequences that are repeated in a 7-day cycle. Each sequence shall have the following programmable set points:
      1) Day of week
      2) Time of day to start
      3) Duration of cycle

I. Remote Communications

1. Remote Communications. The control shall include Modbus TCP communications via Ethernet 10BASE-T and Modbus RTU communications via RS-485 half duplex with configurable baud rates from 2.4k to 57.6k.
2. Remote Monitoring Software. The control shall provide Monitoring Software with the following functionality
   a. Provide access to all date and events on generator set communications network
   b. Provide remote control capability for the generator set(s).
   c. Ability to communicate via Modbus RTU or remote modem to facility SCADA.

J. Local and Remote Annunciation

1. Local Annunciator (NFPA 99/110, CSA 282). Provide a local, control panel mounted, annunciator to meet the requirements of NFPA 110, Level 1.

   a. Annunciators shall be networked directly to the generator set control

   b. Local Annunciator shall include a lamp test pushbutton, alarm horn and alarm acknowledge pushbutton

   c. Provide the following individual light indications for protection and diagnostics:

      1) Overcrank

      2) Low coolant temperature

      3) High coolant temperature warning

      4) High coolant temperature shutdown

      5) Low oil pressure warning

      6) Low oil pressure shutdown

      7) Overspeed

      8) Low coolant level

      9) EPS supplying load

      10) Control switch not in auto

      11) High battery voltage

      12) Low battery voltage

      13) Battery charger AC failure

      14) Emergency stop

      15) Spare (or ATS Remote Start wiring failure)

      16) Spare (or Tier 4 SCR when applicable)

2. Remote Annunciator (NFPA 99/110, CSA 282). Provide a remote annunciator located in East Portal Control Room to meet the requirements of NFPA 110, Level 1.

a. The annunciator shall provide remote annunciation of all points stated above and shall incorporate ring-back capability so that after silencing the initial alarm, any subsequent alarms will sound the horn. Ability to be located up within East Portal Control Room. Communication maybe over existing CDOT fiber from West to East Portal.

## 2.6 GENERATOR OVERCURRENT AND FAULT PROTECTION

A. Generator Protector: Microprocessor-based unit shall continuously monitor current level in each phase of generator output, integrate generator heating effect over time, and predict when thermal damage of alternator will occur. When signaled by generator protector or other generator-set protective devices, a shunt-trip device in the generator

disconnect switch shall open the switch to disconnect the generator from load circuits. Protector shall perform the following functions:

1. Initiates a generator overload alarm when generator has operated at an overload equivalent to 110 percent of full-rated load for 60 seconds. Indication for this alarm is integrated with other generator-set malfunction alarms.
2. Under single or three-phase fault conditions, regulates generator to 300 percent of rated full-load current for up to 10 seconds.
3. As overcurrent heating effect on the generator approaches the thermal damage point of the unit, protector switches the excitation system off, opens the generator disconnect device, and shuts down the generator set.
4. Senses clearing of a fault by other overcurrent devices and controls recovery of rated voltage to avoid overshoot.

B. Ground-Fault Protection: Comply with NFPA 70, signals for ground-fault. Integrate ground-fault alarm indication with other generator-set alarm indications.

## 2.7 GENERATOR, EXCITER, AND VOLTAGE REGULATOR

A. Comply with NEMA MG 1.

B. Drive: Generator shaft shall be directly connected to engine shaft. Exciter shall be rotated integrally with generator rotor.

C. Electrical Insulation: Class H insulation. Windings shall be of the form wound type. Temperature rise shall not exceed 130°C over 40°C ambient temperature.

D. Stator-Winding Leads: Brought out to terminal box to permit future reconnection for other voltages if required.

E. Construction shall prevent mechanical, electrical, and thermal damage due to vibration, overspeed up to 125 percent of rating, and heat during operation at 110 percent of rated capacity.

F. Enclosure: Drip proof.

G. Instrument Transformers: Mounted within generator enclosure.

H. Voltage Regulator: Solid-state type, separate from exciter, providing performance as specified.

1. Voltage adjustment on control and monitoring panel shall provide plus or minus 5 percent adjustment of output-voltage operating band.

I. Strip Heater: Thermostatically controlled unit arranged to maintain stator windings above dew point.

J. Windings: Two-thirds pitch stator winding and fully linked amortisseur winding.

K. Subtransient Reactance: 12.56% percent or less.

## 2.8 VIBRATION ISOLATION DEVICES

A. Restrained Spring Isolators: Freestanding, steel, open-spring isolators.

1. Housing: Steel with resilient vertical-limit stops to prevent spring extension due to wind loads or if weight is removed; factory-drilled baseplate bonded to 1/4-inch- (6-mm-) thick, elastomeric isolator pad attached to baseplate underside; and adjustable equipment mounting and leveling bolt that acts as blocking during installation.
2. Outside Spring Diameter: Not less than 80 percent of compressed height of the spring at rated load.
3. Minimum Additional Travel: 50 percent of required deflection at rated load.
4. Lateral Stiffness: More than 80 percent of rated vertical stiffness.
5. Overload Capacity: Support 200 percent of rated wet load fully compressed, without deformation or failure.
6. Genset shall be mounted on top of base fuel tank.

## 2.9 ENCLOSURE

A. Attenuated Enclosure

1. The complete diesel engine generator set, including generator control panel, engine starting batteries and fuel system, shall be enclosed in a factory assembled, sound attenuated enclosure mounted on the sub base fuel tank.

a. A weather resistant, sound attenuated enclosure of steel with electrostatically applied powder coated baked polyester paint. The enclosure shall have a resulting sound level of 78dba @23ft with the genset running under full load. It shall consist of a roof, side walls, and end walls. Fasteners shall be either zinc plated or stainless steel.

b. Enclosure Sound Attenuation: Acoustical foam shall be provided between all supports and inside doors and sound baffles on air intake and air discharge.

c. Enclosure accessories:

1. Mini Power-Zone Transformer / Panelboard, NEMA 1, 480Volt, 3 phase primary, 208Volt, 3 Phase, 4 Wire secondary, main circuit breaker and branch circuit breakers. Size Mini-Power Zone to feed; battery charger, jacket water heater, internal and external lights, emergency lights, convenience receptacles, fuel system, control panel, pumps and conditioner plus 30% spare capacity. Provide a spare circuit breaker for each size used.

2. Internal LED roof mounted lighting to provide an average of 30 foot-candles at floor level of enclosure. Lights to be controlled by toggle switches located at access points.

3. External LED wall mounted lighting to provide sufficient illuminance at enclosure egress and access points. Lights to be controlled with internal photocell.

4. Internal emergency LED egress lighting.

5. Convenience 120Volt 20Amp Duplex receptacles. Provide one on each wall of enclosure interior. Provide one weatherproof GFI external receptacle on each side of exterior enclosure.

B. Service Catwalk

1. Provide 36” wide elevated steel grate service platform along two sides of generator with access doors. Provide access stairs to each platform. Paint to match generator enclosure. Service platform shall be supported with steel posts anchored to concrete equipment pad. Provide structural engineered shop drawing of service platform with dimensions, member sizes, bracing and grate material.

## 2.10 FINISHES

A. Indoor and Outdoor Enclosures and Components: Manufacturer's standard finish over corrosion-resistant pretreatment and compatible primer. Exterior color to be BROWN as specified by CDOT.

## 2.11 EQUIPMENT MOUNTING PAD

A. Structural concrete pad designed per Manufacturer’s recommendations to suit site conditions and equipment requirements. Pad shall extend a minimum of 48” beyond equipment enclosure.

B. Prepare level site for structural pad. Remove and repair asphalt as needed, grade, remove and backfill site as needed. Provide drainage to eliminate low spots and puddling areas.

C. Provide traffic protection bollards per CDOT requirements around all equipment.

## 2.11 SOURCE QUALITY CONTROL

A. Prototype Testing: Factory test engine-generator set using same engine model, constructed of identical or equivalent components, and equipped with identical or equivalent accessories.

1. Tests: Comply with NFPA 110, Level 1 Energy Converters and with IEEE 115.

B. Project-Specific Equipment Tests: Before shipment, factory test engine-generator set and other system components and accessories manufactured specifically for this Project. Perform tests at rated load and power factor. Reference system Commissioning Specifications for additional requirements. Include, at a minimum, the following tests:

1. Test components and accessories furnished with installed unit that are not identical to those on tested prototype to demonstrate compatibility and reliability.

2. Full load run.

3. Maximum power.

4. Voltage regulation.

5. Transient and steady-state governing.

6. Single-step load pickup.
7. Safety shutdown.
8. Provide 30 days' advanced notice of tests and for observation of tests by CDOT / ATKINS.

## PART 3 - EXECUTION

### 3.1 EXAMINATION

A. Examine areas, equipment bases, and conditions, with Installer and manufacturer present, for compliance with requirements for installation and other conditions affecting packaged engine-generator performance.

B. Examine roughing-in of piping systems and electrical connections. Verify actual locations of connections before packaged engine-generator installation.

C. Proceed with installation only after unsatisfactory conditions have been corrected.

### 3.2 INSTALLATION

A. Comply with packaged engine-generator manufacturers' written installation and alignment instructions, NFPA 110 and all local codes

B. Install packaged engine generator to provide access, without removing connections or accessories, for periodic maintenance.

C. Install packaged engine generator with restrained spring isolators having a minimum deflection of 1 inch.

D. Electrical Wiring: Install electrical devices furnished by equipment manufacturers but not specified to be factory mounted. Electrical wiring includes but is not limited to battery chargers, heaters, control power, load bank, grounding, remote annunciator panels, remote control panels, etc. Contractor to include as part of their scope of work, all wiring and empty conduit indicated on contract drawings, specified herein, indicated/noted on approved manufacturers shop drawings, and as required to provide a fully functional system.

### 3.3 CONNECTIONS

A. Connect fuel, cooling-system, and exhaust-system piping adjacent to packaged engine generator to allow service and maintenance.

B. Connect cooling-system water piping to engine-generator set and with single braid corrosion resistant type 302 stainless steel wire braid and compression fittings.

C. Connect engine exhaust pipe to engine with stainless steel flexible connector.

D. Connect fuel piping to engines with a gate valve and union and stainless-steel flexible connector. Provide all required fire safe-off and solenoid valves.

E. Connect to SCADA System, coordinate with SCADA controls integration contractor.

F. Ground equipment according to Division 26 Section "Grounding and Bonding for Electrical Systems."

G. Connect wiring according to Division 26 Section "Low-Voltage Electrical Power Conductors and Cables."

## 3.4 IDENTIFICATION

A. Identify system components according to Division 26 Section "Identification for Electrical Systems."

## 3.5 FIELD QUALITY CONTROL

A. Field Testing: If factory service technicians cannot provide the field testing specified as part of manufacturer's start-up, this contractor shall engage a qualified factory certified and authorized testing agency to perform tests and inspections and prepare test reports required by manufacturer.

B. Manufacturer's Field Service: Contractor to include field services of factory-authorized service representatives to provide start-up testing as well as to assist in 3rd party system commissioning as specified under the system commissioning specifications. Testing will not be concurrent so multiple travel days shall be included as per the approved schedule.

C. Perform tests and inspections and prepare test reports.

D. Contractor is responsible for providing all fuel needed for commissioning, testing and training of equipment. Upon completion and final acceptance contractor shall provide a full fuel tank.

E. Tests and Inspections:

1. Perform tests recommended by manufacturer and each electrical test and visual and mechanical inspection for "AC Generators and for Emergency Systems" specified in NETA Acceptance Testing Specification. Certify compliance with test parameters. Generators shall be tested individually and in parallel.

2. The Contractor shall provide resistive load bank(s) with associated controls as required to perform the specified load tests. During cold start testing the generator shall reach 90% of rated voltage and frequency within 10 seconds. During recovery testing the generator shall reach 90% of rated voltage and frequency within ½ second. The generated voltage shall not drop below 85% of the rated voltage during any portion of the generator load testing (part or full load testing). Minimum load testing shall be as follows:

    a. 25%, 50%, and 75% of rated load for 30 minutes each.

    b. 100% of rated load for 3 hours.

    c. Recovery test in a single step from no load to 100% of rated load.

3. NFPA 110 Acceptance Tests: Perform tests required by NFPA 110 that are additional to those specified here including, but not limited to, single-step full-load pickup test.

4. Battery Tests: Equalize charging of battery cells according to manufacturer's written instructions.

a. Measure charging voltage and voltages between available battery terminals for full-charging and float-charging conditions. Check electrolyte level and specific gravity under both conditions.

b. Test for contact integrity of all connectors.

c. Verify acceptance of charge for each element of the battery after discharge.

d. Verify that measurements are within manufacturer's specifications.

5. Battery-Charger Tests: Verify specified rates of charge for both equalizing and float-charging conditions.

6. System Integrity Tests: Methodically verify proper installation, connection, and integrity of each element of engine-generator system before and during system operation. Check for air, exhaust, and fluid leaks.

7. Exhaust Emissions Test: Comply with applicable government test criteria to confirm adherence to EPA Tier rating.

8. Voltage and Frequency Transient Stability Tests: Use recording oscilloscope to measure voltage and frequency transients for 50 and 100 percent step-load increases and decreases and verify that performance is as specified.

9. Harmonic-Content Tests: Measure harmonic content of output voltage under 25 percent and at 100 percent of rated linear load. Verify that harmonic content is within specified limits.

10. “Pull the Plug Test”: Automatic start-up by means of simulated power outage to test remote-automatic starting, transfer of the load, and automatic shutdown. Prior to this test, all transfer switch timers shall be adjusted for proper system coordination. Engine coolant temperature, oil pressure, and battery charge level along with generator set voltage, amperes, and frequency shall be monitored throughout the test.

F. Coordinate tests with tests for transfer switches and run them concurrently.

G. Test instruments shall have been calibrated within the last 12 months, traceable to standards of NIST, and adequate for making positive observation of test results. Make calibration records available for examination on request.

H. Leak Test: After installation, charge system and test for leaks. Repair leaks and retest until no leaks exist.

I. Operational Test: After electrical circuitry has been energized, start units to confirm proper motor rotation and unit operation.

J. Test and adjust controls and safeties. Replace damaged and malfunctioning controls and equipment.

K. Remove and replace malfunctioning units and retest as specified above.

L. Retest: Correct deficiencies identified by tests and observations and retest until specified requirements are met.

M. Report results of tests and inspections in writing. Record adjustable relay settings and measured insulation resistances, time delays, and other values and observations. Attach a label or tag to each tested component indicating satisfactory completion of tests.

## 3.6 DEMONSTRATION

A. Engage a factory-authorized service representative to train Owner's maintenance personnel to adjust, operate, and maintain packaged engine generator. Owner's training shall consist of two (2), four (4) hour trainings with Owner's Maintenance & Operations Personnel.

## 3.7 OPERATION AND MAINTENANCE MANUALS

A. Provide two (2) sets of operation and maintenance manuals covering the generator, switchgear, and auxiliary components. Include final as-built wiring interconnect diagrams and recommended preventative maintenance schedules.

**END OF SECTION**

## EXHIBIT A – MOTOR REPAIR EQUIPMENT SPECIFICATION – TUNNEL OPERATIONS, INDUCTION MOTOR REPAIR

### PURPOSE and SCOPE

This specification will establish uniform procedures to be followed by all repair facilities when servicing CDOT induction motors. If a CDOT motor requires repair, the specification will be used to identify general guidelines and minimum acceptable standards for the disassembly, inspection, repair, testing, and reassembly of the motor.

The scope of work includes rewinding of (16) sixteen 480Volt, 3 Phase, 600H.P. fan (exhaust or supply) motors located on fan deck of East and West Portals for the North Tunnel. Motor Repair Shop / Contractor is responsible for ALL work associated with disassembly, reassembly, transportation, coordination and scheduling with CDOT Tunnel Maintenance. Only (1) one exhaust fan motor and (1) one supply fan motor will be allowed off-line at a time per Portal side. Total of 4 motors at a time. In the event CDOT Maintenance has a fan motor off-line for other repairs the contractor shall make it a priority to rewind it concurrently.

### APPLICABILITY

This specification shall apply to all electric motors with a voltage rating of 440V and above and a horsepower rating of 100HP and above, and may be used for any integral HP motor. Separate specifications will address DC motors and synchronous fields.

### DEFINITIONS

CDOT - Colorado Department Of Transportation

MAINTENANCE RESOURCES (CDOT)

Any member of the EJMT Tunnel Engineering of CDOT

CDOT – Tunnel Operations

Refers to the CDOT facility from which the motor originated. CDOT also refers to departments and individuals within the facilities organizational structure (e.g. stock room, system engineer, maintenance supervisor).

MOTOR MANUFACTURER (OEM)

The company or corporation that originally designed, constructed, and tested the motor.

SUPPLY CHAIN

Center for Procurement and Contract Services

PURCHASE ORDER

A written contractual document prepared by an agent in Procurement and Contract Services to describe all the terms and conditions of the purchase.

**MOTOR IDENTIFICATION**

The motor nameplate information shall be recorded to identify the motor.

| **C-DOT LOCATION** | | **MOTOR APPLICATION** | |
|---|---|---|---|
| **MANUFACTURER -**<br>**GE ☐ W ☐ EM ☐ S-A ☐ REL ☐ Other ☐ _____** | | | |
| **HP** | **VOLTAGE** | **AMPS** | **RPM** |
| **FRAME** | **CODE** | **RATED RISE** | **CLASS** |
| **MODEL NO.** | | **SERIAL NO.** | |

**REPAIR SPECIFICATIONS**

GENERAL

The motor repair facility shall use good shop practice and industry accepted methods and materials for all repairs of CDOT motors. Any motor repair facility should be ISO Certified in accordance with ISO 9001:2015 standards. All repair processes shall conform to the applicable standards of ANSI, IEEE, NEMA, EASA, IACS, and AFBMA unless explicitly modified or supplemented by this specification. Any repair procedure that is not covered by or that contradicts this specification shall be brought to the attention of CDOT before repair begins.

The motor repair facility shall assume full responsibility for the motor once the motor is in possession of the repair facility or its representative. Any damage to the motor during this period will be repaired by the repair facility to the satisfaction of CDOT. Due to the life safety nature of motors used by CDOT, local support within 4 hours drive is required.

The following REPAIR PROCEDURES describe guidelines for repair and minimum acceptable standards for work on CDOT motors. Procedures calling for CDOT to be notified or consulted are "Hold" points that *shall be adhered to*. Hold points generally require a review before repair work begins. The job supervisor shall read and understand this specification before beginning work.

All documentation and test data shall be submitted to CDOT upon delivery once repairs are complete.

REPAIR PROCEDURES

PICKUP / DELIVER MOTOR
The motor repair facility shall provide transportation and shipping protection of the motor. The repair facility shall ensure the motor is properly secured to prevent movement and suitably covered to protect against the elements.

RECEIPT INSPECTION
Before commencing any disassembly or repair, the repair facility shall fully document the 'as-found' condition of the motor. This documentation shall include a list of all

parts and assemblies shipped with the motor, the general condition of the motor including any obvious damage, and a 500VDC Polarization Index of the stator winding. Photographs and a detailed report are required.

DISASSEMBLY / REASSEMBLY OF MOTOR

Disassembly

All parts removed from the motor shall be match-marked, tagged, or labeled to prevent losing and to ensure proper reassembly.

The motor repair facility is responsible for disassembly of the motor, removal from the fan deck and all equipment required to move the motor. Fan Deck structural restrictions limit crane or forklift equipment to a MAX size / weight of XXXX.

All motor components shall be adequately protected to prevent damage or contamination during storage.

All piping or ports to oil lubricated bearings shall be temporarily capped.

Each motor shall be given a complete visual inspection to assess the integrity of the various components. If a component has experienced an obvious failure, other failures or imminent failures may exist which can be detected visually. The inspection shall include but not be limited to the following:

- Winding insulation condition.
- End-turn blocking and support condition.
- Power, RTD and thermocouple lead condition.
- Slot wedge tightness and condition.
- Stator and rotor core iron condition.
- Rotor bar and shorting ring condition.
- Bearing, oil seal, and rotor journal condition.
- Frame and endbell condition.

CDOT shall be consulted if any problems are identified within the motor that may indicate a design or materials inadequacy, or misapplication of the motor. Potential problems include excessive loose end-turn blocking, loose slot wedges or filler strips, fractured stator or rotor core iron, and excessive cracks in the rotor bar/shorting ring connections.

Runout readings shall be taken on the rotor journals, oil seal fits, coupling rim and face, and on machined shaft surfaces adjacent to the rotor body. The appropriate rotor surfaces shall be cleaned before taking readings.

Rotor journal and seal fit diameters shall be measured. Journal measurements shall consist of two readings, 90° apart, at the inner, center, and outer locations of the bearing seat. Seal fit readings shall consist of two readings, 90° apart, at the axial center of the seal fit.

Sleeve bearing inside diameters shall be measured to assure uniformity in diameter and absence of any taper. Bearing measurements shall consist of two readings, 90° apart, at the axial center of the bearing and at either edge. The clearance between the rotor journal and the corresponding bearing shall be compared against the Motor Manufacturer's tolerance.

Oil seal inside diameters shall be measured to assure uniformity in diameter. Seal ring readings shall consist of two readings, 90° apart, at the axial center of the seal ring. The clearance between the rotor seal fit and the ID of the corresponding oil seal shall be compared against the Motor Manufacturer's tolerance.

Reassembly

All motor components (e.g. bearing reservoirs & piping, end-bells & air shields, etc) shall be thoroughly cleaned using industry approved methods and materials.

Bearing assemblies and oil seals shall be checked for mutual concentricity and proper fit within the endbell or end housing. End-bells shall be positioned so that the bearing bores are in-line and positioned with respect to the stator bore according to the Motor Manufacturer's recommendation. If this information is unavailable, the bearing bores shall be positioned on the same axis as the stator bore.

Sleeve bearings shall be installed to eliminate end thrust against either bearing during normal operation. Total endplay shall be in accordance with the Motor Manufacturer's specifications. Rolling element bearings shall be installed and positioned to prevent undesirable loading under all normal operating conditions.

A skid pan or similar device shall be used where possible to protect stator core iron and end-turn insulation when installing rotor.

The air gap shall be verified clear after the rotor is in its final position in the bearings. When access to the air gap is provided, air gap measurements shall be taken at 90° increments around the circumference on both ends of the stator. Maximum variation shall be within the Motor Manufacturer's tolerance. If this value is unavailable, the maximum deviation of any one reading shall not exceed 10% of the average.

After reassembly, proper bearing lubrication shall be provided and the motor test run until bearing temperatures stabilize. The following steps shall be performed:

Listen for unusual sounds from the bearings, fans, etc.

Verify magnetic center and end-limit scribes on the shaft are accurate. If scribe lines are inaccurate or not present, the coupling-end shaft extension shall be blued adjacent to the bearing housing and the shaft scribed at the bearing housing interface.

Measure vibration amplitude and/or velocity on the IB and OB bearing caps in the horizontal and vertical direction.

Measure amps on each phase and check for unbalance.

Measure bearing and winding temperatures.

A new or a supplementary nameplate shall be provided if any of the original nameplate information is changed due to a repair, upgrade, or modification of the motor. The supplementary nameplate shall list the changes and shall be mounted below the original nameplate with cadmium screws.

RECONDITIONING MOTOR

General

The stator winding, rotor, and frame assembly shall be steam cleaned to remove all dirt, grease, and oil deposits. Any additives such as cleaning agents introduced into the steam shall not cause any adverse effects to the stator insulation system. Steam cleaning shall be followed by a baking cycle to positively remove all moisture from the stator assembly. Winding temperature during baking shall not exceed 95°C by thermometer for any insulation class (Class A, B, F, H). After cool down, the stator winding shall be tested according to Section 5.2.5.3, Paragraph C (Insulation Resistance & P.I.).

Stator

On stators with form wound coils, the core iron shall be tested using a core loop test at near rated flux density or an EL CID test. On stators with random wound coils, the core iron may be tested by the above two methods or by a core loss tester using a watts/pound acceptance criteria. Any hot spots in the core laminations shall be corrected by one of the following methods:

- Separating laminations and inserting mica or insulating resin,
- Acid etching the hot spot and painting with a thin insulating resin, or
- Grinding the hot spot with a silicon carbide, grinding wheel and painting with a thin insulating resin.

CDOT must approve alternate repair methods before commencing work.

Repairs shall be followed by a core loop test. Maximum permissible temperature differential between the average core temperature and any other core location is 5°C.

All loose end-turn blocks shall be replaced in kind with thicker blocks of like material or with compressed impregnated Dacron® felt. Loose or shifted non-felt type blocks shall be repositioned and secured with glass-based cord or roving. Loose end-turn cord or roving shall be replaced.

Loose phase rings or motor leads shall be repositioned and secured with glass-based cord/roving, or banding tape. Additional ties shall be installed as required to prevent any future movement.

All slot wedges and underlying filler strips that have migrated outward shall be tapped back into place and secured with an appropriate adhesive. Wedges or filler strips shall not be secured to the coil armor.

After all repairs on the stator assembly are completed, the stator winding shall be processed using a VPI process. VPI materials used shall be Von Roll epoxy #74035. VPI process shall be followed by a baking cycle to properly cure all insulating materials. Baking temperature shall not exceed the temperature rating of the motor insulation. A minimum of two VPI /bake cycles shall be performed.

Final testing shall consist of a winding insulation resistance and polarization index (Section 5.2.5.3, Paragraph C), slot RTD DC resistance and insulation resistance (Section 5.2.5.3, Paragraph E & F), and a balanced phase load test (Section 5.2.5.3, Paragraph H) if the motor is re-assembled.

Rotor

All rotor bar to shorting ring connections shall be visually inspected for breaks, cracks, or separations. A 'growler' or similar test shall follow the visual inspection. CDOT shall be consulted before beginning any repairs.

Rotor core laminations that are smeared shall be separated with a knife blade or similar tool and painted with a thin varnish or insulating paint.

Laminations that are burned, if not severe, shall be cleaned and painted. If iron loss from burning has resulted in a significant reduction in the radial support of one or more bars, CDOT must approve the method of repair.

All rotor core clamping components, such as through bolts or clamping rings/fingers, shall be inspected for looseness, shifting, or breakage. CDOT shall be consulted before beginning any repairs.

Rotor fan blades or blowers, including mounting bolts, shall be inspected for cracks, breaks, significant chips, or deformation. Damaged nonmetallic blades shall be replaced. Damaged metallic blades or blowers shall be particle blasted and dye penetrant checked. If the blade or blower is repairable, proven standard welding techniques shall be used.

Rotor journals and seal fits shall be visually inspected for scratches, nicks, and scoring. Superficial marks may be hand polished or lapped out. Journal surfaces should be polished to a 16-microinch finish or finer. Significant marks may require some form of resurfacing. CDOT shall be consulted before beginning any resurfacing of journals or seal fits.

If runout readings taken during disassembly exceed 0.001", the appropriate journal, seal fit, or coupling surface shall be trued. If taper along the journal surface exceeds 0.003" per inch of journal length, the journal shall be trued. Maximum permissible runout after truing is 0.001". CDOT shall be notified before truing.

If any repair work is performed on the rotor that could potentially affect operating vibration levels, the rotor shall be balanced in accordance with *Section 5.2.28*.

Bearings, Oil Seals, and Frame

Rolling element bearings shall be replaced unless otherwise specified by the CDOT. Proper clearance of the bearing on the shaft and in the endbell fit shall

be checked. New and reused greaseable (non-sealed) bearings shall be thoroughly cleaned in an approved solvent and packed with a lubricant that is in accordance with the bearing manufacturer's recommendation and that is compatible with grease used by the CDOT. The motor shall be tagged to indicate bearing grease used.

The clearance between the rotor journal and the corresponding bearing, as measured during disassembly, shall be compared against the Motor Manufacturer's tolerance. An undersized bearing shall be machined as required. If a bearing is oversized, CDOT or the CDOT shall be consulted regarding re-babbitting or replacing the bearing.

Sleeve bearings shall be tested for flaws. Tests shall consist of dye penetrant of the babbitt and ultrasonic test of the babbitt-to-shell bond. Minimum contact between babbitt and shell is 80%. Babbitt surfaces shall be polished to a 32-microinch finish or finer. Oil rings shall be visually inspected and dye penetrant tested for cracks or flaws.

The clearance between the rotor seal fit and the ID of the corresponding oil seal, as measured during disassembly, shall be compared against the Motor Manufacturer's tolerance. If an oil seal is oversized, CDOT shall be notified regarding refurbishing or replacing the seal.

Insulation resistance of insulated bearings, bearing temperature detectors, and vibration sensors - in the installed position - shall be measured with a 500 VDC megohmmeter. Minimum acceptable resistance is 10 megohms.

Removal of internal rust in the frame shall be by sandblasting, wire brushing, or chemical treatment. These areas shall be covered with a rust inhibiting primer. The motor exterior surfaces shall be properly masked, prepared, and painted with industrial-grade enamel that closely matches the original color.

COMPLETE STATOR REWIND - FORM WOUND COILS

Winding Removal

Slot RTD's and/or other winding sensors shall be identified prior to winding removal so exact replacements can be reinstalled.

Motor heaters, if installed, shall be identified and removed. CDOT shall be consulted to ascertain whether the heaters should be reinstalled.

Stripping of the stator winding shall be accomplished by one of the following methods:

- Non-VPI motors can be stripped by removing the slot wedges and removing the winding. Cutting off the end turns may facilitate this process.
- Coil wedges and insulation on top of the coil can be cut out with a circular saw and the wire removed. Insulation must then be removed from the core by another method as described in this section.

- Burn Out Oven - During the burnout process, the oven temperature shall not exceed 800°F and should be maintained at a level somewhat lower (e.g. 700 - 760°F). The temperature selected shall not damage stator core interlaminar insulation. The burn out oven must be a radiant heat type without direct flame impingement on the motor windings, core, or frame. The burnout oven must be equipped with a steam or water injection system for maintaining the desired temperature.
- Water Blast or a hydro laser shall not be used to remove a winding unless prior approval is given by CDOT.

The stator core and frame shall be cleaned after stripping the winding but before testing the core iron. Steam cleaning, cleaning agents and water, and particle blasting are acceptable cleaning methods providing the interlaminar insulation is left unaffected.

All stator cores shall be tested as described in Section 5.2.5.3, Paragraph *B* (core iron test) before installing any new coils.

New Stator Winding

Wire size and shape, turns per coil, coil pitch and span, and winding connection & configuration shall be identical to the Motor Manufacturer's original design. Any redesign or modification of the winding configuration shall be submitted in writing and approved by CDOT before implementation.

Conductor material shall be 100% conductivity IACS copper with the same or greater cross sectional area as that originally used in the motor. Preferred strand insulation is a minimum of two layers of Dacron® or approved equal glass fiber, reverse wrapped and bonded to enamel-coated copper. If use of the preferred strand insulation necessitates a net reduction in the dielectric strength of the ground wall insulation, compared to the original design, heavy enamel film may be substituted. Additional mica turn insulation shall be applied when turn-to-turn voltages exceed 40 volts.

All insulation, blocking, tying, wedging, and filler materials shall be compatible and suitable for Class F or higher operation. Motor rated temperature rise shall be as per nameplate, (i.e. Class B temperature rise with Class F insulating materials). Where the original motor insulation class is greater than Class F, then all materials discussed above shall be rated at least the temperature class of the motor.

Groundwall insulation shall consist of a minimum of two half-lapped layers of mica-based tape or two and a half turns of mica-based sheet or wrapper material. If a wrapper is used, the end-turn tape interface must half-lap the wrap taper on each layer. Dielectric strength of mica insulation shall be 60 V/mil or greater. A protective layer of half-lapped glass binder shall be applied over the groundwall insulation.

The slot portion of all motors rated over 4500V shall be coated with semi-conducting material and the end turns graded with voltage-grading paint to eliminate corona.

All series and phase connections shall be brazed or soldered, and insulated for full voltage with mica-based insulation and glass binder as discussed in Paragraph D above.

Spacer blocks between end turns shall be of Dacron® felt compressed during insertion. Spacers shall be of sufficient length to support the entire depth of each adjacent coil. All Dacron® felt blocking and spacers used in the end turn support structure shall be compressed during the assembly process. Doubled blocking should be used wherever possible. If the entire wound stator is to be given a VPI treatment (Section 5.2.6), the Dacron® felt blocking and spacers shall be installed dry. On B-Stage and non-VPI windings (Section 5.2.6 & 5.2.7), the Dacron® felt shall be installed compressed as described above, after being saturated with a suitable resin which provides a solid block after curing.

Surge rings shall be repaired or replaced if damaged. Replacement rings shall have the same mechanical qualities as the original. All conductive surge rings shall be insulated for at least Paragraph D above. On non-VPI windings, each coil shall be tied to all support rings with suitable glass cord or banding material. On VPI windings, the coils shall be secured to all support rings in a manner that is equal to or greater than the motor Manufacturer's standard.

Any significant change to the mechanical support structure of the end turns shall be reviewed and approved by CDOT prior to implementation. This refers to major changes such as more or less support rings or radical changes in number and\or location of support blocks.

All sensors (temperature or other) shall be replaced with an equal number of new sensors of equal or better quality. All new sensors shall be located in the identical location as original sensors unless a change is authorized by CDOT.

Slot wedges and slot filler material shall be suitable for at least Class F operation as stated in Paragraph C above. Slot filler material shall be installed the entire length of the stator slot in sufficient quantity such that voids are eliminated and installed wedges secure the winding tightly in the slot.

New motor leads shall be supplied on all rewound motors. Motor leads shall be of flexible copper strands and be capable of continuously carrying 110% of rated full load amps times the Service Factor without exceeding the temperature rating of the lead insulation. Motor lead insulation shall be rated for at least phase-to-phase voltage. Preferred insulation material is Silicone rubber or Hypalon™.

Leads shall be suitably long for connections in the field. Unless otherwise specified, leads shall be equipped with lugs identical to those on the original leads. All leads shall be marked or colored in accordance with the nameplate and as necessary to indicate correct connection. Ends of new motor leads shall be sealed or suitably treated to prevent penetration of the strands by VPI resin or varnish. All motor leads shall be supported and sealed per the original Motor Manufacturer's design.

Testing Form Wound Motors

All testing shall comply with appropriate IEEE, NEMA, EASA and ANSI standards unless otherwise specified by CDOT.

Testing of the stator core iron shall be performed after winding removal and core cleaning. This testing shall be either a core loop test conducted at near rated flux density, or an EL CID test. Any hot spots in the core laminations shall be corrected by one of the following methods:

- Separating laminations and inserting mica or insulating resin,
- Acid etching the hot spot and painting with a thin insulating resin, or
- Grinding the hot spot with rubber polishing wheels and painting with a thin insulating resin.

C-DOT must approve alternate repair methods before commencing work.

Repairs shall be followed by a core loop test. Maximum permissible temperature differential between the average core temperature and any other core location is 5°C.

All rewound motor stators shall be given an insulation resistance and Polarization Index test. This test shall be conducted after the rewind process is completed and the stator has cooled to ambient temperature from oven curing. Satisfactory readings shall be obtained from the insulation resistance and Polarization Index test prior to any high potential testing. The insulation resistance readings shall be taken between the motor leads (with all leads connected together) and the stator core/frame. Readings shall be taken over 10 minutes with a Polarization Index developed from the ratio of the 10 minute reading divided by the one minute reading. Test voltages are as follows:

| RATED MOTOR VOLTAGE | MAXIMUM TEST VOLTAGE |
|---|---|
| Less Than 1000V | 500VDC |
| 1000V or Greater | 1000VDC |

The minimum acceptable value of polarization index for motors rated above 1000V is 2.0. The minimum acceptable insulation resistance is 200 megohms.

High Potential testing shall be conducted, but only after acceptable values are obtained for insulation resistance and Polarization Index. DC high potential testing is the only method approved by C-DOT for final acceptance testing. An AC high potential test may be performed in addition to the DC test at the discretion of the repair facility. All motor leads shall be jumpered together and all RTD leads shall be tied together and grounded before testing.

A polarization index (see Paragraph C) shall be taken at approximately 10% of the final DC test voltage. Minimum acceptable Polarization Index to allow continuation of the DC high potential test for motors rated above 1000V is 2.0.

Maximum AC test voltage for a new winding is [2 * E] + 1.0, where E is rated motor voltage in AC kilovolts RMS. Equivalent DC voltage can be determined by

multiplying by 1.7. Thus, for a 4.0KV motor, the maximum AC test voltage is [2 * 4.0] + 1.0 = 9.0KV, and the final DC test voltage (for acceptance) is [(2 * 4.0) + 1.0] * 1.7 = 15.3KV. The leakage current after 60 seconds at the final DC test voltage shall be recorded.

The DC resistance of all stator Resistance Temperature Detectors shall be measured and corrected to 25°C.

The insulation resistance of each Resistance Temperature Detector shall be measured with a 500VDC megohmmeter. Minimum acceptable insulation resistance is 200 megohms.

Turn insulation or surge testing is not required by this specification. Surge testing, if performed, shall be conducted only on new coils, on the bench or in the stator core, but prior to connecting that coil into the winding. Unless special circumstances prevail, surge testing of a partially or completely connected stator winding SHALL NOT be performed.

If the motor is assembled, a balanced phase load test shall be conducted at approximately 10% voltage. The maximum deviation from the average phase amps shall not exceed 5%.

All test values shall be recorded and supplied to C-DOT upon delivery of the rebuilt motor.

IMPREGNATED (VPI) INSULATION SYSTEM

The preferred insulation system is Vacuum Pressure Impregnation (VPI) of the entire wound stator assembly. The entire wound stator shall be preheated, placed in an impregnating tank, and subjected to a high vacuum to evacuate moisture and volatiles. The impregnating tank shall then be flooded with Von Roll #74035 or approved equal epoxy resin and the wound stator allowed to soak at atmospheric pressure. The impregnating tank shall then be pressurized to force the resin into all voids in the wound stator. The stator shall be removed from the tank and oven cured. A second VPI treatment shall be performed. The first VPI treatment shall be with the connection rings up; the second treatment shall be with the connection rings down. Following the specified number of VPI cycles, an epoxy or varnish coating shall be applied to the rewound stator by spraying or dipping.

In the event that VPI treatment of the entire stator assembly is not possible, (usually because the motor is too large for the VPI tank or rewind is done in the field), a "B Stage" process is acceptable. The "B Stage" process shall use impregnated semi-cured coils and blocking materials that shall, after an oven cure, provide a rigid, void free system similar to a VPI-processed insulation system.

NON-IMPREGNATED (NON-VPI) INSULATION SYSTEM

In certain conditions, complete VPI or B Stage insulation systems may be undesirable. In these cases, the motor shall be wound with already cured coils. The coils may be partially or totally processed in the VPI tank or may be varnished between layers of mica and gAlass to provide a soft flexible coil. Due to the variety of possible methods for producing this type of coil, a special specification will be developed as required.

COMPLETE STATOR REWIND - RANDOM WOUND COILS

Winding Removal

Winding removal shall be completed in accordance with *Section 5.2.5.1, WINDING REMOVAL*.

New Stator Winding

All insulating, blocking, tying, wedging, filler materials, and insulating resins shall be compatible and suitable for Class H or higher operation. Motor rated temperature rise shall be as per nameplate, (i.e. Class B temperature rise with Class F insulating materials). Where the original motor insulation class is greater than Class F, then all materials discussed above shall be rated at least the temperature class of the motor.

Magnet wire used in the winding shall be copper and insulated with film insulation that is rated Class H minimum and bonded to the wire. Wire size, turns per coil, and winding connection or configuration shall be identical to the original winding unless changes are specified in *Section 6.0, ADDITIONAL REQUIREMENTS*. Any redesign or modification of the winding configuration shall be submitted in writing and approved by CDOT prior to implementation. Under no circumstances shall a motor with form wound coils be rewound as a random wound motor.

Stator slots shall be insulated full length with a slot cell of Nomex®, Dacron® Mylar Dacron®, Nomex® Mylar Nomex®, or other material which is mechanically and dielectrically equal to or better than Nomex®. Slot liners shall extend beyond the laminations to increase the creepage path. Slot cell materials shall be rated Class F minimum. Slot separators of polyester glass mat, preformed epoxy glass, Nomex®, or other material mechanically and dielectrically better than Nomex®, shall be used between coils the full length of all slots.

Phase insulation, such as resin-treated glass cloth, shall be employed in the end turn region between adjacent coils of different phases. Insulation material shall be rated Class F or higher.

Stator slot wedges shall be Nomex® or approved equal, rated Class H, or material mechanically and dielectrically equal to or better than Nomex®.

End turns shall be fully compacted such that no loose wires are present. End turns on both ends of the motor shall be tied with glass cord such that each coil at some point is secured to one or more other coils.

All sensors (temperature or other) shall be replaced with an equal number of new sensors of equal or better quality. All new sensors shall be located in the identical location as original sensors unless a change is authorized by CDOT.

Sleeving used on stator connections, such as an acrylic coated fiberglass, shall be Class F or higher material with a minimum voltage rating of 2500V.

New motor leads shall be supplied on all rewound motors. Motor leads shall be of flexible copper strands and be capable of continuously carrying 110% of rated full load amps times the Service Factor without exceeding the

temperature rating of the lead insulation. Motor lead insulation shall be rated for at least phase-to-phase voltage. Leads shall be suitably long for connections in the field. Unless otherwise specified, leads shall be equipped with lugs identical to those on the original leads. All leads shall be marked or colored in accordance with the nameplate and as necessary to indicate correct connection. New motor leads shall be installed after the insulation system is cured and baked, or the ends shall be suitably treated to prevent penetration of the strands by VPI resin or varnish. All motor leads shall be supported and sealed per the original Motor Manufacturer's design.

Insulation Impregnation And Cure

VPI system described in *Section 5.2.*6 must be used on a random wound stator.

Testing Random Wound Motors

Testing shall be performed in accordance with *Section 5.2.5.3, TESTING*, with the following exception:

High-potential testing shall be conducted, but only after acceptable values are obtained for insulation resistance. CDOT must approve DC or AC high potential testing for final acceptance testing. Maximum AC test voltage for a new winding is [2.0 * E] + 1000, where E is rated motor voltage in AC volts RMS. Equivalent DC voltage can be determined by multiplying by 1.7. Thus, for a 480V motor, the final AC test voltage for acceptance is [2.0 * 480] + 1000 = 1960VAC, and the final DC test voltage is [(2.0 * 480) + 1000] * 1.7 = 3332VDC. The leakage current after 60 seconds at the final DC test voltage shall be recorded.

REPLACE FORM WOUND COIL

In certain situations where a top coil failure is irreparable, the top coil half can be replaced. To remove the coil, all ties and blocks between the damaged coil and adjacent coils must be removed. The series connection(s) on both ends must be opened either by un-brazing or cutting. If the end connections are cut, sufficient copper must remain on the adjacent coils to allow connecting the new coil. The slot wedges may be removed by driving out or cutting. A non-VPI coil can usually be removed with little difficulty. A VPI coil will require preheating prior to lifting to avoid damage to adjacent coils. Preheating can be accomplished by external heat application such as a heat gun or portable oven. Once the VPI resin is softened, the coil can be carefully lifted.

The slot portion of the coil can be cut with a circular saw to assist in coil removal. Care must be exercised not to damage the bottom coil in the slot or the core iron. After coil removal, the core iron must be inspected for damage and repaired per Section 5.2.13.

The replacement coil shall be constructed of compatible materials in accordance with Section 5.2.5.2, Paragraphs A through E, NEW STATOR WINDING. Spacer blocks between end turns shall be of Dacron® or approved equal felt impregnated in a compatible Class F or higher resin prior to insertion and compressed during installation. Spacers shall be of sufficient length to support the entire depth of each adjacent coil.

All end-turn connections shall be brazed or soldered, and insulated for rated line voltage with mica-based insulation and glass binder. The completed connection shall be coated with a compatible Class F or higher resin after insulating.

Slot wedges and slot filler material shall be compatible and suitable for at least Class F operation. Slot filler material shall be installed the entire length of the stator slot in sufficient quantity such that voids are eliminated and installed wedges secure the winding tightly in the slot.

All repaired motors shall be tested in accordance with Section 5.2.5.3, Paragraph C (Insulation Resistance & P.I.) and Paragraph D, (DC hi-pot). Test voltage for the high potential test shall be lowered to 1.3 times rated voltage for repaired motors (e.g. 1.3 X 4 X 1.7 = 8.84 KV for a 4KV motor).

In some extreme cases where motor condition is questionable and there is a large economic penalty for having the motor out of service, the high potential test voltage can be decreased or the test eliminated. CDOT will judge this on a case-by-case basis.

REPAIR FORM WOUND COIL INSULATION

If coil insulation in the end turn area has been damaged, usually due to foreign particle impingement or damaged during disassembly, a repair can usually be made in the field. If the damage includes loss of copper or turn insulation damage, the coil may have to be replaced or cut out (See Section 5.2.9 and Section 5.2.11).

Minor damage such as a nick which does not penetrate more than two layers of mica tape shall repaired by flooding the area with a compatible sealant and covering the area with a piece of glass binder. This repair is not acceptable if copper is exposed or if the damaged area was subject to an electrical flash.

If more than two layers of mica tape are damaged, the insulation shall be penciled back from the damaged area, and the area reinsulated. It is particularly important if an electrical flash has occurred to remove all traces of the carbon path before re-insulating.

If the damaged area is inaccessible, the coil will have to be lifted. To lift the coil, all ties and blocks between the damaged coil and adjacent coils must be removed. The series connection(s) must be opened, and slot wedges must be removed as required to avoid bending the coil at too small a radius.

Non-VPI coils can usually be lifted with little difficulty; VPI coils will require heating prior to lifting the damaged coil. Heating can be accomplished by passing current through the coil to be lifted or by external heat application such as from a heat gun or portable oven. Once the VPI resin is softened, the coil can be carefully lifted.

When lifting a coil, either VPI or non-VPI, the radius of the bend must be as large as practicable, and the coil should be lifted only far enough to accomplish the required work. Extreme care must be used not to crack the insulation or kink the copper where the coil is bent or the coil will have to be replaced.

Once the coil is lifted, the insulation must be stripped all around the coil at the damaged spot. Enough insulation must be removed to allow re-taping. The edges of the stripped area must be penciled back at approximately 45 degrees. The copper

must be inspected to verify a) the turn insulation integrity, b) that the turns are still bonded together, and c) the insulation damage did not result in copper loss. If problems in any of the above conditions are discovered, CDOT shall be consulted before taking any further corrective action.

Prior to re-insulating, the damaged area should be cleaned thoroughly with a compatible non-wetting solvent to remove all dirt and debris from the area. After cleaning, the area to be reinsulated should be brushed with a compatible air dry resin and wrapped with half-lapped mica based tape. The resin should be brushed between each layer of mica tape. The mica tape must be installed to at least the thickness of the original groundwall insulation.

A final layer of half lapped glass binder with resin brushed between layers must be applied over the repair for physical strength. A heat gun can be applied to the area to speed resin curing.

The coil can now be carefully lowered into the slot in the same manner in which it was lifted. Blocking and ties shall be reinstalled in accordance with Section 5.2.12. Slot wedges shall be installed in accordance with Section 5.2.5.2, Paragraph K. Series connection(s) shall be brazed or soldered, and insulated in accordance with Section 5.2.5.2, Paragraph F.

All repaired motors shall be tested in accordance with Section 5.2.5.3, Paragraph C (insulation resistance & P.I.) and Paragraph D (DC hi-pot). Test voltage for the DC high potential test shall be lowered to 1.3 times rated voltage for repaired motors (e.g. 1.3 X 4 X 1.7 = 8.84 KV for a 4KV motor).

In some extreme cases where motor condition is questionable and there is a large economic penalty for having the motor out of service, the high potential test voltage can be decreased or the test eliminated. C-DOT will judge this on a case-by-*case basis*.

CUT OUT FAILED FORM WOUND COIL

If a failed coil cannot be repaired or replaced, such as a bottom coil failure or a VPI coil that cannot be removed, the coil may be cut out of the circuit. This is considered an emergency or short-term repair. CDOT shall be consulted before implementing this procedure. The following guidelines shall be followed:

Locate the damaged coil. In some cases, the damage will be obvious as a burned open connection or damage from foreign material. In cases where the failure is not obvious, such as a failure in the slot, a load box can be used and a maximum of 2 amps passed through the failure to ground. A clamp on ammeter can then be used on the end-turn connections to determine the failed coil.

If the failure is in the slot, perform a core loop or El Cid test to assess the condition of the core iron. Indications of inaccessible significant core damage may necessitate coil removal or a total rewind, rather than isolating the damaged coil.

If the core iron integrity is acceptable, cut open both lead connections on the failed coil. Carefully saw or cut the failed coil at the nose on both ends of the winding, ensuring the individual copper strands are isolated from each other.

Jumper together the leads that were connected to the failed coil by brazing in a copper conductor with a cross section equal to the lead. This will effectively jumper out the failed coil.

Insulate both the new jumper and the stub ends of the failed coil for full phase to ground voltage using half-lapped mica tape followed by a protective layer of half-lapped glass binder.

After all repair work is completed, the stator shall be tested in accordance with Section 5.2.5.3, Paragraph C (Insulation Resistance and P.I.) and Paragraph D (DC hi-pot). Test voltage for the DC high potential test shall be lowered to 1.3 times rated voltage [e.g. 1.3 * 4 * 1.7 = 8.84KV for a 4KV motor].

*In some cases where the winding condition is questionable and there is a large economic penalty for having the motor out of service, the high potential test voltage can be de creased or the test eliminated. CDOT will judge this on a case-by-case basis.*

REPAIR END TURN BLOCKS AND TIES

This section relates to both form wound and random wound induction motor stators. Loose tie blocks have caused motor failures in the past when the vibrating tie blocks wore through the insulation of the bottom coils and caused a ground fault.

All materials used shall be compatible with the existing insulation system and of the same temperature class or higher.

All loose blocks and ties should be removed from the motor, if possible. If the blocks are impregnated Dacron®, they cannot be reused. If the blocks are hard fiberglass type material, they can be tightened by wrapping in impregnated felt and reinserting, replaced with a thicker block of like material, or replaced with impregnated Dacron® or approved equal felt which is compressed on insertion as per Section 5.2.5.2, Paragraph G, NEW STATOR WINDING.

Loose ties shall be replaced with a glass cord or glass banding material. All loose original ties shall be replaced, and additional ties may be necessary depending on the motor condition. Where additional ties are deemed necessary, CDOT should be consulted prior to implementation.

All repaired motors shall be tested in accordance with *Section 5.2.5.3, Paragraph C* (Insulation Resistance & P.I.).

REPAIR / REPLACE CORE IRON

When inspection or testing locates shorted laminations or core hot spots, these areas must be repaired. A general rule of thumb is that not more than three adjacent laminations should be shorted together.

Driving a knife between laminations can separate laminations. After separating laminations, sheet mica can be inserted and/or the area brushed with a compatible insulating resin.
If the laminations are smeared as in the case of a rub, the repair will require either acid etching or grinding. Either method should be done until all individual laminations are visually perceptible. The area etched or ground shall then be

brushed with a thin insulating resin. The resin shall be brushed between the laminations as much as possible.

After any core repair work, a loop test shall be conducted per *Section 5.2.5.3, Paragraph B, TESTING*. Maximum permissible temperature differential between the average core temperature and any other core location shall be less than 5°C.

If the core iron damage is too severe to repair, the core must be partially or completely restacked, or the damaged laminations replaced. If the old core iron is to be reused, it shall be removed and carefully stored to ensure the laminations are restacked in the same direction. Damaged laminations shall be uniformly distributed so all the damaged iron is not in the same area. A high temperature inorganic varnish shall be used to insulate laminations.

Core clamping pressure shall be returned to the Motor Manufacturer's specifications.

After restacking the core iron, a loop test shall be conducted as per *Section 5.2.5.3, Paragraph B, TESTING*. Maximum permissible temperature differential between the average core temperature and any other core location shall be less than 10°C.

REWEDGE STATOR CORE SLOTS

Slot wedging and underlying filler strips shall be removed with extreme caution to avoid damage to the core iron or coil armor.

Slot wedges and slot filler material shall be rated Class F or the insulation class of the motor, whichever is greater. Slot filler material shall be installed the entire length of the stator slot in sufficient quantity such that voids are eliminated and installed wedges secure the winding tightly in the slot.

Rewedged stators shall be tested in accordance with *Section 5.2.5.3, Paragraph B* (core iron test), *Paragraph C* (Insulation Resistance and P.I.), and *Paragraph D* (DC hi-pot). Test voltage for the DC high potential test should be lowered to 1.3 times rated voltage for rewedged stators (1.3 * 4 * 1.7 = 8.84KV for a 4KV motor).

*In some extreme cases where motor condition is questionable* and *there is a large economic penalty for having the motor out of service, the high potential test voltage can be decreased or the test eliminated. C-DOT will judge this on a case-by-case basis.*

REPLACE / RE-INSULATE MOTOR LEADS

Replace Motor Leads

All materials used in lead replacement shall be compatible with the existing insulation system.

Motor leads shall be of flexible copper strands and be capable of continuously carrying 110% of rated full load amps times the Service Factor without exceeding the temperature rating of the lead insulation. Motor lead insulation shall be rated for at least phase-to-phase voltage. Preferred insulation material is Silicone rubber or Hypalon™.

Leads shall be suitably long for connections in the field. Unless otherwise specified, leads shall be equipped with lugs identical to those on the original leads. All leads shall be marked or colored in accordance with the nameplate and as necessary to indicate correct connection. New motor leads shall be installed after the insulation system is cured and baked, or the ends shall be suitably treated to prevent penetration of the strands by VPI resin or varnish. All motor leads shall be supported and sealed per the original Motor Manufacturer's design.

Copper bus or copper leaf motor leads shall be replaced with identical material having equal or larger cross-sectional area as the original. Ground insulation shall consist of half-lapped layers of mica-based tape, with a compatible resin brushed between layers, in sufficient thickness to supply full phase-to-phase voltage protection. An outer layer of glass binder shall be applied over the mica tape. The insulated leads must be coated with a compatible resin. The resin can be either air dry or require oven cure.

Repair Motor Leads

All materials used in lead repair shall be compatible with the existing insulation system.

If a cable-type motor lead has failed, replacement is the desired form of repair. If time or materials will not allow replacement, repair of a failed motor lead can be performed. All damaged insulation shall be removed and the area thoroughly cleaned. If a cable splice kit is available, the splice shall be installed per instructions. If a splice kit is unavailable, the lead can be repaired with electrical tape. After removing the damaged insulation, the insulation shall be penciled back from the damaged area. The area shall be thoroughly cleaned with a solvent that will not damage the existing insulation. Compatible high voltage insulating tape shall be installed half-lapped and stretched per manufacturers instructions. Sufficient insulating tape must be applied to provide insulation value at least equal to the existing cable. The repair shall be covered with half-lapped 3M™ Scotch 130 or similar for physical toughness.

A copper bus or leaf type lead can be repaired in place if the failure did not result in significant copper damage. All damaged insulation shall be removed and the area cleaned with a compatible solvent. The damaged area shall be wrapped with half-lapped mica based tape, with a compatible resin brushed between layers, in sufficient thickness to supply full phase to phase voltage protection. An outer layer of glass binder shall be applied over the mica tape and covered with a compatible resin.

Testing After Lead Repair or Replacement

All repaired motors shall be tested in accordance with *Section 5.2.5.3, Paragraph C* (Insulation Resistance & P.I.) and *Paragraph D* (DC hi-pot). Test voltage for the DC high potential test shall be lowered to 1.3 times rated voltage for repaired motors (e.g. 1.3 * 4 * 1.7 = 8.84 KV for a 4KV motor).

*In some extreme cases where motor condition is questionable and there is a* large *economic penalty for having the motor out of service, the high potential*

*test voltage can be decreased or the test eliminated. C-DOT will judge this on a case-by-case basis.*

REPLACE / REPAIR CONNECTION RINGS

Replace Connection Rings

When connection rings require replacement, the insulation material used shall be compatible with the existing motor insulation and be rated Class F or the rating of the motor insulation class, whichever is greater. The conductor material shall have equal or larger cross-sectional area as original. Ground insulation shall consist of half-lapped layers of mica-based tape, with a compatible resin brushed between layers, in sufficient thickness to supply full phase-to-phase voltage protection. An outer layer of glass binder shall be applied over the mica tape. The insulated rings shall be coated with a compatible resin. The resin can be either air dry or require oven cure. All phase connections shall be brazed or soldered and insulated for full phase-to-phase voltage as described above.

Repair Connection Rings

Damaged connection rings may be repaired in place if the failure did not result in copper damage. All damaged insulation shall be removed and the area cleaned with a compatible solvent. The damaged area shall be wrapped with half-lapped mica-based tape, with a compatible resin brushed between layers, in sufficient thickness to supply full phase-to-phase voltage protection. An outer layer of glass binder shall be applied over the mica tape and covered with a compatible resin.

Testing After Connection Ring Replacement or Repair

All repaired motors shall be tested in accordance with Section 5.2.5.3, Paragraph C (Insulation Resistance & P.I.) and Paragraph D (DC Hi-Pot). Test voltage for the high potential test shall be lowered to 1.3 times rated voltage for repaired motors (eg. 1.3 * 4 * 1.7 = 8.84 KV for a 4KV motor).

*In some extreme cases where motor condition is questionable and there is a large economic penalty for having the motor out of service, the high potential test voltage can be decreased or* the *test eliminated. This will be judged by CDOT on a case-by-case basis.*

COMPLETE REBAR OF SQUIRREL CAGE ROTOR

Material - An independent laboratory shall test a sample of one of the original bars to determine its composition. Replacement bars shall be of identical material. If the original cage had bars of different materials alternated in a repeating pattern, the same pattern shall be used. Cross-sectional geometry shall be identical to the original bars. The length may be longer if the bars are set into notches in the shorting ring, but the length of the bars between shorting rings may not be changed.

Assembly - The bars shall be tight in their slots both side-to-side and top to bottom. Copper bars may be swaged or dipped in an epoxy varnish if there is excessive looseness. VPI treatment using epoxy or polyester resin shall not be used to make rotor bars tight in slots.

Attachment - The Motor Manufacturer's attachment procedure shall be followed. If this procedure is unavailable, the following attachment procedure shall be used:

Copper or Brass - The area of the braze of both the shorting ring and the bars shall be cleaned by wiping with lint free rags moistened with acetone followed by sanding with emery paper and/or wire brushing to bright metal. All sanding residue shall be removed. If foil filler is to be used for brazing, it shall be placed tightly between the bars and the shorting ring. If brazing rod is used, a clearance of between .001" and .006" shall be maintained between the bars and the shorting ring before brazing. For copper-to-copper brazes, the brazing material shall be AWS BCuP-5 Copper-Phosphorus type with a 15% silver content. Flux is not necessary with this material. For brazing copper-to-brass or brass-to-brass a brazing alloy with at least 45% silver content shall be used. Brazing flux of AWS Type 3A must be used. The parts being brazed should be heated slowly and uniformly. A "soft" (i.e. low flow of oxygen and acetylene), neutral or slightly reducing flame should be used. If the flame is not producing adequate heat to properly heat the joint, a larger tip should be used. The inner cone of the flame should not be brought closer than one inch from the joint. The joint should be heated until the metal begins to blush (dull red). If foil filler has been used, it should melt at this point. If a brazing rod is being used, apply it to the joint at this time, allowing the alloy to flow until a slight fillet has formed around the entire joint.

Aluminum - The gas metal arc welding process (also known as MIG) shall be used to join the bars and create a shorting ring. The oxide on the surface of aluminum absorbs water that releases hydrogen into the weld causing porosity, so it must be removed prior to welding. It should be removed using a stainless steel brush or a special high-speed grinding wheel made for aluminum. The metal may also be wiped with a lint free rag moistened with acetone to remove any oils from the metal. The welding should proceed as soon as possible following cleaning to limit the amount of oxide buildup. Normally, electrical grade aluminum is high purity and in the 1XXX alloy designation. Filler metal for these alloys should be ER 1100, though ER 4043 or ER 4047 may be used for certain applications. Welding grade inert gas shall be used, preferably a helium-argon mixture. Preheat of the work is not recommended. The electrode diameter, welding current, arc voltage, wire feed speed, gas flow, and travel speed shall be consistent with AWS and/or the Motor Manufacturer's recommended practices.

REPLACE BARS IN SQUIRREL CAGE ROTOR

CDOT in some instances may elect to replace certain cage bars rather than rebar the entire rotor.

Removal - The bar extensions should be machined off and a notch milled in each shorting ring, in line with each bar being removed. The bars may then be driven out through one of the notches.

Material - An independent laboratory shall test a sample of one of the original bars to determine its composition. Replacement bars shall be of identical

material. If the original cage has bars of different materials alternating in a repeating pattern, care shall be taken to ensure that replacement bars maintain the same pattern. Cross-sectional geometry shall be identical to the original bars. The bar length shall be sufficient to fill the notches machined in the shorting rings.

Assembly - The bars shall be tight in their slots both side-to-side and top-to-bottom. Copper bars may be swaged or dipped in an epoxy varnish if there is excessive looseness. VPI treatment using epoxy or polyester resin shall not be used to make rotor bars tight in slots.

Attachment - Refer to *Section 5.2.17, Paragraph C* (Bar/Ring Attachment).

REPLACE SHORTING RINGS

Copper Shorting Rings

Disassembly - If the cage is to be reused and only the shorting ring is being replaced, then the old ring should be machined off taking care to remove as little of the bar material as possible. If the bars are being replaced as well (i.e. a full rebar), the most expedient means of disassembly is acceptable providing the core iron is not damaged in the process.

Material - An independent laboratory shall test a sample of one of the original rings to determine its composition. The replacement ring shall be of identical material. Ring geometry shall provide the same electrical characteristic as the original unless a change is approved by CDOT.

Attachment - Refer to the *Section 5.2.17, Paragraph C* (Bar/Ring Attachment).

Aluminum Shorting Rings

Cast aluminum shorting rings shall not be replaced: flaws, cracks, and voids may be repaired. CDOT shall be consulted before repairs of cast or fabricated aluminum shorting rings are performed.

REBRAZE CRACKED BAR-RING CONNECTIONS

For fabricated copper or aluminum cages, CDOT may opt to repair cracked bars rather than replace the bar or the entire cage. If this option is selected, the area to be repaired should be thoroughly cleaned with a wire brush and/or emery paper and then wiped with a lint free rag moistened with acetone. The repair itself shall conform to the procedures outlined in *Section 5.2.17, Paragraph C* (Bar/Ring Attachment).

REPLACE / RE-MACHINE RETAINING RINGS

Retaining rings shall be match-marked, without scoring the metal, before removal. This is to ensure the rings are reinstalled in the same relative position. If retaining ring damage is found after removal, CDOT shall be notified. A determination will then be made as to repair or replacement of the ring. Retaining rings shall not be heated above 400°F during removal or installation. In the event that the rotor cage and/or shorting rings are replaced, the bar extensions and shorting ring shall be machined to obtain the design interference fit with the ring ID. The Motor Manufacturers minimum interference for any locking fits shall be maintained.

If the ring is to be replaced, the new forgings shall have the same metallurgical characteristics and shall be machined to the same dimensions as the original ring. The ring shall be fully inspected and tested (e.g. dye penetrant, ultrasonic) before and after installing. In no case shall metal or glass banding be used as a substitute for retaining rings.

REPAIR ROTOR CORE IRON

Laminations that are smeared, as from a rub, shall be separated with a knife blade or similar tool and painted with a thin varnish or insulating paint.

Severe smearing may be cleaned by taking a light machine cut on the rotor OD. Depth of cut shall not exceed 10% of the air gap distance. CDOT shall be consulted before any machining is performed.

Laminations that are burned, if not severe, shall be cleaned and painted. If iron loss from burning has resulted in a significant reduction in the radial support of one or more bars, the laminations shall be unstacked and rotated so that no more than one lamination in every three has a burned area over the same bar. Core clamping pressure shall be returned to the Motor Manufacturer's specifications. CDOT must approve alternate methods of repair.

REPLACE / REPAIR FAN BLADES AND BLOWERS

Nonmetallic Blades - Blades shall be replaced upon identification of damage, which would either limit its air handling capacity or tend to propagate into a more severe condition. Repair of nonmetallic fan blades shall not be attempted.

Metallic Blades - Repair of cast fans or fan blades shall not be attempted. Non-cast fan blades or blowers, including mounting bolts, with cracks, breaks, or significant chips shall be particle blasted and dye penetrant checked to determine the total extent of the damage. If the failure mechanism is identifiable (e.g. foreign object) and the damage is repairable, the fan blade or blower may be repaired by proven standard welding techniques. If the failure mechanism can not be determined or the damage is not repairable, CDOT or the CDOT shall be notified. Following repair of any fan blade or blower, proper balance of the rotor shall be verified. (See *Section 5.2.28, BALANCING*).

REPLACE / REPAIR BEARINGS

Ball and Roller Bearings

Rolling element bearings shall be replaced unless otherwise specified by the CDOT. New bearings shall be free from visible defects. Greaseable (non-sealed) bearings shall be thoroughly cleaned in an approved solvent and packed with a lubricant that is in accordance with the bearing manufacturer's recommendation and that is approved by the CDOT. The motor shall be tagged to indicate bearing grease used.

Reused greaseable (non-sealed) bearings shall be thoroughly cleaned in an approved solvent and shall be packed with a lubricant that is in accordance with the bearing manufacturer's recommendation and that is approved by the CDOT. The motor shall be tagged to indicate bearing grease used.

Bearings shall be removed and installed using tools designed for that purpose. Tools shall apply equal force 360° around the inner bearing race. The preferred method for installing a bearing is to heat the bearing uniformly to allow the inner race to just slide over the journal fit.

Bearing housing bores in the end-bells shall be checked for uniformity in diameter and absence of taper. Housing bores that are out-of-round or distorted shall be trued by metallizing the bore and machining.

The following bearing alignment checks shall be made when possible:

Inner race is flush against the shaft shoulder (if present) and bearing face is perpendicular to the shaft.

Outer race is flush against the housing shoulder and bearing face is perpendicular to the housing bore.

Housing bore in each endbell are on the same centerline.

Bearings shall be installed with proper interference and slip fits according to the Bearing/Motor Manufacturer's specification.

Knurling, peening, and gluing shall not be used to secure bearings to the shaft or end shields.

Bearing insulation shall be cleaned and inspected. Insulation resistance of insulated bearings, bearing temperature detectors, and vibration probes - in the installed position - shall be measured with a 500 VDC megohmmeter. Minimum acceptable resistance is 10 megohms.

Sleeve Bearings

General - All Sleeve Bearings

Sleeve bearing inside diameters shall be measured to assure uniformity in diameter and absence of any taper. Bearing measurements shall consist of two readings, 90° apart, at the axial center of the bearing and at either edge. The diametric readings and the clearance between rotor journal (after any truing) and corresponding bearing shall be compared against the Motor Manufacturer's specifications. An undersized bearing shall be machined as required. If a bearing is oversized, CDOT shall be consulted regarding rebabbitting or replacing the bearing.

An under/oversized journal is discussed in *Section 5.2.26*.

The bearing shell shall be checked for proper fit in the endbell housing. The bearing assemblies shall be adjusted within the endbells so that the bearing bores are on the same axis and positioned with respect to the stator bore according to the Motor Manufacturer's recommendation. If this information is unavailable, the bearing bores shall be positioned on the same axis as the stator bore.

Bearings shall be installed to eliminate end thrust against either bearing and provide sufficient endplay to allow for shaft expansion caused by thermal growth. Total end play shall be according to the Motor

Manufacturer's specifications. If this information is unavailable, end play should be approximately 1/16" per inch of shaft journal diameter.

Lead-based babbitts shall be replaced in kind unless a conversion to a tin-based babbitt is specified by the CDOT.

Tin-based babbitts (high grade) shall be replaced in kind and shall not be contaminated by mixing with lead-based babbitt material. Acceptable babbitt material includes ASTM B23 No.2 or No.3.

Sleeve bearings shall be suitably grooved for proper distribution of lubricant. Holes for bearing temperature detectors shall be drilled in the bearing assembly according to the Motor Manufacturer's design.

Oil rings and bearing oil ring grooves shall be hand polished as required to assure proper lubricating action of the oil rings.

Bearing surfaces shall be smooth and polished and free of defects. Babbitt finish shall be 32 micro-inch or finer.

Sleeve bearings shall be tested for flaws. Tests shall consist of dye penetrant of the babbitt and ultrasonic test of the babbitt/shell bond. Minimum contact between babbitt and shell is 80%.

Bearing insulation shall be cleaned and inspected. Insulation resistance of insulated bearings, bearing temperature detectors, and vibration probes - in the installed position - shall be measured with a 500 VDC megohmmeter. Minimum acceptable resistance is 10 megohms.

Spincasting and puddling shall both be considered as acceptable methods of re-babbitting.

The radius of the bearing thrust face shall be maintained larger than the radius of the shaft thrust shoulder.

Replacement of Sleeve Bearings - New bearings shall meet all the Motor Manufacturer's design specifications. Any exceptions will be explicitly noted by the CDOT.

Repair of Sleeve Bearings

The use of thermal spray (metallizing) techniques in the repair of bearing housing bores is acceptable. Thermal spray techniques shall conform to industry-accepted standards to ensure quality workmanship and shall be performed in accordance with proven standard metallurgical procedures. CDOT shall retain the right to examine these procedures at any time.

Re-tinning of chemically bonded babbitt shall be performed only with equipment specifically designed for this task.

Rebabbitting a chemically bonded babbitt by cutting mechanical anchors into the shell is unacceptable.

Clearance from bearing bore to shaft shall be restored to the Motor Manufacturers' specifications. If this data is unattainable, the following guidelines may be used:

Horizontal Motors - 0.002" per inch shaft journal diameter.

AC Vertical Motors - 0.002" or less for the first inch of shaft journal diameter, plus 0.001" for each additional inch.

DC Vertical Motors - Not more than 0.005" per inch of shaft journal diameter.

REPLACE / REPAIR OIL SEAL RINGS

General - All Oil Seals

Oil seal ring inside diameters shall be measured to assure uniformity in diameter and absence of any taper. Measurements shall consist of two readings, 90° apart, at the axial center of the ring and at either edge. The diametric readings and the clearance between rotor seal fit (after any truing) and corresponding seal ring shall be compared against the Motor Manufacturer's specifications. An undersized seal ring shall be machined as required. If a seal is oversized, CDOT or the CDOT shall be consulted regarding refurbishing or replacing the oil seal.

An under/oversized shaft seal fit is discussed in Section 5.2.26.

The oil seal assembly shall be checked for proper fit in the endbell housing. The seal assemblies shall be adjusted within the endbell so that the seal ring bores are on the same axis and positioned with respect to the stator bore according to the Motor Manufacturer's recommendation. If this information is unavailable, the seal ring bores shall be positioned on the same axis as the stator bore.

Replacement of Oil Seals - New oil seals shall meet all the Motor Manufacturer's design specifications or CDOT will explicitly note any exceptions.

Repair of Oil Seals

Oversized oil seals shall be restored to proper dimension using the appropriate metallurgical process including preparation, heat treatment, and thickness recommended by the Motor Manufacturer. In the absence of the Motor Manufacturer's recommendation, a description of the chosen metallurgical process shall be submitted to CDOT for review prior to proceeding with the repair.

Oil seals shall be tested for flaws. Tests shall consist of dye penetrant or magnetic particle examinations.

RECONDITION ROTOR JOURNALS & SEAL FITS

Runout readings shall be taken on the rotor journals and seal fits if not taken during disassembly. Journals and seal fits with runouts exceeding the Motor Manufacturer's tolerance shall be trued. Maximum permissible runout after truing is 0.001". Journal finish shall be from 8 to 16 micro-inches.

Rotor journals and seal fits shall be visually inspected for scratches, nicks, and scoring. Superficial marks may be hand polished or lapped out. Significant marks may require resurfacing. CDOT shall be consulted before beginning any resurfacing.

Rotor journal and seal fit diameters shall be measured. Journal measurements shall consist of two readings, 90° apart, at the inner, center, and outer locations of the bearing seat. Seal fit readings shall consist of two readings, 90° apart, at the axial center of the seal fit. If journal or seal fit diameters exceed the Motor Manufacturer's tolerance, they shall be restored to proper dimension. The appropriate metallurgical process shall be used including preparation, heat treatment, and thickness recommended by the Motor Manufacturer. The process may include installing a sleeve or chrome plating the shaft. In the absence of the Motor Manufacturer's recommendation, a description of the chosen metallurgical process shall be submitted to CDOT for review, either verbally or in writing, prior to proceeding with the repair. Journal finish shall be from 8 to 16 micro-inches.

Machined shoulders on the shaft acting as a thrust face for the bearing shall be polished smooth. The thrust shoulder shall be checked for trueness to assure complete contact with the bearing thrust face. The radius of the shaft thrust shoulder shall be maintained smaller than the radius of the bearing thrust face.

STRAIGHTENING BOWED SHAFTS

General - Final total indicated runout (TIR) on straightened shafts shall not exceed 0.002" at the shaft end for motors rated up to 1800 RPM. Final TIR for motors rated above 1800 RPM shall not exceed 0.001". Worn keyways shall be welded and re-machined true as required to accommodate keys to a tap fit.

Shaft Replacement

1800 RPM or less - These rotors typically utilize a rib assembly or 'spider' to support the core iron. Shafts may be replaced by removing any retainer blocks that secures the spider hub axially on the shaft and pressing the shaft out. The new shaft shall have the identical metallurgical composition and shall be machined to the same dimensions as the original. The core and cage assembly shall be preheated in an oven before installing the new shaft. All retainer blocks or other mounting hardware shall be installed to duplicate the original design. Rotor shall be balanced according to *Section 5.2.28, ROTOR BALANCING*.

More than 1800 RPM - These rotors typically have the core iron shrunk directly on the shaft. Shafts may be replaced by removing any retainer blocks that secures the core iron axially on the shaft and drilling out the old shaft until the wall thickness is thin enough to collapse. An alternate method is to quickly heat the rotor core iron and press the shaft out of the core with a hydraulic press. Pressure plates or clamping structures shall be used to maintain compression of the core iron. The new shaft shall have the identical metallurgical composition and shall be machined to the same dimensions as the original. The core and cage assembly shall be preheated in an oven before installing the new shaft. All retainer blocks or other mounting hardware shall be installed to duplicate the original design. Rotor shall be balanced according to *Section 5.2.28, ROTOR BALANCING*.

Installing Stub Shaft - Use of any stub shaft design including straight cut, cut and counter-bored, and sleeve designs SHALL REQUIRE PRIOR APPROVAL by CDOT. Before approval, an analysis shall be made as to the resultant structural integrity

of the entire shaft assembly. Materials used in stub shaft designs shall be of equal strength and quality to that of the original shaft. Welding of stub shafts shall be performed in accordance with proven standard practices. All welds shall be stress relieved and machined to remove any stress risers.

Welding, Straightening and Re-machining - The various combinations of processes including heat straightening, jacking, and application of weld material to build shaft diameter and machining shall be allowed subject to the following requirements:

The repair facility SHALL OBTAIN PRIOR APPROVAL by CDOT based upon consideration of the motor application, the urgency of the repair and the economics of the particular situation.

The metallurgical composition of the shaft shall be known or determined and all welding and stress relieving shall be performed in accordance with proven standard practices for that material.

BALANCING OF ROTORS

All rotors requiring balancing shall be dynamically balanced before assembly or return to CDOT. If the coupling-half has been removed, a steel key with half the weight as the original key shall be secured in the shaft extension keyway prior to balancing. If the coupling half is with the motor, the motor rotor shall be balanced with the original key and coupling-half installed.

Rotors that operate above 3000 rpm should be balanced at operating speed. The following table delineates the allowable unbalance in ounce-inches per pound of rotating weight.

| OPERATING SPEED (rpm) | UNBALANCE LIMIT (oz-inch per pound) |
|---|---|
| above 3000 | 0.005 |
| 1600 to 3000 | 0.010 |
| 1000 to 1599 | 0.015 |
| up to 999 | 0.020 |

If the entire motor is at the service facility it shall be test run unloaded and vibration readings taken horizontally, vertically, and axially for a horizontal frame motor; or vertically and in two horizontal planes 90° apart for a vertical frame motor. If vibration measurement locations are already marked on the frame, they shall be used for the readings required by this section. The readings shall be recorded on the motor test record sheet. The maximum allowable vibration on the bearing housing in mils displacement peak-to-peak is delineated in the following table:

| MAXIMUM VIBRATION | |
|---|---|
| **OPERATING SPEED (rpm)** | **DISPLACEMENT @ BEARING HOUSING (mils - peak to peak)** |
| above 3000 | 0.5 |
| 1600 to 3000 | 1.0 |
| 1000 to 1599 | 1.5 |
| up to 999 | 2.0 |

REPAIR CRACKS AND WELDS IN FRAME

All cracks or breaks in the frame or endbells shall be repaired. Industry approved metallurgical processes shall be used including appropriate preparation, heat treatment, application techniques, thickness, and stress relief.

Air gap, bearing alignment, and concentricity of bearings and seals shall be checked and corrected, if necessary, following any frame work which has any potential for disturbing these factors.

REPLACE ACOUSTICAL INSULATION IN FRAME

New acoustical insulation shall have the identical sound-deadening characteristics as the original insulation. New insulation shall not be installed in such a way that ventilation is blocked or restricted. The insulation shall be securely fastened to the frame with fastening devices designed for the application. New insulation shall be suitable for the motor application with consideration for temperature, air velocity, and airborne contaminants.

**END OF SECTION**

**PROJECT SPECIAL PROVISIONS**

| REVISION OF | DATE |
|---|---|
| Section 202 - Removal of Electrical Equipment | 10/21/2021 |
| Section 210 - Scada System Integration and Integrator Requirements | 10/21/2021 |
| Section 613 - Electrical Conduit and Raceways | 10/21/2021 |
| Section 613 - 24.9 kV Switchgear Assemblies | 10/21/2021 |
| 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 – Motor Power and Control Wiring | 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 |

## 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

The existing (2) 500kW natural gas generators (one in West Portal & one in East Portal) entirely including but not limited to all associated electrical equipment, controls, panels, ATS, conduit, (with the exception of conduit routed through interstitial space) and conductors. Conduit to remain shall be labeled and provided with pull string. Removal of natural gas connection to genset. Gas line shall be capped at wall in generator room. Removal of entire exhaust system from genset through to and above roof. Removal of entire engine cooling system including remote roof mounted radiator, motor, piping, fluid and associated electrical. Removal of entire genset compressed air system. At completion of demolition roof repairs shall be made by certified roofing installer, panelboard and switchboard directories and labels shall be updated to indicate spares. Refer to Specification Section 26 32 13 Packaged Engine Generators

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

Subsection 202.02 shall include the following:

The Contractor shall coordinate with the Engineer who shall coordinate with CDOT EJMT Maintenance Staff and obtain the approval of the Engineer and CDOT EJMT Maintenance Staff prior to disconnecting or de-energizing any existing feeder or circuit to ensure operational and safety control. Any safety critical work where power will or has the potential to be interrupted shall only occur between 10PM and 4AM.

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.

Payment will be made under:

| **Pay Item** | **Pay Unit** |
|---|---|
| Removal of Electrical Equipment | Lump Sum |

## 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 Power Control Board shall be made in accordance with the requirements of the Revision of Section 613, 24.9kV Switchgear Assemblies.

**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. The purpose of this project is to add to the SCADA system the ability to monitor the status and provide alarms for the new emergency generator and its associated Siemens SIPROTEC protection relay on the 24.9kV switchgear lineup. It will provide programming for the ventilation systems in the north and south tunnels to limit the number of fans that can be run concurrently when the generator is running and sequence when the fans can be started to limit the power draw on the generator. Additionally, the SCADA system will be configured to monitor the status and provide alarms for the new heat trace 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 emergency generator, protection relay and heat trace system.
4. Attend and facilitate a programming workshop with the engineer and owner to establish the sequence of operations and limitations for fan startup and operation while under emergency power. Heat trace alarms will also be discussed during this workshop.
5. Modify the west ventilation building PLC program to detect new generator running I/O point and run the ventilation fans with the startup limitations established during the programming workshop.
6. Configure KepServer connectivity platform to communicate with the emergency generator, its associated protection relay in the 24.9kV switchgear and the heat trace system.
7. Modify the existing FactoryTalk View SE configuration to add displays and alarms to support the addition of the emergency generator, protection relay and the heat trace system.
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:

*Emergency Generator*

Network I/O points to be included:

1. Inputs
    a. Generator Running
    b. Generator in Auto
2. Outputs
    a. Generator Stop
    b. Generator Start
3. Alarms
    a. Generator Fault Hardwired I/O points to be included:

1. Inputs
    a. Generator Running

*Protection Relay*

Network I/O points to be included on SCADA:

1. Inputs
    a. Breaker Open
    b. Breaker Closed
    c. Phase A Current (amps)
    d. Phase B Current (amps)
    e. Phase C Current (amps)
    f. Phase AB Voltage (kilovolts)
    g. Phase BC Voltage (kilovolts)
    h. Phase AC Voltage (kilovolts)

i. Real Power (megawatts)

j. Reactive Power (megavolt-amps reactive)

k. Apparent Power (megavolt-amps)

2. Outputs

a. Breaker Open

b. Breaker Close

3. Alarms

a. Communication Failure (generated from KepServer)

*Heat Trace*

Network I/O points to be included on SCADA:

1. Inputs

a. Circuit Temperature (per circuit)

2. Alarms

a. The following alarms are available from the heat trace 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 Alarm Relay Output

**System Operation**

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

*Emergency Generator*

1. Running, auto and alarm status of the emergency generator displayed on SCADA.
2. Popup that allows an operator to manually start or stop the generator if in automatic mode.

*Protection Relay*

1. Generator relay status and values displayed on existing 24.9kV SCADA display using existing FactoryTalk Global Object.

2. Popup using existing FactoryTalk Global Object to enable manual closing and opening of breaker from SCADA screen.

*Ventilation System*

1. When the generator is running the SCADA system will limit the operation of the ventilation system fans. Details of these limitations will be developed in the programming workshop but shall include the general functionality as follows:
    a. SCADA system will limit the number of fans that can be run at 100% speed.
    b. SCADA system will limit the startup sequence of the fans to avoid drawing too much current during the initial startup of the fans, especially those in the south tunnel.

*Heat Trace*

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

Subsection 210.12 shall include the following:

SCADA System Integration will be measured but will be paid for on a lump sum basis.
Subsection 210.13 shall include the following:

Payment for SCADA System Integration will be the contract lump sum bid and will be full compensation for all equipment, labor and materials required to complete the item as specified herein.

Payment will be made under:

| **Pay Item** | **Pay Unit** |
|---|---|
| SCADA System Integration | Lump Sum |

## 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.

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.

(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:

**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.

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.

(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.

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:

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

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.

Subsection 613.12 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.

Payment will be made under:

| **Pay Item** | **Pay Unit** |
|---|---|
| Conduit | Lump Sum |

Payment for conduit shall also include all conduit connections and terminations, pull and junction boxes, conduit fittings, hangers and supports, and identification materials.

Payment for Wiring shall also include all wire and cable splices, terminations, and identification tags.

## REVISION OF SECTION 613
## 24.9KV GIS SWITCHGEAR SECTION

Section 613 of the Standard Specifications is hereby revised for this project as follows:

### DESCRIPTION

Add the following subsection:

**613.13** This Section specifies the requirements for metal-enclosed, medium voltage metal-clad draw-out type vacuum-type circuit breaker switchgear. The general arrangement of the switchgear shall be as follows:

(1) The new section for the new generator interconnect shall be install on the right-hand side of the existing 25kV GIS Switchgear lineup located in the West Portal main electric room.

The existing switchgear base structure serves as a conduit entry, cable pulling point and medium voltage terminations clearance space. The existing base structure shall be modified and extended to support the new GIS section. Contractor shall use same construction method and materials as existing structure. Any alterations that may be required to the existing platform structure shall be the responsibility of the contractor.

### MATERIALS

Add the following subsections:

**613.14 Design and Performance.** Design and performance of components and methods specified herein shall comply with all applicable Federal, State, and Local laws, ordinances, regulations and codes, and the latest industry standards including, but not limited to the entities listed below.

(1) American National Standards Institute (ANSI)

(2) National Electrical Manufacturers Association (NEMA)

(3) National Fire Protection Association (NFPA)

(4) Underwriters Laboratories (UL)

The switchgear shall be designed, manufactured, and tested in accordance with the latest revision of the applicable ANSI, NEMA, and UL Standards. Where a discrepancy exists between the various standards, the most stringent requirements shall apply.

The tunnel is located at an elevation of approximately 11,160 ft. above sea level. The equipment to be provided shall be fully rated for the various parameters in this Specification at that altitude.

**613.15 Quality Assurance.** Switchgear and all components of types and sizes required shall have been satisfactorily used for purposes similar to those intended herein for not less than ten years.

Entities manufacturing equipment shall have experience on at least two projects involving complexities similar to those required under this Contract.

The switchgear and circuit breakers shall be suitable for and certified to meet all applicable seismic requirements of Uniform Building Code (UBC) for Zone 1 application. Guidelines for the installation consistent with these requirements shall be provided by the switchgear

manufacturer and be based upon testing of representative equipment. The test response spectrum shall be based upon a 5% minimum damping factor, UBC: a peak of 0.09g, and a Zero Period Acceleration (ZPA) of 0.075g. The tests shall fully envelope this response spectrum for all equipment natural frequencies up to at least 35 Hz.

**613.16 Submittals.** The switchgear submittal shall include the following information:

1. Master drawing index
2. Front view elevation
3. Floor plan
4. Top view
5. Single line diagram
6. Schematic diagram
7. Nameplate schedule
8. Component list
9. Conduit entry/exit locations
10. Assembly ratings including:
    a. Switchgear assembly short-circuit withstand rating
    b. Enclosure internal arc short circuit rating
    c. Voltage
    d. Continuous current
    e. Basic impulse level
11. Major component ratings including:
    a. Voltage
    b. Continuous current
    c. Interrupting ratings
13. Cable terminal sizes
14. Product data sheets
15. Connection details between close-coupled assemblies
16. Composite floor plan of close-coupled assemblies
17. Key interlock scheme drawing and sequence of operations
18. Descriptive bulletins
19. Certification that the equipment is suitable for installation and operation at an elevation of 11,160 feet above sea level

**613.17 Spare Parts And Special Tools.**

A minimum of six (6) spare fuses of each size and type used in the switchgear shall be furnished for switchgear assembly.

Furnish one set of all special tools required for the , operation, and maintenance of all equipment furnished in switchgear section..

Furnish six (6) spare indicating lamps of each type installed for each switchgear assembly.

**613.18 Manufacturers.** Medium voltage switchgear shall be manufactured by Siemens.

**613.19 Ratings.** The switchgear shall have the following ratings, as shown on the Contract Drawings:

1. Nominal System Voltage: 24.9/14.4 kV, 3 phase, 3 wire, solidly grounded neutral
2. Rated Maximum Voltage: 27kV
3. Rated Frequency: 60 Hertz
4. Rated Insulation Level: 125kV
5. Rated Continuous Current: 1200 Amperes
6. Rated Short-Circuit Current: 22kA
7. Rated Short Circuit MVA: 1000MVA
8. Short Circuit Current Bus Bracing: 22kA
9. Control Voltage: 125V DC

**613.20 Construction Features.** Switchgear shall be factory assembled, suitable for indoor use, dead front, metal enclosed, free standing, arc-flash resistant, and completely equipped with removable medium voltage vacuum circuit breakers, fuses, instrument transformers, relays, metering, switches, and associated devices as described herein and as shown on the Contract Drawings and conforming to ANSI C37.20.2, C37.55, C37.100, and NEMA SG 5.

Provisions shall be made for extension of the switchgear to the right of new section. Circuit breaker shall be removable, drawout type.

No polyvinyl chloride (PVC) materials, insulation or products shall be used in switchgear, except for removable insulating boots on bus work.

**613.21 Construction.** The switchgear assembly shall consist of an individual vertical section housing generator input circuit breaker. Metal side sheets shall provide grounded barriers between adjacent structures and solid removable metal barriers shall isolate the major primary sections of each circuit. The 27 kV switchgear structures shall be provided with one full height hinged rear cover.

The construction of the switchgear shall permit the addition of new circuit breaker sections at the end of the lineup.

The stationary primary contacts shall be silver-plated and recessed within insulating tubes. A steel shutter shall automatically cover the stationary primary disconnecting contacts when the breaker is in the disconnected position or out of the cell. Provide rails to allow withdrawal of each 27 kV circuit breaker for inspection and maintenance without the use of a separate lifting device.

The switchgear assembly shall be of arc resistant construction that provides Type-2 accessibility around the perimeter (front, sides, and rear) of the line-up in accordance with IEEE C37.20.7.

Vertical section of the switchgear shall include integral and top mounted pressure release flaps to facilitate a controlled upward release of arc created overpressures, smoke, and gasses. Individual vertical sections shall be of a unitized design to allow removal of a damaged vertical section after a fault incident, without requiring the removal of the adjacent vertical sections.

The main bus shall be copper with fluidized bed epoxy flame-retardant and track-resistant insulation. The bus supports between units shall be flame-retardant, track-resistant, cycloaliphatic epoxy. The switchgear section shall be constructed so that all buses, bus supports and connections shall withstand stresses that would be produced by currents equal to the momentary ratings of the circuit breakers. Main bus shall be rated 1200 amperes. . Insulated copper main bus shall be provided and have provisions for future extension. All bus joints shall be plated, bolted and insulated with easily installed boots. The bus shall be braced to withstand fault currents equal to the close and latch rating of the breakers. The temperature rise of the bus and connections shall be in accordance with ANSI standards and documented by design tests.

A copper ground bus shall be extended into the new switchgear section.

The switchgear manufacturer shall provide suitable terminal blocks for secondary wire terminations and a minimum of 10% spare terminals shall be provided. A control circuit cutout device shall be provided in circuit breaker housing. Switchgear secondary wire shall be #12 AWG, type SIS rated 600 volt, 90 degrees C, furnished with wire markers at each termination. Wires shall terminate on terminal blocks with marker strips numbered in agreement with detailed connection diagrams.

Incoming line and feeder cable lugs shall be 2- hole mounting, long barrel, copper compression lugs.

Feeders shall be for conduit and cable. Cable entry shall be from either the top or the bottom of the enclosure..

**613.22 Circuit Breaker.** The circuit breaker shall be horizontal drawout type, capable of being withdrawn on rails. The breakers shall be operated by a motor-charged stored energy spring mechanism, charged normally by a universal electric motor and in an emergency by a manual handle. The primary disconnecting contacts shall be silver-plated copper.

Circuit breaker shall contain three vacuum interrupters separately mounted in a self-contained, self-aligning pole unit, which can be removed easily. The vacuum interrupter pole unit shall be mounted on cycloaliphatic epoxy supports. A contact wear gap indicator for each vacuum interrupter, which requires no tools to indicate available contact life, shall be easily visible when the breaker is removed from its compartment. The current transfer from the vacuum interrupter moving stem to the breaker main conductor shall be a non-sliding design. The breaker front panel shall be removable when the breaker is withdrawn for ease of inspection and maintenance.

The secondary contacts shall be silver-plated and shall automatically engage in the breaker operating position, which can be manually engaged in the breaker test position.

Interlocks shall be provided to prevent closing of a breaker between operating and test positions, to trip breakers upon insertion or removal from housing and to discharge stored energy mechanisms upon insertion or removal from the housing. The breaker shall be secured positively in the housing between and including the operating and test positions.

The circuit breaker compartment door shall be mechanically interlocked with the breaker levering mechanism to prevent opening of the door unless the breaker is first opened and withdrawn to Test/Disconnected position with the door closed.

The design shall allow normal circuit breaker functions to be carried out with the door closed. Those functions include: manual open and close, manual levering to and from connected position, and manual charging of the circuit breaker closing springs. Shatter proof viewing windows shall be provided on the door to enable viewing of circuit breaker position inside the compartment, circuit breaker contact status (open/closed), and spring charged/discharged indication.

When a remote operable electrical levering device is specified under the accessories, the design shall allow levering of the circuit breaker using such a device with the door closed.

The breakers shall be electrically operated by the following control voltages: 125-volt DC close and 125 volt DC trip. Breaker shall be complete with control switch and red and green indicating lights to indicate breaker contact position.

DC control voltage shall be supplied by from existing battery/charger system.

**613.23 Protective Relays.** The switchgear manufacturer shall furnish and install, in the metal-clad switchgear, the quantity, type and rating of protection relays. Required to provide the protection and perform the operation described in the project specifications. Relays shall be mounted in a separate area metal barriered from medium voltage.

Relays shall be Microprocessor-Based Protective Relays. with ANSI device functions 51/50, 54/50N, 46, 59, 27, 32, 67, 46, 55, 81O, 81U, 47, and 50BF.

**613.24 Auxiliary Devices.** Ring type current transformers shall be furnished. The thermal and mechanical ratings of the current transformers shall be coordinated with the circuit breakers. Their accuracy rating shall be equal to or higher than ANSI standard requirements. The standard location for the current transformers on the bus side and line side of the breaker units shall be front accessible to permit adding or changing current transformers without removing high-voltage insulation connections. Shorting terminal blocks shall be furnished on the secondary of all the current transformers.

Voltage or potential transformers shall be supplied. Voltage transformers shall be mounted in drawout drawers contained in an enclosed auxiliary compartment. Rails shall be provided for auxiliary drawers to permit easy inspection, testing and fuse replacement. Shutters shall isolate primary bus stabs when drawers are withdrawn. Voltage transformers for each assembly shall consist of three 14.4kV to 120 volt transformers with primary and secondary fuses.

Lightning/Surge Arresters shall be intermediate class, rated for 18kV.

**613.25 Enclosures.** Indoor switchgear shall be provided with a NEMA 1 enclosure.

Arc exhaust shall be discharged into the space above the switchgear.

**613.26 Nameplates.** Engraved nameplates, mounted on the face of the assembly, shall be furnished. Nameplates shall be laminated plastic, white characters on black background, and secured with screws. Characters shall be 3/16-inch high, minimum. Furnish master nameplate for each switchgear lineup giving information in accordance with IEEE Std C37.20.2-1999, section 7.4.1 and IEEE C37.20.7, section 6.3. Circuit nameplates shall be provided with circuit designations.

Control components mounted within the assembly, such as fuse blocks, relays, pushbuttons, switches, etc., shall be suitably marked for identification corresponding to appropriate designations on manufacturer's wiring diagrams.

**613.27 Finish.** The finish shall consist of a coat of gray (ANSI-61), thermosetting, polyester powder paint applied electrostatically to pre-cleaned and phosphatized steel and aluminum for internal and external parts. The coating shall have corrosion resistance of 600 hours to 5% salt spray.

**613.28 Accessories.** The switchgear manufacturer shall furnish accessories for test, inspection, maintenance, and operation. Each accessory set shall include:

1. One – Maintenance tool for manually charging the breaker closing spring and manually opening the shutter
2. One – Levering crank for moving the breaker between test and connected positions
3. One – Test jumper for electrically operating the breaker while out of its compartment
4. One – Breaker lifting yoke used for attachment to breaker for lifting breaker on or off compartment rails, when applicable
5. One – Set of rail extensions, when applicable

**613.29 Corona-Free Design.** The switchgear section shall be corona free by design and shall be tested for partial discharges in accordance with EEMAC standard G11-1. The corona discharges measured during the tests shall be less than 100 picocoulombs.

**613.30 Partial Discharge Sensing Equipment.** The switchgear section shall be equipped with factory installed partial discharge (PD) sensors and relay for continuous monitoring of the partial discharges under normal operation. The partial discharge sensing shall identify potential insulation problems (insulation degradation) by trending of PD data over time so that corrective actions can be planned and implemented before permanent insulation deterioration develops.

The existing PD sensing and monitoring system shall be extended into the new section. consist of sensors and relay(s) specifically developed for such applications. A sensor shall be provided for installation around ground shields of the incoming and outgoing power cable terminations for detection of PD activity in the cables up to 100 feet from the switchgear. Output signals from each shall be factory wired to PD monitoring relay for continuous monitoring.

**613.31 Relays, Control Switches and Fuses.** Protective relays shall conform to ANSI C 37.90 and be of the semiflush mounted, removable type, with built-in test facilities. Current transformer secondaries shall be automatically short circuited when the relay is removed from its case. Auxiliary relays shall be surface mounted and front connected.

In addition, the main and tie circuit breakers shall be provided with electro-mechanical lockout relays, with manual reset, that shall be engaged when the breakers are tripped on overcurrent.

Control, transfer, and instrument switches shall be of the heavy duty rotary, multi-position, cam operated, multi-stage type, with dust cover, rated 600VAC, with silver to silver contacts rated for continuous current of 20 amperes. Each circuit breaker control switch shall have red and green target. Each switch shall be equipped with engraved plastic escutcheon or

nameplate identifying its function and position. Handle styles shall be pistol grip for control, and oval for instrument or transfer switches.

Circuit Breaker shall be provided with a control switch on the door of each circuit breaker cubicle for performing breaker close and open operations. Mechanical red/green targets shall be incorporated in the switch to indicate breaker "Closed/Open" position. A spring-return mechanism shall return the switch handle to the normal vertical position.

**613.32 Indicating Lamps.** Indicating lamps shall be light emitting diodes (LED) of the low voltage, low burden series resistor type, with lens colors as approved by the Engineer. Lamps shall be replaceable from the front of the panel.

**613.33 Terminal Blocks.** Terminal blocks for all external control connections shall be 600 volt, barrier type, having a minimum rating of 20 amperes with identifying marker strips. Terminal strips in each cubicle, shall have at least 20 percent spare terminals and shall be in accordance with NEMA ICS 4. Terminal blocks for current transformer secondary connections shall be of the short circuiting type.

**613.34 Nameplates and Mimic Bus.** Nameplates shall be provided for switchgear section, for all externally and internally mounted devices, including, but not limited to, instruments, meters, control switches, and relays to identify its function, and where applicable, its position.

Nameplates shall consist of letters and numbers back engraved on a laminated thermosetting plastic material, providing white letters and numbers on a black background. Size of letters and figures shall be approximately 1/8 inch for device nameplates and 7/16 inch for cubicle nameplates, and 1 inch for switchgear designations.

Nameplates shall be fastened with two oval-head stainless steel machine screws. Number, location and designation of nameplates shall be as approved by the Engineer.

Mimic bus shall be provided on the face of the switchgear representing actual bus arrangements within the switchgear assembly. Circuit breaker control switches and indicating lights shall be located in the proper position on the mimic bus. The mimic bus shall be 1/8 x 3/4 inch, high strength thermosetting plastic material, secured every twelve (12) inches with self tapping screws.

**613.35 Interlocking.** New control switches with key interlocking shall be provided for the Power Control Board located in the Control Room in the East Ventilation Building.

**613.36 Additional Grounding Requirements.** The switchgear section shall be provided with a solderless copper ground lug attached to a non-painted surface. The lug shall have the capacity for connection of two No. 4/0 wires.

**613.37 Shop Painting.** Prior to assembly and before shop painting, all surfaces of the switchgear enclosure shall be thoroughly cleaned of rust, oil, grease, dirt and mill scale and receive a phosphatizing treatment, and then be primered with one coat of rust-inhibitor for a dry film thickness of 1-2 mils.

The exterior and interior of the switchgear shall be given two or more finish coats of corrosion resistant paint for a final dry film thickness of at least 2-4 mils. The color of the finish on the switchgear shall be ANSI number 61 light gray.

Alternative painting process, such as electrostatically applied paint, can be utilized, subject to the approval of the Engineer.

**613.38 Factory Testing.** The following standard factory tests shall be performed on the circuit breaker element provided under this section. All tests shall be in accordance with the latest version of ANSI standards.

1. Alignment test with master cell to verify all interfaces and interchangeability
2. Circuit breaker operated over the range of minimum to maximum control voltage
3. Factory setting of contact gap
4. One-minute dielectric test per ANSI standards
5. Final inspections and quality checks

The following production test shall be performed on each breaker housing:

1. Alignment test with master breaker to verify interfaces
2. One-minute dielectric test per ANSI standards on primary and secondary circuits
3. Partial discharge tests, when applicable.
4. Operation of wiring, relays and other devices verified by an operational sequence test
5. Final inspection and quality check.

The manufacturer shall provide three (3) certified copies of factory test reports. The owner's representative will witness factory tests as outlined above.

1. The manufacturer shall notify the owner two (2) weeks prior to the date the tests are to be performed.

**CONSTRUCTION REQUIREMENTS**

Add the following subsections:

**613.39 Delivery, Storage, and Handling.** Prior to shipment, the switchgear section shall be cleaned by wiping with a clean, dry cloth.

Oil and grease marks shall be removed and wiped dry. All insulation shall be cleaned thoroughly. Dirt, soot, grease, or paint shall be removed from the circuit breaker contacts and surface of the entire current carrying structures.

All relays and instruments shall be firmly blocked to prevent damage during shipment.

The overall dimensions and weight of each shipping section shall be limited to the maximum allowable by applicable state and local codes governing shipment of materials over public roads or construction site handling limitations, whichever is less. Each shipping section shall have a label indicating dimensions and weight.

All equipment and materials shall be suitably wrapped, crated, boxed, or otherwise prepared for shipment to prevent damage during handling and shipping. All openings shall be properly protected to prevent the entrance of any dirt or debris. All parts not constructed to be normally exposed to the weather shall be suitably weatherproofed.

Each box or crate shall be equipped with suitable lifting devices to facilitate unloading and shall contain a detailed packing list.

Packaging shall be labeled and numbered so that each section or assembly may be identified before being uncrated. Any items not fully assembled to the switchgear structure shall be

packaged separately. Removable circuit breaker units shall be packaged and shipped separately.

Adequate means shall be provided for lifting by fork lifts and cranes and for moving the equipment on rollers. Lift points shall be marked on each crate.

Indoor switchgear that cannot be installed immediately shall be stored in a dry, clean location within a heated building. During storage, the switchgear shall be placed on a level surface.

**613.40 Field Supervision.** Provide the services of a qualified, factory-trained switchgear manufacturer's representative to provide technical field support in the installation and start-up of the equipment specified in this Section. The manufacturer's representative shall provide technical direction and assistance in general assembly of the equipment, connections, calibrations, adjustments, and testing of the assembly and components contained therein.

**613.41 Field Tests.** Field tests shall be performed in accordance with the manufacturer's recommendations, International Electrical Testing Association (NETA), NEMA, UL, ANSI, and as required in this Section and/or as directed by the Engineer. Tests shall be performed only after the equipment has been thoroughly cleaned.

All Work shall be performed with due regard for the protection of personnel and equipment. Test shall be performed only after the equipment has been thoroughly cleaned.

All field tests shall be conducted in the presence of the Engineer or his designee for the purpose of demonstrating that the equipment and systems comply with the requirements of this Section to assure the Engineer that the entire installation meets applicable codes and standards requirements, and that all systems will function as designed.

All controls shall be checked individually prior to operational tests. Wiring diagrams and manufacturer's drawings shall be marked during checkout. Checked items shall be marked in yellow; discrepancies shall be corrected, and modifications shall be recorded in red. Marked wiring diagrams and manufacturer's drawings shall be submitted to the Engineer.

Record all test values, settings, and calibrations and furnish the Engineer with copies of test reports after completion of each individual test. These reports shall include a description of the test procedures. All test data for each test required in this Section shall be recorded on test forms.

The Engineer shall be advised, in writing, upon failure of any equipment or material to pass the tests performed or to properly function as intended.

Integrity Tests: The switchgear shall successfully complete the following tests as recommended by NETA and listed under the "Switchgear and Switchboard Assemblies" Section:

1. Visual and Mechanical Inspection
    a. Inspect for physical, electrical, and mechanical condition.
    b. Compare equipment nameplate information with latest one-line diagram and report discrepancies.
    c. Check for proper anchorage, required clearances, physical damage, and proper alignment.
    d. Inspect all doors, panels, and sections for paint, debris, scratches, fit, and missing hardware.

e. Verify that fuse and/or circuit breaker sizes and types correspond to the Contract Drawings.

f. Verify that current and voltage transformer ratios correspond to the Contract Drawings.

g. Inspect all bus connections for high resistance. Use low-resistance ohmmeter, or check tightness of bolted bus joints by using a calibrated torque wrench. Refer to manufacturer's instructions for proper torque levels.

h. Test all electrical and mechanical interlock systems for proper operation and sequencing.

i. Closure attempt shall be made on locked open devices.

ii. Opening attempt shall be made on locked close devices.

iii. Key exchange shall be made with devices operating in off-normal positions.

i. Clean switchgear section using manufacturer's approved methods and materials.

j. Inspect insulation's for evidence of physical damage or contaminated surfaces.

k. Verify proper barrier and shutter installation and operation.

l. Lubrication

i. Verify appropriate contact lubricant on moving current carrying parts.

ii. Verify appropriate lubrication on moving and sliding surfaces.

m. Exercise all active components.

n. Inspect all mechanical indicating devices for proper operation.

2. Electrical Tests

a. Perform tests on all instrument transformers in accordance with NETA published values.

b. Perform ground-resistance tests in accordance with NETA published values.

c. Perform insulation-resistance tests on each bus section, phase-to-phase, and phase-to-ground for one (1) minute. Test voltages and minimum resistances shall be in accordance with NETA published values.

d. Perform an overpotential test on each bus section, each phase-to-ground, for one (1) minute at values recommended by the manufacturer.

e. Perform insulation-resistance test on shipping split control wiring. Do not perform this test on wiring connected to solid-state components.

f. Perform control wiring performance test. Use the elementary diagrams of the switchgear to identify each remote control and protective device. Conduct tests to verify satisfactory performance of each control feature.

g. Perform secondary voltage energization test on all control power circuits and voltage tests as detailed below in paragraph k, and l. Check voltage levels at each point on terminal boards and at each terminal device.

h. Perform current injection test on entire current circuit in switchgear section.

i. Perform current tests by primary injection, where possible, with magnitudes such that a minimum of 1.0 ampere flows in the secondary circuit.

ii. Where primary injection is impractical, utilize secondary injection with a minimum of 1.0 ampere.

iii. Test current at each device.

i. Determine accuracy of all meters and calibrate watt-hour meters per NETA recommendations.

j. Perform phasing check on double ended switchgear to ensure proper bus phasing from each source.

k. Potential Transformer Circuits

i. Perform secondary wiring integrity test. Disconnect transformer at secondary terminals and connect secondary wiring to proper secondary voltage. Check voltage at all devices.

ii. Verify secondary voltage by energizing primary winding with system voltage. Measure secondary voltage with the secondary wiring disconnected.

**613.42 Records of Tests.** Types of Records: Maintain complete and accurate records of all tests. These records shall include the following:

1. Description of test equipment used, including serial numbers.
2. Equipment or circuit identification, description, and location.
3. Complete nameplate data, including serial number.
4. Readings and measurements taken, including temperature and humidity.
5. Description of test, including date and tester's signature.
6. Test results (written description as required).
7. Other observable data applicable to equipment tests.
8. Description of any necessary corrective actions.
9. Certification of satisfactory completion of wiring and installation in accordance with applicable items of this Section.

**613.43 Training.** Provide at the construction site training sessions for CDOT Tunnel Operations personnel, for two (2) - eight (8) hour days.

The training sessions shall be conducted by a manufacturer’s qualified representative. The training program shall consist of the instruction on the operation of the assembly, circuit breakers, and major components within the assembly.

**613.47 Modifications to Existing Power Control Board.** The existing Power Control Board, located in the Control Room of the East Ventilation Building shall be modified to included new section and generator function. New control switches shall be provided with key interlocks. Keys for key interlocks shall be furnished in the quantity required, and one spare key of each type shall be provided which shall be turned over to CDOT. Indicating lamps shall be M

**ASSEMBLIES**

**613.48 Measurement**. Electrical Switchgear Section, will be measured by each unit furnished, installed and accepted as described herein.

**613.49 Payment.** The completed and accepted work for conduits will be paid for at the contract unit price for the pay items listed below that appear in the bid schedule.

| **Pay Item** | **Pay Unit** |
|---|---|
| 24.9kV GIS Switchgear | Each |

## 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.

**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:
    A. Packaged Generator Set, Controls and Fuel System.
    B. Medium Voltage Step-Up Pad-Mounted Transformer
    C. 25kV GIS Switchgear
    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).

## 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.
    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.

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 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 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.

## METHOD OF MEASUREMENT

Electrical Modifications will not be measured, but will be paid for on a lump sum basis.

## BASIS OF PAYMENT

The completed and accepted work for the Electrical Modifications will be paid for at the contract lump sum price for the pay item listed below.

Payment will be made under:

| **Pay Item** | **Unit** |
|---|---|
| Electrical Modifications | Lump Sum |

## 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 |

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.
    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.

*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 generator, 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 emergency generator, 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.

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.

    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.

*Emergency Generator System Grounding*. Grounding shall meet the following requirements:

1. The neutral point of the emergency generator system shall be grounded in a manner identical to that used for service entrance equipment except that the system will require connection to only one of the grounding electrode means. The ground bus in the generator output and control switchboard shall be used as the reference point of the emergency system and shall be grounded to the grounding electrode. Connect the neutral leads from the generator to the reference point using a full size neutral run with the phase conductors, to the switchboard neutral bus, and a bonding jumper between the switchboard neutral and ground bus. Provide a grounding electrode conductor, without splice or joints, of a minimum of 250 MCM copper conductor, or 12.5 percent of the circular mil area of the phase conductors, whichever is larger, between the reference ground point and the grounding electrode. Connect the generator frame to the reference ground point using a minimum No. 4/0 AWG copper conductor.
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.

*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.

**METHOD OF MEASUREMENT**

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

## REVISION OF SECTION 622
## MOTOR POWER AND CONTROL WIRING

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

### DESCRIPTION

This work is furnishing, installation, connection and testing of motor power and control wiring in accordance with these specifications and in conformity with the details shown on the plans or established.

### MATERIALS

The Contractor shall provide all conduits, wires, and accessories as required to perform the Work.

The Contractor shall provide all conduits and wires in accordance with Revision of Section 622 – Raceways, and Revision of Section 622 – Wires, Cables, Splices, Terminations. PVC-insulated wiring and cables shall not be used in areas subject to the requirements of National Fire Protection Association (NFPA) 130 or NFPA 502.

The Contractor shall provide angle iron supports, brackets or hangers for mounting starters, control panels and control devices in accordance with Revision of Section 622 – Supporting Devices.

All fuses and circuit breakers provided under this Section shall be of the ratings and types as shown on the Contract Drawings or, if not shown on the Contract Drawings, shall be as recommended by equipment manufacturers. Fuses and circuit breakers shall be in accordance with Revision of Section 622 - Over-Current Protective Devices.

All motor control equipment shall be manufactured in compliance with NEMA ICS2, NEMA ICS4, ANSI/UL 65, ANSI/UL486E, ANSI/UL486A-486B, ANSI/UL 969, ANSI/UL 467, ANSI/UL 508, and UL 1059.

### CONSTRUCTION REQUIREMENTS

*Examination.* Prior to making electrical connections, the Contractor shall check all electrical equipment furnished under other sections of the Specifications for the specified voltages and directions of rotation. Prior to energizing motors, verify the specified overload rating of all heater elements and relay settings, furnished with the motor starters under other Sections of the Specifications, so that the proper running protection will be provided for the motors. Should the overload ratings not be correct, notify the Engineer.

*(b) Installation.* All motor starters, control devices, conduits, wires and accessories shall be installed in accordance with the requirements of NFPA 70 and the manufacturers' installation procedures. Make final connections in accordance with approved shop drawings. Install all conduits, wires, accessories and supports in accordance with the requirements of this Section.

*(c) Field Tests.* The Contractor shall perform tests, in the presence of the Engineer, to demonstrate the following, and give the Engineer 24-hours advance notice of tests.

1. That each control device and its related motor starter operate as designed.
2. That each overload protective and safety device functions as designed.

Tests shall be performed in accordance with the equipment manufacturers' start-up and field test instructions and made jointly with all affected trades. Should the tests reveal any defects, promptly correct such defects and rerun the tests until the entire installation is satisfactory in all respects.

## METHOD OF MEASUREMENT

Motor Power and Control Wiring will not be measured and paid for separately, but shall be included in the lump sum price for Electrical Modifications.

## 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 ¾ - 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.
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.
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 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:

| 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.

**METHOD OF MEASUREMENT**

Supporting Devices will not be measured and paid for separately, but shall be included in the lump sum price for electrical Modifications.

## 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.

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 “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:

(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.

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; 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.
    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;

(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

(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. Fircproofing 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**

*Preparation.* Prior to pulling wires and cables, raceway systems shall be cleaned of all foreign matter and ll 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

   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:

(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.

*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.

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.

*(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.

**METHOD OF MEASUREMENT**

Over-Current Protective Devices (600 Volts or Less) will not be measured and paid for separately but shall be included in the lump sum price for Electrical Modifications.