SECTION 34 22 23

TRACTION POWER CABLES

PART 1 – GENERAL

1.01 SECTION INCLUDES

A. 35 kV Power Cables

B. 35kV Cable Termination and Splice Kits

C. Spark Gap Assembly

D. DC Power Cables

E. Miscellaneous Materials

1.02 MEASUREMENT AND PAYMENT

Not Used

1.03 REFERENCE STANDARDS

A. Association of Edison Illuminating Companies (AEIC):

1. AEIC CS8 Specifications for Extruded Dielectric, Shielded Power Cables Rated 5 through 46 kV

B. American National Standards Institute (ANSI):

1. ANSI/ASC H35.1 Alloy and Temper Designation Systems for Aluminum

C. American Society for Testing and Materials (ASTM):

1. ASTM A153 Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware

2. ASTM A167 Specification for Stainless and Heat-Resisting Chromium-Nickel Steel Plate, Sheet, and Strip

3. ASTM A325 Specification for High-Strength Bolts for Structural Steel Joints

4. ASTM B3 Specification for Soft or Annealed Copper Wire

5. ASTM B8 Specification for Concentric-Lay-Stranded Copper Conductor, Hard, Medium-Hard, or Soft

6. ASTM B173 Specification for Rope-Lay-Stranded Copper Conductor Having Concentric-Stranded Members, for Electrical Conductors

7. ASTM B766 Specification for Electrodeposited Coatings of Cadmium

8. ASTM B496 — Specification for Compact Round Concentric Lay-Stranded Copper Conductors

D. Insulated Cable Engineers Association (ICEA):

1. ICEA S-93-639 (NEMA WC-74) — 5 – 46 kV Shielded Power Cable for Use in the Transmission and Distribution of Electric Energy

2. ICEA S-94-649 — Concentric Neutral Cables Rated 5 – 46 kV.

3. ICEA S-95-658 (NEMA-WC-70) — Non-Shielded Power Cables, 2000 V or Less

4. ICEA S-96-659 (NEMA WC-71) — Non-Shielded Cables Rated 2001 – 5000 Volts for Use in the Distribution of Electric Energy

5. ICEA S-97-682 — Utility Shielded Power Cables Rated 5 – 46 kV

6. ICEA T-26-465 (NEMA WC-54) — Guide to Frequency of Sampling Extruded Dielectric Power, Control, Instrumentation, and Portable Cables for Test

7. ICEA T-33-655 — Guide for Low-Smoke, Halogen-Free (LSHF) Polymeric Cable Jackets

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

1. IEEE 48 — Standard Test Procedures and Requirements for High-Voltage Alternating-Current Cable Terminations

2. IEEE 383 — Type Test of Class 1E Electric Cables, Field Splices, and Connections for Nuclear Power Generating Systems

3. IEEE 400 — Guide for Making High-Direct - Voltage Tests on Power Cable Systems in the Field

4. IEEE 404 — Cable Joints for Use with Extruded Dielectric Cable Rated 5,000 Through 46,000 Volts, and Cable Joints for Use with Laminated Dielectric Cable Rated 2,500 Through 500,000 Volts

F. Department of Defense, Military Specifications (MIL):

1. MIL-P-23469/4 — Pin-Rivet, Grooved, Round Head; Straight Shank, Multiple Locking Grooves, Aluminum Alloys, Corrosion-Resistant and Carbon Steels

G. National Electrical Manufacturers Association (NEMA)

1. NEMA WC-26 — Bi-National Wire and Cable Packaging Standard

H. National Fire Protection Association (NFPA):

1. NFPA 130 Fixed Guideway Transit Systems

I. Underwriters Laboratories Inc. (UL):

1. UL 44 Rubber-Insulated Wires and Cables

2. UL 486A Wire Connectors and Soldering Lugs for use with Copper Conductors

3. UL 1072 Medium-Voltage Power Cables

4. UL 1685 Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables 1992

J. State of California

1. CEC California Electrical Code, CCR, Title 24, Part 3

1.04 SUBMITTALS

A. General: Refer to Section 01 33 00, Submittal Procedures, and Section 01 33 23, Shop Drawings, Product Data, and Samples for submittal requirements and procedures.

B. Shop Drawings: Submit the following shop drawings:

1. Cable section details for materials and cable assembly construction no later than 60 days prior to start of cable manufacturing.

2. Installation details for the spark gap assembly and enclosure showing overall dimensions and clearances, backboard support details, mounting details, cable routing and outline dimensions and tolerances, installation details, splicing details, and grounding installation details.

3. Splices and cable terminations showing cross sections and installation details, no later than 60 days prior to scheduled ordering of these items.

4. Cable reel components and construction details.

C. Product Data: Submit data for power cables and associated materials and accessories such as splices, terminations, connectors, and fireproofing tape. Product data shall include product description and detailed technical specifications.

D. Samples:

1. Provide the following sample products after completion of first production lot of cables and materials:

a. Two foot sample of each cable size, type, and use for: 35 kV power cable, 5 kV dc feeder cable, contact rail termination cable assembly, expansion joint shunt

assembly, flex jumper cable assembly, and 2kV cable for the load measuring system.

b. Jumper connection block comprising of rosette with cover and lugs for 750 kcmil and 350 kcmil dc power cables.

c. Jumper and feeder cable identification nameplates, showing type, size, embossing and method of attachment.

d. A complete set of 35 kV cable splice kit.

e. A complete set of 35 kV cable termination kit.

f. A complete set of 5 kV cable splice kit.

g. Conduit sealing fittings/bushings for the 35 kV and 5 kV cables.

2. Samples shall be labeled with the following data: name of Manufacturer; cable type, size, voltage rating, insulation, and thickness; brand name; and, application and use.

3. Before submitting the samples, ensure that the product will be available in the quantities required for the Contract. No change or substitution will be permitted after submittal of the samples.

4. Products incorporated in the work shall match the approved samples.

E. Submit product test program plan, procedures, and reports in accordance with Section 01 45 24, Testing Program Requirements. Manufacturer shall certify factory design and production test reports indicating compliance of cables and accessories with referenced Standards and these Specifications.

F. Installation, Termination, Splicing and Testing Manuals:

1. Provide a detailed written narrative describing the installation, terminating methods, manufacturer recommended field testing procedures and maintenance instructions for the power cables to be furnished. Drawings, sketches, tabulation of pulling tensions, allowable bending radius descriptions, part numbers, and sources of all special tools, gauges, and handling equipment required shall be included in the manual. Manual format and contents shall conform to the requirements for Operation and Maintenance Manuals as defined in Section 01 78 23, Operation and Maintenance Data.

2. Draft versions of the manuals for the 35 kV and 5 kV cables shall be submitted for approval. Final versions of manuals shall be submitted 30 days after receipt of District's comments and not less than 60 days prior to start of cable installation.

3. The manual shall include at a minimum the following:

a. Site storage instructions including handling, and storage requirements for short and long term;

b. Installation equipment checklist, equipment set-up with diagram, illustrations, and sketches; and recommended lubricants for cable pulling during installation;

c. Physical limitations of the cables relevant to cable pulling, including maximum pulling tensions, and maximum sidewall pressure;

d. Cable pulling technique, cable training and bending methods and limits;

e. Cable terminations, splicing supports, and fireproofing;

f. Instrumentation and procedures for field testing after installation and splicing. The testing procedures shall include all relevant settings and parameters such as test voltages and duration of application. The manual shall also include the fail/pass criteria for each test and any remedial measures that may be appropriate should a test fail.

G. Shipping, Packaging, and Marking Methods. Submit proposed procedures and methods for shipping, handling, unloading, and storing of power cables 60 days prior to first material shipment.

1. Power cables shall be packaged for arrival at the site undamaged by handling and weather.

2. Power cables shall be placed on non-returnable individual reels. Each reel shall contain only one continuous length of cable. Reels shall have drums with diameters of at least 12 times the outside diameter of the cable shipped thereon and shall be of substantial construction to withstand multiple handling in transit and in cable installation and outdoor storage. Each reel shall be constructed and packaged as a minimum requirement per NEMA WC26. Submit for approval a drawing of cable reel components and construction.

3. Reels shall have weather-resistant markings on both sides showing the purchase order number, reel number, weight, actual length, cable type, conductor type and size, number of conductors, ground wire size, voltage rating, and the appropriate UL labels. The numerals and letters shall be at least one inch high. Packing and shipping papers shall be identified with the information shown on reels. Each reel shall also be marked clearly "STAND REEL ON RIMS ONLY. DO NOT LAY ON SIDE".

4. Power cables shall be handled so as to prevent damage to the jacket and insulation. The ends of the cable shall be hermetically sealed with heat shrinkable elastomeric cap to prevent dirt and moisture from entering the cables during storage, handling, and installation.

H. Submit cable lubricant manufacturer's certification that lubricant is compatible with cable.

1.05 SUPPLIER QUALIFICATIONS

A. The Manufacturer of the power cables shall furnish a certification proving a minimum of five (5) years business experience in the supply and manufacture of the same type and rating of power cables being supplied.

B. The Manufacturer of power cables with EPR insulation shall provide certification that the insulating and semi-conducting compounds used in the cable construction are to be a major manufacturer's proven development of their own in-house formulation and mixture, with an established quality control program for all suppliers products used in the compound make-up.

C. Submit for District approval, a certificate of experience for each engineer, technician, splicer, and cable lug welder that will perform installation work. Experience cited for each shall include performance during the immediate past three years in splicing and terminating cables of the types specified herein. Certification for the 35 kV splicer and terminator shall be issued by the splice kit manufacturer and certification for welders shall be issued by the manufacturer of the exothermic welding materials or by an independent laboratory qualified to test this type of welding.

PART 2 – PRODUCTS

2.01 GENERAL

A. Power cables shall be suitable for operation in wet and dry locations including underground ducts, moisture and sunlight resistant, and rated for cable tray use.

2.02 35 kV AC POWER CABLES

A. General: 35 kV ac power cables shall consist of stranded copper conductors with a semi-conductive screen, ethylene-propylene rubber (EPR) insulation, an insulation screen, metallic shield, concentric neutral conductors, a polyester film, and an outer jacket. The cable insulation and semi-conductive screens shall be manufactured by a single pass triple tandem extrusion.

B. Ratings:

1. Voltage Rating: The voltage rating of the ac power cables shall be 35 kV, 133 percent insulation level.

2. Temperature Ratings: The cables shall be designed to operate at a maximum conductor temperature of 105 ºC for normal operation, 140 ºC under emergency overload conditions, and 250 ºC under short circuit conditions, in accordance with ICEA S-93-639 and UL 1072.

C. Conductors

1. Conductors shall be uncoated soft copper, concentric, round, compressed or compact, Class B strand per ASTM B8 or B496.

2. Electrical resistance values of conductors shall meet the requirements of ICEA S-93-639 (NEMA WC74).

3. Conductor size shall be 250 kcmil.

D. Conductor Screen

1. An extruded layer of black semi-conducting thermosetting compound shall be applied over the conductor. The material shall be compatible with the conductor metal and

insulating compound and shall be uniformly and firmly bonded to the overlying insulation and be free stripping from the conductor. The screen shall have similar temperature coefficient of expansion as the EPR insulation.

2. The conductor screen shall comply with ICEA S-97-682.

E. Insulation

1. The insulation shall be EPR type and shall meet all the requirements of ICEA S-93-639 (NEMA WC74) and AEIC CS8. The EPR compound shall meet the qualification tests specified in ICEA S-94-649 and ICEA S-97-682.

2. The insulation shall have an average thickness of 420 mils, based on 133 percent level in accordance with ICEA S-93-639. The minimum insulation thickness at any point of the cable shall not be less than 90 percent of the specified average thickness.

F. Insulation Screen

1. An extruded layer of black semi-conducting thermosetting compound shall be applied over the insulation. The material shall be compatible with the insulation and overlying metallic shield. The material shall be free stripping from the insulation. The outer surface of the insulation screen shall be marked to indicate that it is semi-conducting.

2. The non-metallic insulation screen shall comply with ICEA S-93-639.

G. Metallic Shield and Concentric Neutral Conductors

1. The insulation screen shall be covered with a helical wrap of uncoated copper tape. The minimum tape thickness shall be 5 mils, and tape shall be applied with nominal 12- 1/2 percent overlap.

2. A sufficient number of concentric neutral conductors shall be applied over the metallic tape so that the combined conductivity of the tape and wire shields shall be at least 33 percent of the conductivity of the phase conductor.

3. The concentric conductors shall be No. 14 or No. 12 AWG bare, uncoated copper. They shall be evenly spaced and helically applied over the copper tape with a lay of not more than 12 times the cable diameter measured over the concentric conductors.

H. Outer Jacket

1. Jacket thickness shall be in accordance with ICEA S-93-639.

2. The jacket shall be low smoke, zero halogen material in compliance with the requirements of ICEA T-33-655, UL 1685, and ICEA S-93-639.

3. A thin polyester film shall be provided between the jacket and the concentric neutral conductors.

I. The cable shall be certified as passing the flame test specified in IEEE Standard 383, Article 2.5, and UL 1072. Cable shall also pass the flame and smoke release test specified in UL 1685.

J. Markings. Cables shall be identified with continuous markings in accordance with UL 1072 and AEIC CS8, Label Requirements. The markings shall include the name of the manufacturer, type, voltage rating, insulation and thickness and year of manufacture on the surface of the jacket. The cable markings shall also include the label "Sunlight Resistant Type MV-105 for Cable Tray Use". The identification shall remain legible for the life of the cable under normal conditions of operation.

2.03 35 kV CABLE TERMINATION AND SPLICE KITS

A. Termination kits shall meet Class 1 termination requirements and shall conform to the requirements of IEEE 48 and IEEE 383. The kits shall also meet the Cyclic Aging Test in accordance with IEEE 404. The kits shall consist, as a minimum, of heat-shrinkable stress control and outer non-tracking insulation tubings, a high relative permittivity stress relief mastic for insulation shield cutback treatment, a heat activated sealant for environmental sealing, and installation instructions. The kits shall accommodate any common form of cable shielding/construction without the need for special adapters or accessories and shall accommodate commercially available connectors.

B. 35 kV Cable Splicing Kits: Splices shall be either in-line or insulated splices that meet the requirements of IEEE 404.

1. In-line or Continuous Splicing: Splice kits shall be factory engineered kits containing all necessary components to reinstate primary cable insulation, metallic shielding and grounding systems and overall jacket to the equivalent of the cable itself. The splice kits shall be capable of properly splicing the specified 35 kV power cables. The kits shall be manufactured and tested in accordance with the requirements of IEEE 404, IEEE 383, and IEEE 48. The kits shall consist, as a minimum, of stress-control sleeve, splice insulating sleeve, abrasion-resistant outer jacketing sleeve, shielding braid and mesh, stress relief material, and auxiliary crimps. The splice kits shall be provided with the required cable splice copper connectors, approved by a nationally recognized testing laboratory for the applications, sized to fit the cables. Splices shall be suitable for continuous immersion in water.

2. Insulated Splicing: Splice kits shall be the same as the in-line splicing kits except that the metallic shielding and concentric neutral at each half of the splice joint shall be provided with cable with adequate and compatible insulation for complete isolation and separation. The kits shall consist of all the materials and accessories provided with the in-line splicing except shielding braid and mesh.

C. Cable termination and splice kits shall contain all components required for a complete splice or termination. The kits shall be supplied with solderless connector grounding accessory kits designed to maintain solid contact with the cable shield, and shall include the solderless connectors and solder-blocked tinned copper braid sized to match the cable shield ampacity. Splicing and termination kits shall be of the heat shrink type, and completed splices and terminations shall provide insulation properties equivalent to the insulation class of the cable they connect. Cable accessories shall be suitable to withstand the high-pot field test voltages with the specified duration and magnitude.

D. Cable preparation kits shall also be furnished for use in 35 kV power cable termination and splicing preparations. The kits shall consist of solvent wipes, abrasive strip and instruction card.

E. Furnish tools and other accessories required for a complete installation of cables, termination kits, and splice kits.

F. Lugs shall be compression type, two-hole, long barrel, seamless, tin-plated copper, and listed per UL 486A

2.04 SPARK GAP ASSEMBLY

A. Spark gap assembly shall be provided for 35 kV cable sheath overvoltage protection as indicated, complete with the following:

1. Spark Gap: Spark gaps shall be fabricated of bronze with stainless steel bolts, nuts, and washers. The spark gap assembly shall be mounted on a dielectric backboard. The backboard shall be glass polyester with high dielectric strength and of the type utilized in switchgear. The spark gap shall be provided with mechanism to allow adjustment of disk separation within the specified flashover voltage range. The spherical surfaces of the bronze disks of the spark gap assembly shall be braced and constructed for the following ratings:

a.	Current Withstand Rating (60Hz)	5 kA, 3 seconds
b.	Voltage Withstand Rating (60Hz)	13 kV RMS, 1 minute
c.	Flashover Voltage Range (kV)	adjustable from 4 kV. rms min, to 14 kV rms max.
d.	Flashover Voltage Factory Setting (kV)	7 kV rms

2. Gauge: Gauges shall be furnished, calibrated for different flashover voltages, to allow field setting of disk separation within the specified flashover voltage range of the spark gaps.

3. Spark Gap Enclosure: The spark gap enclosure shall be of preformed galvanized steel channels, angles, and side sheets braced and welded together to form an outdoor, free standing or panel mounted NEMA 3R metal enclosure, with front double hinged doors with padlock provisions. The enclosure NEMA classification shall be modified by vent holes located as indicated. The bottom of the enclosure shall have provisions for conduit entrance of the spark gap cables and for the bare copper grounding conductors. The spark gap enclosure shall not exceed 24 inches in depth, with height and width as required to mount the spark gaps, cables and all accessories and to maintain the indicated clearances. The enclosure shall form a rigid structure free of mechanical vibration and shall have steel channels as required to mount the dielectric backboard. The interior and exterior surfaces of the enclosures shall be primed and finish painted as indicated. The enclosure inside finish color paint shall be white and the outside finish color paint shall be gloss finish Munsell No. 2.5 G8/4 or equal. A nameplate as indicated shall be provided in the front of each enclosure.

4. Cable terminal lug shall be NEMA 1-hole compression type size to fit 250 kcmil, 5 kV EPR insulated cable. A 1/4 inch clear plastic or acrylic barrier shall be provided as indicated.

2.05 DC POWER CABLES

A. General

1. Ratings:

   a. Voltage Rating: Dc power cables shall be rated 5000 V dc, except for the high-voltage control power cable which shall be insulated for 2000 V dc minimum.

   b. Temperature Rating: The dc cables shall be designed to operate at a maximum conductor temperature of 90 ºC for normal operation, 130 ºC under emergency overload conditions, and 250 ºC under short circuit conditions, in accordance with ICEA S-96-659.

2. Markings: Cables shall be identified with continuous markings showing name of manufacturer, cable type, voltage rating, temperature rating, insulation type and thickness, and year of manufacture printed on the surface of the insulation. The identification shall be durable to the extent that it will remain legible for the life of the cable under normal conditions of operation.

3. Application: Use for dc power cables shall be as follows:

   a. Contact rail positive and negative return feeder cables - Positive feeder cables connect the dc feeder circuit breakers in the traction substations to the contact rail system, and the negative feeder cables connect the rectifier negative bus in the traction substations to the shunts at the running rails.

   b. Negative Grounding Device (NGD) cables – Connect between NGD and rectifier negative bus, and between NGD and substation ground grid.

   c. Contact rail jumper cables - used to connect adjacent sections of contact rail.

   d. Contact rail termination cables - connect the rosette at which the feeder or jumper cables are terminated to the contact rail.

   e. Contact rail shunt cables - used as jumper across contact rail expansion joints.

   f. High-voltage control power cable - used in control circuits exposed to the 1000 V dc potential, such as connections of load measuring resistors and contactors, wiring on the high-voltage side of isolation transducers, and connections of the load measuring circuit in the gap breaker stations to the running rail.

B. Contact Rail Positive and Negative Return Feeder Cables, Contact Rail Jumper Cables, and NGD cables: The cables shall be non-shielded, jacketed, Ethylene Propylene Rubber (EPR) insulation suitable for installation in metal raceways, cable trays, metallic and non-metallic conduits, and underground ducts. The cables shall be suitable for operation at normal voltage levels varying between 750 to 1250 Vdc, with transient over-voltages of up to 3000 Vdc. The cables shall also sustain operation when subjected to a 720Hz ripple voltage with a magnitude of approximately 100V peak-to-trough superimposed on the average dc voltage. The cables shall

be manufactured and tested in accordance with ICEA S-96-659 (NEMA WC71), AEIC CS8, UL 1072, ICEA T-33-655, IEEE-383, UL-1685, and ASTM B8.

1. Conductor: Conductor shall be 750 kcmil annealed uncoated copper, concentric, round, Class B stranding, conforming to ASTM B8.

2. Conductor Strand Shielding: An extruded semi-conducting thermosetting compound or tape shall be applied over the conductor in accordance with ICEA S-96-659. The material shall be compatible with the copper and insulating compound, uniformly and firmly bonded to the overlying insulation, and free stripping from the conductor. The shield shall have similar temperature coefficient of expansion as the EPR insulation.

3. Insulation: The EPR insulation compound shall be heat, moisture, flame, sunlight and ozone-resistant, corona resistant, and meet or exceed the electrical and physical characteristics specified in ICEA S-96-659. The cable shall have at least a 155-mil average insulation thickness. The minimum thickness at any point shall not be less than 90 percent of the average insulation thickness.

4. Jacket: The jacket shall be low smoke, zero halogen material in compliance with the requirements of ICEA T-33-655-1994 and UL-1685. In addition to the general requirement on marking, the cable shall be identified "LS" for low smoke in compliance with UL1685.

5. Cable Overall Diameter: The maximum overall diameter of the cable shall be 1.47 inches.

C. Contact Rail Termination Cables, and Contact Rail Shunt Cables: The cables shall be manufactured and tested in accordance with the requirements of ICEA S-96-659 (NEMA WC71), AEIC CS8, and UL 1072, as applicable to non-shielded single-conductor power cable. The cables shall conform to the following requirements:

1. Conductor Size: Contact rail termination cables shall be 350 kcmil and contact rail shunt cables shall be 500 kcmil copper.

2. Stranding: Class H rope lay stranding in accordance with the requirements of ASTM B173.

3. Insulation: Insulation shall be ethylene-propylene rubber thermosetting compound (EPR), witjh the same properties as that specified for the feeder cables, rated for 5,000 volts minimum, with an average insulation thickness of 155 mils.

4. Jacket: The outer jacket shall be made of chlorosulfonated polyethylene (CSPE) material conforming to NEMA WC71 (ICEA S-96-659) and UL 1072.

5. Construction: The contact rail termination cables shall be 42 inches long and shall be provided with preassembled right angle terminal lug on one end. Contractor shall determine length of the contact rail shunt cables, and cables shall be furnished with factory-assembled lugs on both ends.

6. Flame Test. The finished cable shall be certified as passing the flame test specified in UL 1072.

D. High-Voltage Control Power Cable: The cable shall be non-shielded, jacketed, with EPR insulation. The cable shall have a 90 degrees C temperature rating and a voltage rating of at least 2000 V. The cable shall be manufactured and tested in conformance with NEMA WC70 (ICEA S-95-658) and UL44, and shall conform to the following requirements:

1. Conductors: Conductors shall be No. 6 AWG soft or annealed copper, concentric, round, Class B stranded.

2. Insulation: Insulation compound shall be EPR type, with average thickness not less than 70 mils. The minimum thickness at any point shall be not less than 90 percent of the average.

3. Jacket: The outer jacket shall be made of chlorosulfonated polyethylene material conforming to ICEA S-95-658.

4. Flame Test. The finished cable shall be sunlight resistant, suitable for installation in wet or dry locations, and shall be certified as passing the flame test specified in UL 44.

E. Cable Connection Assemblies: Cable connection assemblies shall be furnished for termination of contact rail termination and shunt cables.

1. Contact Rail Termination Cable Connection Assembly.

a. Contact rail connection plate shall be aluminum 6101-T6, dimensioned and drilled as indicated.

b. Lugs and Welding Molds: One end of flexible jumper cable shall be pre-assembled with right angle lug. Tinned copper lugs with two-hole NEMA type configuration and welding molds shall be the product of a standard manufacturer of exothermic welding materials. Welding shall be performed in strict conformance with the manufacturer's printed recommended procedures and instructions. The welding process shall not damage the tin coating on either surface of the outstanding leg of the lug.

c. Feeder and jumper cable connection blocks shall be designed to join 350 kcmil stranded cables to 750 kcmil stranded cables. Cable adapter shall be on one piece construction. Lugs for 350 kcmil and 750 kcmil cables shall be included with connection block. Connection block and cable lugs shall be as indicated.

d. Fasteners for connection of cable to contact rail connection plate: Bolts shall be 1/2 inch diameter, ASTM A325, Type 1, cadmium plated in accordance with ASTM B766. Locknuts and washers shall be ASTM A325, Type 1, cadmium plated in accordance with ASTM B766, sized to fit bolts.

2. Contact Rail Shunt Cable Connection Assembly. The assembly shall comply with the requirements specified for contact rail termination cable connection assemblies, except as follows:

a. Connection plate shall be aluminum 6061-T6, dimensioned and drilled as required.

b. The two ends of the shunt cable shall be pre-assembled with right angle lugs.

c. Shunt cable trough raceway, 6 inch fiberglass conduit, shall be provided in lengths as required.

d. The assembly shall consist of 7-500 kcmil cables.

F. DC Power Cable Accessories

1. Conduit Sealing Fittings/Bushings: After dc cable installation, conduits shall be sealed with bushings at each end. Bushings shall consist of slotted PVC coated steel discs, neoprene sealing ring, and stainless steel socket head cap screws and washers. The complete bushing assembly shall be provided with the appropriate number of holes to plug/seal the stub-ups while accommodating the size and number of cables which emerge from the conduit. Spare conduits shall be sealed with blank bushings without holes.

2. Terminal Lugs:

a. Provide compression type terminal lugs with two-hole NEMA type configuration for termination of the cables at the switchgear, at the NGD, and at the signal bonds on the tracks.

b. Load measuring cables shall be terminated using two-hole NEMA lugs on the DC switchgear side, and 3/8 inch plug terminals for bonding at the running rail side.

2.06 MISCELLANEOUS MATERIALS

A. Fireproofing Materials: Fireproofing materials shall be suitable for the voltage ratings specified for cables. The fireproofing tape shall consist of a flexible, conformable fabric having one side coated with a flame retardant, flexible, polymeric coating or a chlorinated elastomer not less than 0.050 inch thick or both, and shall weigh not less than 2.5 pounds per square yard. The tape shall be noncorrosive to cable sheath, shall be self-extinguishing, and shall not support combustion. The tape shall not deteriorate when subjected to oil, water, gases, salt water, sewage, and fungus.

B. Tie Wrap: Ultraviolet resistant nylon tie wrap, in sizes as required, with no metal parts shall be provided to tie feeder cables to support structures, to bundle the power cables, and where required for other uses.

C. Cable Lubricants: Cable lubricants shall be Polywater J manufactured by American Polywater, Slip X-300 manufactured by American Colloid, Wire Lube and Aqua Gel manufactured by Ideal Industries, or equal.

D. Cable Identification Tags: Non-metallic circular discs with two holes. System voltage, cable size, and feeder identification shall be stamped or embossed on each tag in characters of 1/4-inch minimum height. These ID tags shall be used on both ends of each traction power cable.

E. End Cap for Cables: End caps for cables shall be flame retardant heat Shrinkable manufactured by Raychem, Inc., Sigmaform Corporation, or equal. End caps shall be used for temporary sealing of cable ends.

F. Raceways: Refer to Section 20 50 13, Raceways for Facility Services for required raceways and appurtenances.

G. Grounding Materials: Furnish grounding materials in accordance with Section 26 05 26, Grounding and Bonding for Electrical Systems.

H. Cable Racks, Channel Inserts, and Supports: Cable racks, supports, and fasteners shall be furnished in accordance with Section 20 50 13, Raceways for Facility Services .

I. Cable Insulators for Installation on Racks or Channels: Porcelain with a minimum of two inches of bearing surface in the direction parallel to the cable.

J. Sealing Fittings for 35 kV Cables: Conduits for 35 kV cables, including spare conduits shall be sealed with water-tight expandable type fittings.

PART 3 - EXECUTION

3.01 INSTALLATION

A. General:

1. Cables shall be installed in raceways. Cable installation shall be in accordance with the recommended procedures by the cable manufacturers on cable installation, cable pulling, and sidewall pressure calculations and methods.

2. Cable Pulling:

a. Manholes, splice and pull boxes, and conduits shall be thoroughly cleaned, dried, and free from debris prior to cable pulling. Pull wire brush, swab, and mandrel through conduit in a manner which will remove extraneous matter. Install pulleys on pulling irons where provided, otherwise temporary blocking and pulleys shall be installed and confirmed.

b. Cables shall be pulled in the direction that exerts the least tension on the cables. Cables shall be pulled only in one direction. Pull cable directly into raceway from coils or reels. Multiple cables in the same conduit/duct shall be pulled at the same time. Do not install cable which has been laid on dirt. Do not pull cable with its end open. Maintain rubber tape on cable ends. Use cable lubricants where necessary.

c. If cable has been pulled by pulling grips, remove damaged cable ends as soon as cable has been installed.

d. Seal ends of installed cable with heat shrinkable end caps to prevent entry of moisture.

e. Identify ends of cable before making connections or terminations.

f. Terminate each end of conduit with sealing bushing. Ensure that sealing bushing holds cable against movement in both directions, and makes a watertight seal.

g. Tie wrap power cables after installation.

3. Pulling Equipment and Pulling Tension: Contractor shall have suitable pulling equipment on hand that is confirmed to be in good working order. A dynamometer shall be used to measure the pulling tensions. Values obtained shall be recorded and incorporated into the Cable Test Report. The cable manufacturer's recommended maximum pulling tension and sidewall pressure values shall not be exceeded during cable pulling.

4. Cable Splices: Splices shall be suitable for continuous immersion in water and shall only be made in splice boxes or manholes. The splices shall be installed in accordance with the splice kit manufacturer's recommended installation procedures.

5. Cable Supports:

   a. Cables shall be routed and supported in trenches, pullboxes, manholes, and switchgear cubicles as indicated.

   b. As a minimum, cables in manholes shall be supported at 4-foot maximum intervals with support cradles, saddles, or cable trays.

   c. Cables in concrete trenches under the substations and gap breaker stations shall be installed and supported by fiberglass cable trays.

   d. Cables entering the top of switchgear equipment in substations or gap breaker stations shall be supported by cable trays or conduits.

   e. Cables entering the switchgear cubicles from the bottom shall be supported by cable support terminators or with basket-type cable grips of the type that utilizes support rings. Cables entering 1000V dc switchgear cubicles shall be supported as described in Section 34 21 25, DC Switchgear.

6. Cable Fireproofing: Dc positive cables and 35 kV power cables routed through substation and gap breaker station trench cable trays, manholes, pullboxes, or chases shall be fireproofed as follows:

   a. Strips of fireproofing tape approximately 1/16 inch thick by 3 inches wide shall be wrapped tightly around each cable spirally in half-lapped wrapping, or in two butt-joined wrappings with the second wrapping covering the joints in the first. For manholes and pull boxes, the tape shall be applied with the coated side toward the cable and shall extend one inch into the ducts. To prevent unravelling, the fireproofing tape shall be random wrapped the entire length of the fireproofing with pressure sensitive glass cloth tape.

   b. Spliced cables shall be fireproofed in accordance with the paragraph above, except with fireproofing extending only two feet beyond the spliced area on each end. Irregularities of the cable, such as at splices, shall be evened out with insulation putty before the tape is applied.

7. Cable Identification: Cable identification tag shall be affixed to each cable at each entry to and exit from each manhole, pullbox, trench, and switchgear assembly.

8. Cable Terminations: Terminations shall be installed using materials and methods as indicated or specified herein. Terminations shall be installed per the written instructions of the cable manufacturer and the termination kit manufacturer.

9. Electrical Connectors: Tighten electrical connectors and terminals in accordance with the manufacturer's published torque-tightening values. Where manufacturer's torque requirements are not indicated, tighten connectors and terminals to comply with tightening toques specified in UL 486A.

B. 35 kV Power Cables

1. Cable Splices:

a. In-Line or Continuous Splicing: Contractor shall splice conductor with copper connector, primary cable insulation, metallic shielding and grounding systems with solderless connector and solder-blocked tinned copper braid and overall jacket to the equivalent of the cable itself.

b. Insulated Splicing: Contractor shall splice the conductor primary cable insulation, and overall jacket. The metallic shielding and concentric neutral conductors at the splice joint shall be left isolated and insulated and brought out at opposite end of the spliced assembly for connection to the spark gap assembly. The insulated splice shall be constructed such that the 15 minute withstand voltage across the sheath or shield isolation is 35 kV dc. The Contractor shall perform a withstand voltage test on a prototype insulated splice and submit report 60 days prior to start of first insulated splicing of cables.

2. Cables Installed in Splice Boxes: Splices on different phases/cables of a feeder shall be staggered so that there is no physical overlap between the splices. Should the splices overlap, barriers or separators between splices shall be provided. Splices shall be fireproofed.

3. The 35 kV cable minimum bending radius shall be 36 inches in manholes, raceways, and pull boxes. Deviation may be permitted for unusual installation conditions when approved by the Engineer.

4. Grounding: Concentric neutral conductors and the metallic shielding of each 35 kV power cable terminated at the switchgear end shall be grounded. Install and terminate the concentric neutral conductors and metallic shielding in accordance with the approved Contractor's installation details and Section 26 05 26, Grounding and Bonding for Electrical Systems.

5. After field testing, the connections of the 35 kV cable to the bus shall be furnished with isolating, corona-resistant, pre-formed removable boot conforming to standard industry practice.

C. 34.5 kV Spark Gap Assembly:

1. Level and secure the panels to the mounting pads.

2. Install and terminate conduits from the splice box location to the bottom of the Spark Gap panel.

3. Install and terminate cables between spark gap and the spliced cables.

D. DC Power Cables

1. Cables installed in the same raceway shall be of the same polarity.

2. The minimum bending radius for dc power cables shall be 36 inches unless otherwise indicated or approved by the Engineer.

3. Terminate power cables with compression lugs.

E. Contact Rail Shunt Cables:

1. Assemble shunt cable connection plates on contact rails using 3/4 inch aluminum pin bolts and collars.

2. Pull in shunt cables in the protective trough per approved design. No part of the cable shall rest on concrete, ballast, or ground.

3. Connect/terminate each end of each cable to connection plates using 1/2 inch bolts, washers, and nuts. Bolts, washers, and nuts shall be cadmium-plated in accordance with ASTM B766.

F. Contact Rail Termination Cables:

1. Assemble flexible jumper cable connection plates on contact rail using 3/4 inch aluminum pin bolts and collars.

2. Terminate 350 kcmil flexible jumper cable at connection plates.

3. Minimum ground clearance of flexible jumper cable shall be 2 inches.

3.02 TESTING

A. General. Testing shall be performed in accordance with Section 01 45 24, Testing Program Requirements.

B. Factory Testing:

1. 35 kV Power Cables

a. Testing of completed cables shall be performed in accordance with ICEA S-93-639, ICEA S-94-649, ICEA S-97-682, and UL 1072. EPR compound qualification testing shall be in accordance with ICEA S-94-649 and ICEA S-97-682.

b. Each reel of completed cable shall pass the partial discharge (corona) extinction level test per AEIC CS8.

c. Production sampling tests in accordance with AEIC CS8 shall be performed on the cables.

2. 35 kV Termination and Splice Kits: Factory testing of termination and splice kits shall be performed in accordance with the requirements of IEEE 48 and IEEE 404. The design tests for qualifying terminations and splices shall be in accordance with the requirements of IEEE 383.

3. Spark Gap Assembly:

a. The following factory tests shall be performed on a prototype assembly. Tests shall be performed by the Contractor or an independent qualified testing agency approved by the Engineer. Portions of the prototype assembly may be refurbished and used as part of the production assemblies, subject to approval by the Engineer. The factory tests on the prototype shall consist of:

1) Current Withstand Test: The spark gap disks shall be tightened against each other and a 60 Hz current of 5000 amperes shall be applied through the assembly for three seconds. Localized damage to the disc surface shall be repaired. If there is evidence of permanent mechanical deformation of the assembly, the Contractor shall modify the assembly and repeat the test without additional cost to the District.

2) Insulation Voltage Withstand Test: The spark gap disks shall be separated. An AC high potential of 35 kV RMS shall be applied between the electrodes and ground for one minute to verify the withstand capability of the assembly.

3) Spark Gap Adjustment Test: Tests shall be performed to verify the flashover voltage range of the device. The temperature and humidity during the test shall be recorded. An AC high potential tester, adjustable to accommodate the voltage range of the device shall be utilized. The minimum flashover voltage shall be applied across the spark gap, and adjustments shall be made on the sphere separation until flashover occurs. The same test shall be performed at the maximum flashover voltage rating. Disk separation shall be recorded for both the minimum and maximum flashover voltage test. Final test shall be performed at the flashover voltage setting. Voltage equal to the flashover voltage setting shall be applied across the gap, and the gap adjusted until flashover occurs. This test shall be repeated 10 times, recording the disk separation on each test with the average separation to be recorded at the end of the tests.

4) Simulated Operation Test: Under 34.5 kV circuit fault conditions, the maximum anticipated voltage across the spark gap is 15.6 kV RMS with a ground return current of 3500 amperes. For purposes of the simulated operations test, the applied voltage shall be 15 kV RMS. The test circuit shall be capable of driving 3500 amperes through the spark gap assembly. The test circuit shall include a circuit breaker capable of interrupting the current such that the test duration is limited to 5 seconds. For this test, the spark gap disk separation shall be set at the flashover voltage setting. Voltage to ground, voltage across the gap, and current shall be recorded continuously during the

test. The arc shall be contained between the electrodes and shall not migrate to the insulators for the duration of the test.

b. Spark Gap Assembly Production Tests: For each spark gap assembly, complete in its enclosure, perform the insulation voltage withstand test as specified for the prototype, and spark gap adjustment tests as follows: The gap shall be set at the flashover voltage setting, with the voltage across the gap adjusted until flashover occurs. The test voltage at flashover shall be recorded.

4. DC Power Cables: Factory testing of completed cable shall be performed in accordance with NEMA WC71 (ICEA S-96-659) and UL 1072 for the 5 kV rated power cables; and in accordance with NEMA WC70 (ICEA S-95-658) and UL 44 for the 2 kV rated control power cables.

C. Field Testing - 35 kV Power Cables:

1. Insulation Resistance and Polarization Index Tests:

a. Ground cable shields before doing insulation resistance and high potential tests.

b. Measure the cable insulation's resistance and polarization index following cable installation using insulation resistance tester (megohmmeter). The megohmmeter shall be battery powered, with selectable test voltage of up to 5000 V, feature full-scale range of not less than 20 Gohms, and shall have a built-in capability for direct measurement of the polarization index.

c. The insulation resistance (IR) shall be measured 1 minute after the application of the test voltage, while the polarization index (PI) shall be calculated from two time-resistance readings: one taken after 1 minute and the other taken 10 minutes from the start of the test. The temperature shall be recorded as well, and the measured insulation resistance shall be normalized to a base temperature of 20 degrees C. The IR and PI tests shall be performed using 5000 V test voltage.

d. The minimum acceptable insulation resistance and polarization index values shall be based on ICEA and cable manufacturer's recommendations, and shall be subject to the Engineer's approval.

e. Perform the IR and PI tests twice: first, after cable installation, but before splicing or terminating; and second, following the splicing and terminating, but prior to the high potential (hi-pot) test.

f. Carry out the IR and PI tests on each cable, with the test voltage applied between the phase conductor and grounded concentric neutral.

g. Prior to and after each test, discharge the cable capacitance.

h. Follow appropriate safety precautions during the tests, such as handling megohmmeter terminals and cable conductors through insulating gloves.

i. If the splicing or terminating is not performed immediately after cable installation, carry out another insulation resistance and polarization index tests just before splicing or terminating.

2. High Potential (Hi-Pot) Test:

   a. Perform tests with a dc hi-pot tester specifically designed for the purpose, with overload or current-limiting devices to limit a possible short circuit current.

   b. Test each cable installation after all splices are complete. No equipment shall be connected to the cable system during tests.

   c. All cables shall be subjected to the high-voltage dc test of IEEE 400 modified as follows:

      1) The final test voltage shall be 100 kV. Confirm that this test voltage and its duration are acceptable for the splices and terminations, by obtaining such assurance from the respective accessory manufacturer.

      2) Raise the voltage gradually in 10-percent steps to 80 percent of the final, then in 5-percent steps to the 100-kV final level, which shall remain on for 15 minutes. Take current readings at each step after the current has stabilized. Plot the current readings on graph paper. If insulation breakdown is indicated at any point during the test by a sudden increase in current, discontinue the test; locate and remedy the problem and repeat the test from the beginning. If a second breakdown is indicated, replace the cable at no additional cost to the District.

3. Shield Ground Test: Perform a shield-to-ground test with a megohmmeter using 1000 test voltage. Disconnect shield grounds at the equipment terminations prior to the test. Take jacket resistance readings between the equipment ground bus (or ground terminals) and the cable shield to confirm the integrity of the jacket, and that the shield is isolated from ground.

4. Conductivity Test at Splices and Terminations: Clean and polish cable conductor surface before the conductor is compressed into the cable termination lug or splice connector. After the compression and before the insulation system is installed, verify power circuit continuity by measuring the resistance of the connection using a battery operated digital low-resistance ohmmeter. Record and report the resistance value in the Cable Field Test Report. The electrical resistance of the connection shall not exceed 5 micro-ohms with 10 A test current applied, or shall meet the cable accessory manufacturer's recommendation.

D. Field Testing: 5 kV Power Cables:

1. Cables shall be attached to dc switchgear cable supports, but not terminated, prior to conducting insulation resistance and high potential tests.

2. Insulation Resistance and Polarization Index Tests: The tests shall be similar to that specified for the 35 kV power cables above, except that the 5000-volt test voltage shall be applied between conductor and ground.

3. High Potential Test: The tests shall be as specified for the 35 kV power cables above, except as follows:

a. The final test voltage shall be 28 kV, and shall be applied between conductor and ground.

b. The voltage shall be raised gradually in 10-percent steps to 80 percent of the final, then in 5-percent steps to 28 kV, which shall remain on for 15 minutes.

4. Conductivity Test at Splices and Terminations: The test shall be the same as specified for the 34.5 kV cables.

D. Cable Failure: If failure occurs on any specified field test, the Contractor shall correct the deficiency and retest. If the test fails again, the Contractor shall replace the entire cable segment at no extra cost to the District.

END OF SECTION 34 22 23