SECTION 34 23 13

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

A. Measurement: Traction power cables will be measured for payment as a lump sum unit acceptably installed and tested for compliance.

B. Payment: Traction power cables will be paid for at the Contract lump sum price for traction power cables or as part of the lump sum price for Traction Power System, as determined by the lump sum measurement specified above, as indicated in the Bid Schedule of the Bid Form.

1.03 REFERENCE STANDARDS

A. Association of Edison Illuminating Companies (AEIC):

1. AEIC CS5 — Specifications for Thermoplastic and Cross Linked Polyethylene Insulated Shield Power Cables Rated 5 through 35 kV

2. AEIC CS6 — Specifications for Ethylene Propylene Rubber Insulated Shielded Power Cables Rated 5 through 69 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-66-524 (NEMA WC-7)	Cross Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
2.	ICEA S-68-516 (NEMA WC-8)	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
3.	ICEA T-33-655 - 1994	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 Fire Protection Association (NFPA):

1.	NFPA 130	Fixed Guideway Transit Systems

H. Underwriters Laboratories Inc. (UL):

1.	UL 44	Rubber-Insulated Wires and Cables
2.	UL 1072	Medium-Voltage Power Cables
3.	UL 1685	Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables 1992

I. 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:

1. Submit shop drawings and cable section details for materials and cable assembly construction no later than 90 days prior to start of cable manufacturing.

2. The shop drawings shall include equipment design and 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.

C. Product Data: Submit data for power cables and associated materials.

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 test program plan, procedures, and reports as specified in Section 01 45 24, Testing Program Requirements.

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 fire proofing;

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 shall be signed by the Contractor. 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 designed to operate at a conductor temperature of 90 ºC for normal operation, 130 ºC under emergency conditions, and 250 ºC under short circuit conditions in accordance with AEIC CS6 Section A.

B. Power cables shall be suitable for operation in the specified environmental conditions.

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

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-68-516 (NEMA WC8).

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 AEIC CS6.

E. Insulation

1. The insulation shall be EPR and shall meet all the requirements of ICEA S-68-516 (NEMA WC8).

2. The insulation shall have a minimum average thickness of 420 mils, based on 133 percent level in accordance with AEIC CS6. 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 AEIC CS6.

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. The jacket shall be low smoke, zero halogen material in compliance with the requirements of ICEA T-33-655-1994 and UL 1685.

2. 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.

J. Markings. Cables shall be identified with continuous markings in accordance with UL 1072 and AEIC CS6, 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-90 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:

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 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 the metallic shielding and concentric neutral at each half of the splice joint shall be provided with cable with compatible insulation materials 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. The termination and splice kits shall be supplied with solderless connector grounding accessory kits designed to maintain solid contact with the cable shield. Each accessory kit shall include the solderless connectors and a solder-blocked tinned copper braid sized to match the cable shield ampacity.

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.

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 No. 1/0 AWG, 5 kV XLPE insulated cable as specified in Section 26 05 24, Low and Medium Voltage Wires and Cables. A 1/4 inch clear plastic or acrylic barrier shall be provided as indicated.

2.05 DC POWER CABLES

A. General

1. Voltage Rating: Dc power cables shall be rated 5000 V dc, except for the load measuring circuit cable which shall be insulated for 2000 V dc minimum.

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

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

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

e. Load measuring circuit cable - used to connect the load measuring circuit in the gap breaker stations to the running rail.

B. Contact Rail Positive and Negative Return Feeder Cables, and Contact Rail Jumper Cables: The cables shall be non-shielded, jacketed, Ethylene Propylene Rubber (EPR) insulation suitable for installation in metal wireways, cable trays, metallic and non-metallic conduits, and underground ducts. The cables shall be operated between 750 to 1250 Vdc with transient over-voltages of up to 3000 Vdc. The cables shall be subjected to a 720Hz ripple voltage with a magnitude of approximately 100V peak-to-peak and to the rectifier bridge commutation transients of 500 to 900V at 720Hz. The cables shall be manufactured and tested in accordance with ICEA S-68-516 (NEMA WC8), AEIC CS6, ICEA T-33-655-1994, 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 shall be applied over the conductor in accordance with AEIC CS6. 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 and corona resistant. The cable shall have at least a 90-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 NEMA WC8 (ICEA S-68-516), AEIC CS6, and UL 1072, as pertinent 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), rated for 5,000 volts minimum, with a minimum thickness of 90 mils.

4. Jacket: Jacket shall be chlorosulfonated polyethylene conforming to NEMA WC8 (ICEA-S-68-516).

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 assembled cable shall be UL-listed conforming with UL 44 flame test or certified as passing the flame test specified in IEEE 383, Section 2.5.

D. Load Measuring Circuit Cable to Running Rails: The cable shall be non-shielded, non-jacketed, with cross-linked thermosetting polyethylene insulation. The cable shall have a voltage rating of at least 2000 V. The cable shall be manufactured and tested in conformance with NEMA WC7 (ICEA S-66-524) and AEIC CS5. The cable shall conform to the following requirements:

1. Conductors: Conductors shall be No. 6 AWG 19 strands annealed copper, concentric, round, Class B stranded.

2. Insulation: Insulation compound shall be heat, moisture, flame resisting, sunlight and ozone resisting, filled cross-linked polyethylene. The minimum thickness at any point shall be not less than 90 percent of the specified average. Insulation shall meet the requirements of NEMA WC7 (ICEA S-66-524). Insulation shall be certified as passing the flame test specified in IEEE 383.

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, size 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.

E. 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 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 70 26, Common Materials and Methods for Electrical Systems, and 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 70 26, Common Materials and Methods for Electrical Systems

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.

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.

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.

B. 35 kV Power Cables

1. Cable Splices: The splices shall either be an in-line or an insulated splice and shall meet the requirements of IEEE 404.

   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-68-516 and UL 1072.

b. Each reel of cable shall pass the partial discharge (corona) extinction level test per AEIC CS6.

c. Production sampling tests in accordance with AEIC CS6 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 WC7 (ICEA S-66-524), NEMA WC8 (S-68-516), and UL 1072.

C. Field Testing:

1. 35 kV Power Cables:

a. Insulation Resistance Test:

1) Insulation resistance test should be measured on all cables between conductor to grounded shield and shield to ground using a 2500 volt dc megger. Readings shall be taken one minute after voltage is applied. The minimum acceptable resistance shall be 40 megohms per 1000 feet.

2) The test shall be made after cable installation, but before splicing or terminating.

3) If the splicing or terminating is not performed immediately after cable installation, second insulation resistance test shall be made just before splicing or terminating.

b. High Voltage Test:

1) Tests shall be performed with a dc tester specifically designed for the purpose, with overload or current-limiting devices to limit short circuit current.

2) Each cable installation shall be tested after all splices and terminations are complete. No equipment shall be connected to the cable system during tests.

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

a) The test voltage shall be 80 percent of the original factory test voltage as specified in AEIC CS6, Table B1.

b) The test interval at final test voltage shall be 15 minutes.

c) The voltage shall be raised gradually in 10-percent steps to 80 percent of 124 kV, then in 5-percent steps to 124 kV, which shall remain on for 15 minutes. Current readings shall be taken at each step after the current has stabilized. The current readings shall be plotted on graph paper. If insulation breakdown is indicated at any point during the test by a sudden increase in current, the test shall be discontinued; the Contractor shall locate and remedy the trouble and repeat the test from the

beginning. If second breakdown is indicated, the cable shall be replace0d at no additional cost to the District.

c. Shield Ground Test: A shield-ground test shall be done with a 2,500-volt dc insulation resistance test set. Shield ground shall be disconnected at the equipment terminations. Insulation resistance readings shall be taken between the equipment ground bus or ground terminals and the cable shields to confirm that the shield is isolated from ground.

2. 5 kV DC Power Cables

a. Insulation Resistance Test: The tests shall be as specified for the 35 kV power cables above, except as follows:

1) Insulation resistance test shall be measured between conductor and ground using an electronic 5000 volt high-potential tester.

2) Readings in excess of 60 microamps will not be acceptable.

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

1) The test voltage shall be 80 percent of the original factory test voltage as specified in IEEE-400, Table 1.

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

D. Cable Failure: If failure occurs on any specified field test, the Contractor shall correct 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 23 13