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ELECTRICAL POWER CABLE, INSTALLATION OF, SPECIFICATION FOR

ENGINEERING DEVELOPMENT DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

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Approved:

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JOHN F. KENNEDY SPACE CENTER, NASA

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ABBREVIATIONS AND ACRONYMS

ac	alternating current
ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
AWG	American Wire Gage
°C	degree Celsius
°F	degree Fahrenheit
EPR	ehtylene-propylene-rubber
ft	foot, feet
IEEE	Institute of Electrical and Electronic Engineers
in	inch, inches
kPa	kilopascal
KSC	John F. Kennedy Space Center
kV	kilovolt
lb	pound
lb/in	pound per inch
lb/in^2	pound per square inch
m	meter
MI	mineral-insulated
mm	millimeter
MPa	megapascal
mΩ	milliohm
N	newton
NASA	National Aeronautics and Space Administration
NEC	National Electrical Code
NEMA	National Electrical Manufacturer's Association
NFPA	National Fire Protection Association
N/mm	newton per millimeter
OD	outside diameter
PVC	polyvinyl-chloride
SPEC	specification
UL	Underwriter's Laboratories

JOHN F. KENNEDY SPACE CENTER, NASA

ELECTRICAL POWER CABLE, INSTALLATION OF, SPECIFICATION FOR

1. SCOPE

This specification establishes the requirements for installation and testing of 60-hertz alternating current (ac) power cables by support contractors at the John F. Kennedy Space Center (KSC). Open-wire and building-wire construction are not within the scope of this document.

2. APPLICABLE DOCUMENTS

The following documents form a part of this document to the extent specified herein. When this document is used for procurement, including solicitations, or is added to an existing contract, the specific revision levels, amendments, and approval dates of said documents shall be specified in an attachment to the Solicitation/Statement of Work/Contract.

2.1 Governmental.

2.1.1 Specifications.

John F. Kennedy Space Center (KSC), NASA

KSC-SPEC-E-0018	AC Power Wire, General Purpose, Single Conductor, 600V, 60 Hertz, Procurement of, Specification for
KSC-SPEC-E-0019	AC Power Cable, General Purpose, Multi-Conductor, 600V, 60 Hertz, Procurement of, Specification for
KSC-SPEC-E-0020	AC Power Cable, Mineral Insulated, 600V, 60 Hertz, Procurement of, Specification for
KSC-SPEC-E-0021	AC Power Cable, Interlocked Armored, 600V, 60 Hertz, Procurement of, Specification for

KSC-SPEC-E-0022	AC Power Cable, 5,000V, 60 Hertz, Procurement of, Specification for
KSC-SPEC-E-0023	AC Power Cable, 15,000V, 60 Hertz, Procurement of, Specification for

2.1.2 Drawings.

John F. Kennedy Space Center (KSC), NASA

79K06110	MI Cable Termination, Procedure for

(Copies of specifications, drawings, and publications required by contractors in connection with specific functions should be obtained from the procuring activity or as directed by the Contracting Officer.)

2.2 Non-Governmental.

American National Standards Institute (ANSI)

ANSI C119.1	Electric Connectors - Sealed Insulated Underground Connector Systems Rated 600V

(Application for copies should be addressed to the American National Standards Institute, 1430 Broadway, New York, NY 10018.)

American Society for Testing and Materials (ASTM)

ASTM A123	Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shapes, Plates, Bars and Strip
ASTM A153	Zinc Coating (Hot-Dip) on Iron and Steel Hardware
ASTM A386	Zinc Coating (Hot-Dip) on Assembled Steel Products
ASTM A475	Zinc Coated Steel Wire Strand (for guys/messengers/span wires/similar applications)

ASTM B1	Hard-Drawn Copper Wire
ASTM B3	Soft or Annealed Copper Wire
ASTM B8	Concentric-Lay-Stranded Copper Conductors, Hard, Medium Hard, or Soft
ASTM B228	Concentric-Lay-Stranded Copper-Clad Steel Conductors
ASTM B230	Aluminum Wire EC-H19 for Electrical Electrical Purposes
ASTM B231	Aluminum Conductors, Concentric-Lay- Stranded
ASTM B262	Aluminum Wire ED-H16 or H26 for Electrical Purposes
ASTM B323	Aluminum Wire, ED-H14 or H24, for Electrical Purposes
ASTM D574	Ozone-Resisting Insulation for Wire and Cable
ASTM D2301	Vinyl Chloride Plastic Pressure-Sensitive Electrical Insulating Tape

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

Institute of Electrical and Electronics Engineers (IEEE)

IEEE 48	High Voltage AC Cable Terminations
IEEE C2	National Electrical Safety Code

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, PO Box 1331, Piscataway, NJ 08855-1331.)

National Fire Protection Association (NFPA)

NFPA 70	National Electrical Code (NEC) Purposes
NFPA 780	Installation of Lightning Protection Systems

(Application for copies should be addressed to the National Fire Protection Association, 60 Batterymarch Street, Boston, Massachusetts 02110.)

National Electrical Manufacturer's Association (NEMA)

NEMA FB 1	Fittings, Cast Metal Boxes, and Conduit Bodies for Conduit and Cable Assemblies
NEMA WC 3	Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
NEMA WC 5	Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
NEMA WC 7	Cross-Linked Thermosetting Polyethylene Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
NEMA WC 8	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

(Application for copies should be addressed to NEMA Publication Sales, 2101 L Street, NW, Suite 300, Washington, DC 20037-1526.)

Underwriter's Laboratories (UL)

UL	Electrical Construction Materials List
UL 486C	Splicing Wire Connectors

UL 510	Polyvinyl Chloride, Polyethylene and Rubber Insulating Tape
UL 514B	Fittings for Conduit and Outlet Boxes

(Application for copies should be addressed to Underwriter's Laboratories, Inc., Publications Stock, 333 Pfingsten Road, Northbrook, IL 60062-2096.)

US Department of Agriculture, Rural Utilities Service

Informational Publication 202-1	List of Materials Acceptable for Use on Systems of RUS Electrification Borrowers

(Application for copies should be addressed to the Superintendent of Documents, US Government Printing Office, Washington, DC 20402-9325.)

3. REQUIREMENTS

3.1 Materials and Equipment. - Materials and equipment shall be as specified herein and as shown on the drawings and shall be the products of manufacturers regularly engaged in the manufacture of such products. Items of equipment shall essentially duplicate equipment that has been in satisfactory use at least 2 years prior to utilization of this specification and shall be supported by a service organization that is, in the opinion of KSC, reasonably convenient to the site. Where two or more units of the same class of equipment are required, these units shall be of the same manufacturer and shall be directly interchangeable when of the same rating.

3.1.1 Materials. - Materials may include, but shall not be limited to, those listed in table 1 and shall conform to Underwriter's Laboratories (UL) Electrical Construction Materials List. Other materials may be used with the approval of KSC. The inclusion of specific materials on approved design drawings shall constitute approval by KSC for their use in accordance with the requirements of this specification.

3.1.2 Equipment. - Equipment used to install power cables shall include necessary hand tools, power tools, and portable and mobile tools and devices, including that equipment designed specifically to safeguard installation personnel from death or injury.

Table 1. Materials

Materials	Specification
Cable (Type SO, STO, W, G, or USE), 600-volt	KSC-SPEC-E-0019
Cable (mineral-insulated), 600-volt	KSC-SPEC-E-0020
Cable (interlocked armored), 600-volt	KSC-SPEC-E-0021
Cable (Type EPR), 5,000-volt	KSC-SPEC-E-0022
Cable (Type EPR), 15,000-volt	KSC-SPEC-E-0023
Cables, miscellaneous	NEMA WC 3
Conductors, aluminum, concentric-lay-stranded	ASTM B231
Conductors, copper, concentric-lay-stranded, hard drawn	ASTM B8
Conductors, solid hard-drawn	ASTM B1
Connectors, wire, pressure	UL 486C
Fittings, cable and conduit	NEMA FB1
Insulation, ozone-resisting for wire and cable	ASTM D574
Splice, conductor	UL 486C
Tape, plastic	ASTM D2301
Tape, rubber	UL 510
Wire, soft or annealed copper	ASTM B3
Wire, hard-drawn aluminum	ASTM B230
Wire, three-quarter hard aluminum	ASTM B262
Wire, aluminum EC-H14 or EC-H24	ASTM B323
Wire (Type USE), 600-volt	KSC-SPEC-E-0018

3.2 Workmanship. - All cables shall be installed in a workmanlike manner, fully in accordance with the applicable drawings, the manufacturer's recommendations, and the highest professional standards. In all cases of conflict between the requirements of the applicable drawings and the manufacturer's recommendations, the requirements of the applicable drawings shall govern. All cable installations shall be performed by skilled personnel who are fully qualified in accordance with the requirements of 3.3.

3.3 Qualifications of Cable Splicers.

3.3.1 Basic Requirements. - All cable splices and terminations shall be made by journeyman electricians and/or journeyman cable splicers who have had a minimum of 2 years experience as journeymen in the splicing and termination of power cable.

3.3.2 Methods of Qualifying. - Cable splicers can qualify by passing certain tests, by presentation of documented evidence of experience, or by both.

3.3.2.1 Tests. - In lieu of the experience required by the provisions of 3.3.1, a journeyman electrician and/or cable splicer may qualify for work performed in accordance with the requirements of this specification by submitting to extensive tests in performing work on all types of terminations and/or splices used on cables installed under the provisions of this specification, in the presence of a designated NASA representative. Each individual who is to perform cable splicing and/or termination may be required to perform a minimum of one acceptable sample splice and/or termination of each type of cable that the individual will be splicing or terminating in accordance with the requirements of this specification. The sample splices and/or terminations shall be performed on samples of cables, terminals, and connectors, and such samples shall not be incorporated in the finished cable installation. The above mentioned work, if required, shall be in addition to the work required under 3.3.2.2.

3.3.2.2. Course of Instruction. - A course of instruction in cabling splicing and termination shall be given to all individuals who are to perform cable splicing or termination in accordance with the requirements of this specification. This course shall consist of a careful and detailed review of splicing work, termination techniques, and the procedures required by this specification. This course shall consist of a minimum of 24 hours of instruction. The instructors for this course shall be well qualified and shall have a minimum of 5 years experience in the splicing and/or terminating of the types of cables with which the course of instruction shall be concerned. A complete instruction course outline plus the certification of the qualifications of the instructors shall be submitted to the designated NASA representative for approval a minimum of 30 days prior to the scheduled date of the beginning of the course of instruction. The training facility and equipment shall be evaluated by the designated NASA representative prior to the start of the first training course.

3.3.2.3 Certification of Qualification. - The names of all individuals considered to meet the qualifications as stated in 3.3.1, all individuals who have passed the test requirements set forth in 3.3.2.1, and all individuals who have successfully passed the course of instruction described in 3.3.2.2 shall be submitted by letter to the designated NASA representative, together with a certified list of their experiences and a statement of the specific items of work which each individual will perform. The contractor will issue letters of certification for all individuals who are qualified. This certification will specify the type of work for which each individual is certified to perform under the requirements of this specification. No work shall be performed by any individual prior to receipt of certification. No work shall be accomplished by an individual on any type of cable splice or termination for which that individual is not certified. Should such work be performed by an uncertified person, the work will be deemed unacceptable and shall be completely reworked. In the event of continued substandard work by a previously qualified person, his/her certification shall be removed and a repeat of the training course shall be required.

3.3.2.4 Scope of Qualification. - The provisions of 3.3.1 and 3.3.2 shall apply to all personnel engaged in making cable splices and/or terminations in accordance with the requirements of this specification, except that any employee of the contractor who has been certified in accordance with the requirements of 3.3.2.3 and who remains continuously in the employ of the contractor and who remains continuously assigned to such cable splicing and/or terminating duties shall be required to requalify and be recertified no more often than once every year and no less often than once every 2 years.

3.4 Grounding.

3.4.1 Raceway Grounding. - All metallic raceways shall form an electrically continuous path and shall be grounded. Metallic conduit shall be connected to ground through grounding bushings with copper wire, using No. 6 American Wire Gage (AWG), minimum. Cable tray sections shall be bonded together, and the resistance between sections shall be no greater than 0.5 milliohm (mΩ). Cable trays shall be connected to the facility ground network at 15-meter (m) [50-foot (ft)] intervals and at each end with copper wire, using No. 4/0 AWG, minimum.

3.5 Cable and Conductor Identification.

3.5.1 Cable Identification. - Each cable shall be positively identified at each termination and at each joint or splice to minimize the risk of damage to or destruction of equipment resulting from incorrect connection. Such cable identification shall be by combination of letters and numerals in strict accordance with the applicable design drawings.

3.5.2 Conductor Identification. - Each individual conductor in multiconductor cables shall be positively identified at each termination and at each branch, joint, or splice. Such conductor identification shall be by letters, numerals, color code, or a combination of these in strict accordance with the design drawings. Phase designation shall be A, B, and C clockwise for all 3-phase cables. In the case of all 3-phase cables where color coding is used, it shall be as follows: Phase A - black, Phase B - red, Phase C - blue. Where color coding is used on direct current (dc) cables, the negative or grounded conductor shall be white, and the positive conductor shall be black. Where multiconductor Type MI cable is installed, conductor identification shall be by letters, numerals, or a combination of these, which appear on small gummed stickers. Such stickers shall be firmly attached to the "spaghetti" sleeves which are placed over each conductor at termination.

3.5.3 Locations. - Each cable shall be identified within 1 ft of each termination and within 1 foot of the end of each case encasing a splice or branch. Each conductor of multiconductor cables shall be identified at each termination and at each splice or branch.

3.6 Dissimilar Metals.

3.6.1 Prevention. - Dissimilar metals, such as copper and aluminum, shall not be jointed directly, but shall be separated by a heavy coating of tin on the copper. Cadmium plating on the copper is also permissible for such separation. The copper to be coated shall be thoroughly cleaned and then shall be dipped into melted tin at the proper temperature to assure a good coating.

3.6.2 Protection. - Aluminum, wherever connected to a dissimilar metal, shall be protected by approved fittings and treatment. All ferrous metals, whether or not used at junctions of dissimilar metals, shall be hot-dip galvanized in accordance with ASTM A123, A153, or A386, except where other equivalent means of protection is specifically approved. At all junctions of dissimilar metals, the smaller of the two metallic pieces shall be, wherever practical, bent up away from the larger in order to prevent beads of moisture from connecting the two dissimilar metals.

3.7 Underground Duct Cable Installation.

3.7.1 Preparation of Ducts. - Preparation of the duct for receiving cable shall consist of "rodding" the duct with a suitable wire and cleaning the duct to remove dirt and other obstructions and any accumulations of liquids.

3.7.1.1 Rodding and Cleaning. - The duct shall be rodded and a suitable leader wire shall be pulled through the duct by appropriate means. Appropriately sized circular wire brushes, swab, and mandrel shall then be pulled through the duct.

The mandrel shall be 6.5 millimeter (mm) [1/4-inch (in)] in diameter smaller than the inside diameter of the duct. If obstructions are encountered which prevent the passage of the wire brushes, swab and mandrel, additional cleaning shall be performed. The final cleaning operation shall also be used to pull the main cable pulling wire through the duct.

3.7.2 Cable Pulling. - In general, cables shall be pulled off reels and into manholes and ducts in such a manner that the pull shall be as straight as possible with due care being given to avoid twists and kinks, to avoid scraping the cable jacket against manhole edges and similar surfaces and sharp edges, and to avoid exceeding the minimum allowable bending radius for the cable being pulled. (See table 2.) Medium-voltage cables shall be pulled into ducts and utility tunnels with equipment designed for this purpose, including power-driven winch, cable-feeding flexible tube guide, 760-mm (30-in) minimum long radius quadrant block cable pulling sheaves, cable grips, and lubricants. A sufficient number of trained personnel and equipment with two-way radio communications capability shall be employed to ensure the careful and proper installation of the cable. All cables to be initially installed in a conduit shall be pulled at the same time. Cable pulling using a vehicle shall not be permitted.

3.7.2.1 Pulling Forces and Directions. - The cable may be pulled in either direction between the two manholes concerned. However, due consideration shall be given to such factors as relative elevations of the manholes, bends in the ducts, and need for more slack cable in one manhole than in the other, in reaching this decision. The manholes shall be rigged with the necessary sheaves and sheave supports in such manner as to allow as straight a pull off the reel and into the manhole and duct as is practical. The cable shall not be allowed to scrape against the manhole or duct edges or against similar surfaces or sharp corners during the pulling operation. Sheave sizes shall be such that the maximum sidewall pressure and minimum allowable bending radius of the cable are not exceeded. The pulling force for a cable grip on lead-sheathed cable shall not exceed 10.3 megapascals (MPa) [(1,500 pounds per square inch (lb/in^2)] of sheath cross-sectional area. The pulling force for a nonmetallic-sheathed cable shall not exceed the smaller of 11,000 newtons (N) [2,400 pounds (lb)] or a value computed from the following equation:

$$TM = 0.036 \times n \times CM \text{ in newtons } (TM = 0.008 \times n \times CM \text{ in pounds})$$

Where: TM = Maximum allowable pulling tension
n = Number of conductors in the cable
CM = Cross-sectional area of each conductor in circular mils.

3.7.2.2 Pulling Eyes. - The cable to be pulled shall be attached, through a swivel, to the main pulling wire by means of a pulling eye (installed by the factory or approved cable splicer) or a suitable cable grip. The use of a core hitch, or other similar means of attaching a makeshift pulling eye to a cable, is prohibited. The swivel and other hardware used for such attachment shall be appropriately rated to withstand the pulling forces involved.

3.7.2.3 Cable Pulling Speed and Lubrication. - The cable sheath or jacket shall be lubricated, in accordance with the lubricant manufacturer's instructions, immediately prior to its entering the duct during the pulling operation. The lubricant shall be an approved type for the lubrication of metal or plastic-sheathed cable. The use of soap, detergent, and grease-type lubricants for this purpose is prohibited. The cable shall be pulled at a speed just fast enough to keep cable and reel moving smoothly. However, in no case shall the speed exceed that yielded by the maximum allowable pulling force for the cable being pulled, as described in 3.7.2.1.

3.7.2.4 Cable End Sealing and Temporary Support. - Following the pulling operation, the cable shall be cut to the necessary length and, unless splicing or branching is to be done immediately, the cut end shall be sealed in an approved manner with the cut end being held pointing upward during the application of the seal. The end section of the cable remaining outside the duct shall be suitably supported and tied to the supports to prevent falling until permanently attached to its permanent supports or temporary supports. The end of the cable shall be trained high in the manhole to prevent the entry of moisture into the cable in case the end seal is faulty.

3.7.3 Cable Support. - Cables shall be adequately supported on all sides of manholes and on each side of all splices and branches by suitable cable support racks or rack and stanchion combinations, firmly attached to the manhole ceiling or wall, in order to prevent excessive cable sag at such splices and branches.

3.7.3.1 Types. - Support shall be effective by means of a stanchion, firmly bolted to the manhole wall, with suitable supporting brackets attached to the stanchion, by means of a cable rack attached thereto, or by means of a rack attached to the manhole ceiling. Suitably formed insulators, made of porcelain or fibrous materials, shall be placed on all metallic brackets on their top surfaces as the actual supporting members in contact with the cable sheath or jacket. They shall be free to slide laterally along the brackets with thermal expansion and contraction of the cable. The bracket design shall be such that the insulator shall be prevented from sliding off the end of the bracket. All spacers used in wall or ceiling mounted racks which are in actual physical contact with cable sheaths or jackets shall be porcelain, fibrous, or other suitable insulating material. The use of supporting members made of metallic or other conducting materials in actual physical contact with cable

sheaths or jackets is prohibited. All such spacers and bracket insulators shall have no sharp corners or edges in physical contact with the cable sheath or jacket.

3.7.3.2 Training Cable. - Cables shall be trained in all manholes with sufficient offset to allow for splicing and branching, and shall be formed into a complete loop, where possible, around the inside wall of the manhole to allow for thermal expansion and contraction with temperature changes. In the forming of all such offsets and/or loops, sufficient straight length shall be allowed for the making of all necessary splices and branches.

3.7.3.3 Bending Radii. - In the forming of all cable offsets and loops in manholes to allow for splicing, branching, and thermal expansion and contraction, the minimum allowable bending radius of the cable being installed shall not be exceeded. Where manhole space presents a problem, a metallic bellows-type sleeve may be installed on each side of each splice or branch case to allow for thermal expansion and contraction, provided the requirements of 3.6 are not violated. Sufficient straight length of cable shall be allowed at the duct mouth before beginning any bend to prevent the cable sheath from scraping against any sharp edges at the duct mouth during thermal expansion or contraction. Table 2 gives minimum bending radii for most types of cable and shall be followed wherever applicable.

3.7.3.4 Racking and Anchoring. - Cables shall be racked on and through the supports provided, in compliance with the requirements of 3.7.3.1, 3.7.3.2, and 3.7.3.3. Where sufficient difference exists between elevations in adjacent manholes causing a net cable creep toward the lower manhole, due to thermal expansion and contraction, the cable shall be anchored in the higher manhole by means of a suitable basket-type cable grip anchored to the opposite manhole wall or by other approved anchoring methods. Such anchoring shall be applied to the cable not less than 152 mm (6 in) from the duct mouth.

3.7.4 Bonding and Grounding. - The shielding of all metallic-shielded cables shall be bonded to ground and tested at each splice and termination. The cable concentric neutral/shield wires shall be connected across each side of the splice and shall also be connected to one or two bare copper wires which are connected to the manhole grounding system. The total cross sectional area of the bare copper wires shall be at least equal to the shield size. All connections within the splice shall be made utilizing parallel-type compression connectors and appropriate compression tools with proper size dies to ensure a satisfactory mechanical and electrical joint. Bare connections of concentric neutral/shield wires shall be either contained within the splice kit or shall be sealed via an additional outer covering. This outer covering shall consist of a heavy wall, heat-shrinkable tubing containing adhesive material (mastic) that melts as heat is applied, while the outer tubing shrinks to form a

Table 2. Recommended Minimum Bending Radii

A. Power Cables without Metallic Shielding or Armor * The minimum bending radii for both single- and multiple-conductor cable with or without lead sheath and without metallic shielding or armor are as follows:			
	Overall Diameter of Cable, mm(in)		
Thickness of conductor	25.4 (1.000) and Less	25.5 (1.001) to 50.8 (2.000)	50.9 (2.001) and Over
Insulation, mm (65th of an inch)	Minimum bending radius as a multiple of cable diameter		
4.31 (10) and less	4	5	6
4.32 (11) to 7.87 (20)	5	6	7
7.88 (21) and Over	6	7	8
B. Power Cables with Metallic Shielding or Armor *			
Flat tape and wire armored cables:	12 times outside diameter (OD)		
Tape shielded cables:	12 times OD		
Interlock armored without shielded conductors:	7 times OD		
C. Control Cables and Flexible Portable Cable *			
Control cables (19-conductor and larger except armored finish)	8 times OD		
Rubber-jacketed portable cable used on takeup reels or sheaves			
0 to 5 kV	6 times OD		
Over 5 kV	8 times OD		
Control cable (7-conductor and over)	20 times OD		

* The above limits do not apply to conduit bends, sheaves, or other curved surfaces around which the cable may be pulled under tension while being installed. Note that during pulling operations, bending radius is often limited by allowable sidewall pressure to values larger than indicated in this table.

moistureproof environmental seal. This tubing shall conform to ANSI C119.1. Extra precautions shall be taken to seal around the exit area of the bare copper jumpers with additional mastic, in accordance with the splice manufacturer's recommendations. All items within the manhole which are made of metallic or other conducting materials, except those which are normally energized, i.e., the conductors within the cables themselves, shall be bonded by exothermic welding or compression connectors to a ground wire and connected to the manhole ground.

3.8 Aerial Cable Installation.

3.8.1 Preparation. - Preparing for aerial cable installation shall consist of the installation of necessary guys on poles at required locations, the installation on poles of the necessary messenger cable clamps, and single sheave pulleys for messenger and cable pulling.

3.8.1.1 Guying. - Guys shall be provided at the locations, with leads and strengths indicated on the drawings and elsewhere, as required, wherever conductor tensions are not balanced (e.g., at angles, corners, and dead ends). Where a single guy will not provide the required strength, two or more guys shall be provided. All guy anchors and attachments shall provide a strength exceeding the required guy strength. Guy anchors shall be of a type suitable for soil and load conditions. The holding capacity, transverse strength, and longitudinal strength of guys shall conform to the requirements of IEEE C2 for Grade B construction, except where higher minimum values are specified or indicated. The ground end of each guy attached to a ground anchor shall be equipped with a half-round, grey polyvinyl-chloride (PVC) guy protector at least 2 m (7 ft) long. PVC guy protectors shall be Type II, PVC Grade 1, 60 mm (2-1/3-in) outside width, with 2.5-mm (100 mil) minimum thickness of PVC. Wherever possible, guys shall have a lead-to-height ratio of 1 to 1, and shall have a minimum lead to one-half the height of attachment. Storm guys and other guys where road clearance is essential, shall be installed with a minimum lead. Storm guys shall be tensioned sufficiently to remove slack and present a neat appearance. When field conditions prevent the indicated lead-to-height ratio of 1 to 1, anchors shall be placed in a location approved by KSC and the guy strength increased by the ratio of the sine of the lead angle indicated to the sine of the lead angle provided. Guy strand shall be 7-strand, EHS galvanized steel in accordance with ASTM A475, with a breaking strength of not less than indicated on the drawings, except where two or more guys are used to provide the required strength. Anchors shall be installed so that the guy will be in a straight line pull.

3.8.1.2 Messenger. - All aerial cable shall be supported by a suitable messenger wire. Pulling equipment and cable reel shall be positioned with respect to the pole line so as to produce as straight a pulling line as possible. The pulling wire shall be coupled to the messenger through a ball or roller bearing swivel and weighted chain-type pulling line, appropriately rated for the pulling tension to be encountered, in order to prevent the messenger cable or power cable, which has been factory-sheathed with or lashed to messenger, from twisting or untwisting with similar motion of the pulling wire. Aerial cable messenger of all cable which has not been factory-lashed to or factory-sheathed with messenger shall be copper-clad steel in accordance with ASTM B228. Messenger size shall be 7 No. 6 (1/2-in). Messenger tensions shown in table 3 are based on 30-percent conductivity, high-strength

"Copperweld" strand. Messengers shall be installed, in general, in accordance with the applicable details on the drawings. Two-base clamps shall be used to obtain the maximum snubbing action. All splices in messenger cable shall be made with approved mechanical splice or with the overlap and wrap-type splice, with the wrap made with an approved type serving tool. Unless specifically approved otherwise, the wrapping wire shall be No. 9 AWG hard Copperweld wire. The messenger shall be dead-ended in the manner necessary to develop the ultimate strength of the strand. Messengers of all cables which have not been factory-lashed to or factory-sheathed with a messenger cable shall be prestressed as described herein. Messengers shall be pulled to the tension shown under "Prestress" column in table 3 and left at this tension for 12 hours to prestress the poles, messengers, guys, and anchors. At the end of the 12-hour period, the tension shall be checked with a dynamometer. If the reading is 75 percent or more of the original tension (taking into account difference in temperature) the messenger shall be slacked off to tension shown under "Final" in table 3 and installation of cable shall be continued. If the reading is less than 75 percent of the original tension at the end of the 12-hour period, poles, guys, and anchors shall be inspected for settling, slippage, or failure. When the source of trouble has been located and eliminated, the messenger shall again be pulled up to tension shown under "Prestress". If, after a 2-hour period, the dynamometer reading is 90 percent or more of the original reading (corrected for temperature), the messenger shall be slacked off to tension shown under "Final" and installation of cable shall continue. If the reading is less than 90 percent, the trouble shall be corrected and the 12-hour prestress procedure repeated. Installation shall be in accordance with NFPA 780. The messenger shall be bonded and grounded as specified in 3.8.3.1.

Table 3. Messenger Tensions * (Without Cable)

Temperature** °C (°F)	Final 7 No. 6 (1/2 in) N (lb)	Prestress (to be left 12 hours) 7 No. 6 (1/2 in)
4.4 (40)	18 200 (4,100)	28,900 N (6,500 lb) minus 130 N (30 lb) for each degree temperature drop expected during prestress period
101 (50)	17 300 (3,900)	
15.5 (60)	16 000 (3,600)	
21.1 (70)	15 100 (3,400)	
26.6 (80)	14 200 (3,200)	
32.2 (90)	13 300 (3,000)	
37.7 (100)	12 000 (2,700)	
43.3 (110)	11 100 (2,500)	

* Tension measurements in N (lb))
** Temperature in degree Celsius (°C) (degree Fahrenheit (°F))

A dynamometer shall be used to determine messenger tensions. In taking a reading with a dynamometer, the messenger shall first be pulled until it is somewhat tighter than the desired tension and then slowly slacked off until desired tension is obtained. When pulling the messenger to prestress tensions, the tension shall be measured at the pulling end only. The points at which the final messenger tension should be measured under various conditions are on straight sections, free from changes in grade, and on sections including changes in grades or corners. When the straight section is less than 10 spans, the tension shall be measured near the middle of the messenger run. When the straight section is from 10 to 20 spans, the tension shall be measured first at a point two-thirds of the distance from the pulling end and then at a point about one-third the distance from the pulling end. When the straight section is over 20 spans, the tension shall be measured first at a point about three-fourths of the distance from the pulling end, next to a point about one-half the distance, and finally, at one-fourth of the distance from the pulling end. On sections including changes in grade or corners, the tension shall be measured and then at each corner or "change-in-grade" pole, working toward the pulling end. As the desired tension is obtained in each portion of messenger being pulled, the suspension clamp bolts shall be tightened.

3.8.2 Installation. - If the cable was of the self-supporting type, with the messenger either factory-sheathed with or factory-lashed to the cable, the installation of the cable will have been accomplished concurrently with the installation of the messenger. Otherwise, the cable shall have to be pulled and strung separately. In all such installations, the cable reeling and pulling winch shall be positioned with respect to the pole line so that as near to a straight line pull as possible can be achieved. All sheaves used shall be sized to provide adequate clearance to the cable sheath or jacket, in order to prevent scraping of the cable sheath or jacket against the sheave frame, and shall be sized to prevent exceeding the minimum allowable bending radius of the cable being installed. (See table 2.) All cable reels shall be equipped with a suitable brake to prevent overpaying of cable during pulling. The cable reel stand or frame shall be secured against movement or tipping over. If the cable is not furnished with a factory attached pulling eye, the cable shall be attached to a basket-type cable grip. The cable grip or pulling eye shall be attached to the pulling wire through a ball or roller bearing swivel and a chain-type pulling line, appropriately rated for the pulling tension to be encountered, with suitable weights attached to the pulling line so as to prevent the cable from twisting or untwisting with similar motions of the pulling wire. Pulling tensions shall not exceed the limitations of 3.7.2.1. The cable shall be pulled at a speed just sufficient to keep the cable and reel moving smoothly, but in no case shall the pulling speed exceed that yielded by the maximum allowable pulling tension for the type of cable being pulled.

3.8.2.1 Supporting. - The cable shall be supported by the messenger and the messenger-supporting hardware. Aerial cable not factory-sheathed with or factory-lashed to a messenger wire shall be field spun on the messenger. The messenger and installation thereof shall be as specified in 3.8.1.2. Spinning shall be accomplished with copper or copper-clad steel wire, sized in accordance with the recommendations of the manufacturer, but in no case shall the spinning wire be less than 2.3 mm (0.09 in), unless smaller wire is specifically recommended by the cable manufacturer. Spinning tension shall be as recommended by the cable manufacturer and shall support the cable without undue stress on the jacket. Care shall be exercised to ensure that tension of spinning wire is properly adjusted. At any point where the spinning wire is terminated, it shall be secured to the messenger with an approved cable lashing clamp. The cable, after spinning, shall be tight against the messenger except at spliced and messenger support points. To remove excess tension from the spinning wire, two copper cable hangar straps shall be installed on each side of each splice and each messenger support point, or at any other point where the cable deviates from the messenger. Adjacent wraps of spinning wire shall be approximately 220 mm (8-1/2 in) apart. Splices in the spinning wire shall be prohibited. Necessary straightening shoes and long radius-bend or angle shoes shall be properly utilized. Radius of curvature shall be not less than 20 times the outside diameter of the cable. Roller-type cable placing rings shall be used. All possible care shall be taken to prevent kinking, scarring, deforming, or otherwise injuring the cable. Cable so damaged shall be replaced. Spinning, splicing, and all other operations related to the installation of the cable shall be accomplished by workers qualified in this particular field of work by experience and/or special training.

3.8.2.2 Tensions. - The tension of the cable shall be sufficient to prevent the cable from sagging between wraps of the wrapping wire, but not so great as to exceed 50 percent of the ultimate strength of the cable during thermal contraction at the lowest ambient temperature encountered. Cable which has been factory-lashed to or factory-sheathed with a messenger shall be tension stressed in accordance with the manufacturer's recommendations.

3.8.2.3 Sags. - The sag of the cable, if not factory-sheathed with or factory-lashed to a messenger, shall be determined by the sag of the messenger, which shall have been prestressed and final stressed in accordance with the requirements of 3.8.1.2. Cable which has been factory-lashed to or factory-sheathed with a messenger shall be sagged in accordance with the manufacturer's recommendations.

3.8.3 Cable Protection. - The cable and messenger shall be protected against damage from flow of high-fault current in the sheath and messenger and against damage resulting from lightning discharges.

3.8.3.1 Bonding and Grounding. - The messenger, the cable-messenger lashing wire, and all pole hardware shall be bonded to ground with suitable clamps or connectors to the pole butt ground or rod ground at each pole. Cable shields shall be grounded at terminations and splices. The pole butt or rod ground bus shall not be smaller than No. 6 AWG solid copper or its equivalent in ampacity and shall extend in a vertical direction for a minimum distance of 150 mm (6 in) above the top of the pole. The ground conductor shall be protected by a half-round plastic molding to a point at least 2 400 mm (8 ft) above the ground line and throughout the transformer space. The molding shall be stapled to the pole at intervals not exceeding 600 mm (2 ft), with one staple not more than 80 mm (3 in) from each end. Where the ground conductor is not covered by molding, it shall be stapled to the pole at intervals not exceeding 600 mm (2 ft). Staples shall be copper-clad steel and shall be of suitable size to prevent damage to the conductor or to the moldings.

3.8.3.2. Lightning Protection. - A bare, uninsulated lightning protection wire, no smaller than No. 1/0 AWG solid copper, or its stranded equivalent in ampacity, shall be installed above and parallel to the cable at a sufficient distance above the cable to ensure that cable, messenger, and all pole hardware are within the cone of protection. The cone of protection shall be 30 degrees. The lightning protection wire shall be bonded at every pole, to the pole ground, with suitable clamps or connectors with a No. 6 AWG, minimum, solid copper wire. At all points where the pole line has a sufficiently sharp corner to necessitate dead-ending the messenger, the lightning protection wire shall be dead-ended, and the two sections of lightning protection wire shall be bonded together by means of the shortest practical wire, of ampacity at least equal to that of the lightning protection wire. Such bonding shall be by exothermic welding or brazing, or by use of approved clamps.

3.8.4 Hardware. - Hardware for aerial cable installation may include, but shall not be limited to, those listed in the List of Materials Acceptable for Use on Systems of RUS Electrification Borrowers, Informational Publication 202-1.

3.9 Direct Buried Cable.

3.9.1 Preparation. - Preparation for installing direct buried cable shall consist of a route survey to ensure that the proposed installation route does not conflict with the route of any other underground system, such as other power, instrumentation, communication cable systems, and underground pipelines carrying liquids and gases, etc., and that the proposed route does not violate any proximity requirements imposed by safety regulations involving underground lines carrying gases or liquids of a toxic and/or flammable nature.

3.9.1.1 Route Survey. - Within 5 days prior to the installation of a direct buried cable system, the contractor shall conduct a survey of the cable route as shown on the design drawings to ensure that, between the date of completion of the design drawings and the date of the route survey, no structures have been erected or underground cable, piping, or other systems have been installed which would interfere with the direct buried cable system to be installed, or which would cause the installation of the new direct buried cable system to violate any proximity requirement of any safety regulation concerning any nearby underground, surface, or overhead installation. In this connection, the contractor shall first thoroughly familiarize himself with all safety regulations concerning all such installations which impose any minimum proximity requirements with respect to any nearby direct buried power cable system. The contractor shall promptly report in writing to the designated NASA representative for resolution of any such conflict with other existing underground systems or with proximity requirements of safety regulations found during the course of the route survey. Such report shall contain, but not be limited to, full information as to the location and nature of such conflict. The route survey shall take into account necessary clearances for all trenching, laying, tunneling, backfilling, and towing equipment. If, for any reason, installation of the direct buried cable system does not follow initiation of the route survey within 5 days, the contractor shall perform another route survey.

3.9.2 Installation. - In general, direct buried cable shall be installed by digging a trench, laying the cable in the trench, and filling and packing the trench.

3.9.2.1 Trenching. - All trenching shall follow the route designated by the design drawings, or such rerouting as has been specifically approved by KSC, as closely as is practical. Minimum depth shall be such as to allow high voltage (above 600 volts) cable, when placed on top of a 75-mm to 100-mm (3- to 4-in) layer of screened sand or fill dirt, to lie a minimum of 900 mm (36 in) below grade and to allow low voltage (600 volts and below) cable, similarly placed, to lie a minimum of 600 mm (24 in) below grade. Minimum width shall be, in the case of not more than one cable in a trench, such as to allow the cable to lie in the trench slightly reverse-curved laterally (snaked), and, in the case of more than one cable in a trench, allow the cables to lie in the trench separated by a minimum distance of 200 mm (8 in) on centers. Wherever splices or branches are to be made, the trench shall be widened and deepened accordingly.

3.9.2.2 Laying. - Immediately prior to the laying of the cable, all rocks, coral, seashells, and other objects possessing sharp edges shall be removed from the side walls of the trench. Except where necessary to tunnel under a traffic route and where splicing is specifically forbidden, cable shall be laid by being payed off the reel and guided into the trench through sheaves or similar guiding apparatus, as the reel and guiding apparatus are moved along a line parallel to the trench. All

such sheaves or guiding apparatus shall be sized so as to preclude the possibility of scraping or scoring the cable sheath or jacket and the possibility of exceeding the minimum allowable bending radius of the type of cable being laid. (See table 2.) Extremely small, lightweight cable may be laid manually. The speed of forward motion of the laying apparatus shall not exceed that required to allow the cable to be slightly "snaked" in the trench. Splicing and branching direct buried cable shall be avoided wherever practical. Wherever such splicing or branching is necessary, the techniques applicable to the splicing and branching of underground cables in manholes shall be followed; however, the requirements of 3.6 shall not be violated.

3.9.2.3 Road Crossings. - Where indicated on shop drawings and wherever the flow of traffic on heavily traveled routes would be unduly impeded or interrupted by trenching across the route, cable shall be installed on conduit driven under the roads. Conduit shall extend continuously under the traffic route from a point not less than 300 mm (1 ft) past the outside edge of the pavement or traveled surface on one side of the route, to a point not less than 300 mm (1 ft) past the outside edge of the pavement or traveled surface on the opposite side of the route. Galvanized, rigid conduit shall be used. A separate conduit shall be used for each cable being buried. Cable shall be pulled through the pipe or conduit from one side of the traffic route to the other, and along the trench to the nearest point where splicing or branching is permitted. Sufficient slack shall be pulled to allow for maintenance of the required 200 mm (8 in) of separation of adjacent cables. Installation of conduit shall be accomplished by the use of a pipe-pusher or by other approved means. The requirements for installation under railroad trackage shall be the same as for installation under motor vehicle traffic routes.

3.9.2.4 Backfilling. - A layer of screened sand or fill dirt 150 mm to 200 mm (6 to 8 in) thick shall be laid on top of the cable and tamped tightly. A bright yellow plastic ribbon marked "Caution - Electrical Line Below" shall be placed in the trench approximately 200 mm (8 in) below ground level and run continuously in parallel with the cable. The trench shall be filled with the dirt which was dug up to form the trench. Such fill dirt shall be tamped tightly.

3.9.3 Cable Protection. - Direct buried cable shall be protected to the extent possible against physical damage and corrosion.

3.9.3.1 Markers. - Cable route markers shall be located at the ends of all cable runs, at all splices and branches, at approximately every 60 meters (200 ft) along the cable run, and at each change in direction of the cable run. Markers shall be placed approximately 600 mm (2 ft) to the right of the cable trench when facing the longitudinal axis of the run and in the direction of the electrical load. Markers shall be made of Class B concrete, 150 mm (6 in) in diameter (square or round section) by a minimum of 900 mm (3 ft) long. The top edges of the marker shall have a

15-mm (1/2-in) chamfer all around. The letter D with two arrows shall be impressed or cast on top of the marker. One arrow shall be located adjacent to the letter and shall point in a direction parallel to the cable run. The letter and arrow adjacent to it shall be approximately 75 mm (3 in) long. The arrow under the letter shall be approximately 50 mm (2 in) long. The letter and arrows shall be V-shaped and shall have a width of stroke at least 6 mm (1/4-in) at the top and a depth of 6 mm (1/4 in). The tops of the cable run markers shall be flush in paved areas and shall protrude 600 mm to 1200 mm (2 to 4 ft) above finished grade in unpaved areas. Where the cable run changes direction, the arrow adjacent to the letter shall be cast or impressed with an angle in the arrow approximately the same as the angular change of the cable run.

3.10 Conduit Raceway Cable Installation.

3.10.1 General. - In general, the underground duct cable installation requirements of 3.7 shall apply to the installation of cable in conduit raceways. Specific exceptions are the need for rodding the conduit, cleaning the conduit, and the training and temporary support of cable ends in an upward direction because of moisture problems. All splices and branches shall be made in suitable metallic J-boxes, which shall have been installed in accordance with the applicable design drawings. All cable shall be installed strictly in accordance with the applicable sections of the requirements of NFPA 70. Cable with insulation which has been impregnated with any liquid compound having flowing characteristics shall not be installed in vertical risers. This restriction is due to the danger of cable swelling and rupture at the lower elevations and of insulation breakdown at the higher elevations caused by migration of the impregnating compound. The number of conductors installed in any raceway shall conform to the requirements of NFPA 70.

3.10.2 Preparation. - Preparation for installation shall consist of visual inspection and necessary cleaning of the conduit. Prior to cable installation, conduit system shall be subjected to visual inspection, both interior and exterior, which shall include, but not be limited to, checks for water leakage at condulets, fittings, J-boxes, etc., and checks of the interiors of the conduits for dirt and trash. Interior checks shall be made by opening all J-boxes and removing the covers of all condulets. All sections of conduit found to contain dirt and/or moisture shall be cleaned with appropriately sized, circular, wire-bristle brushes, cloth swabs, and mandrels, pulled through the conduit by pulling wire, which shall have been threaded through the conduit by fishtape, pneumatically driven rabbet, or other appropriate means. The contractor shall maintain records of performing these inspections.

3.10.3 Cable Support. - Cables shall be adequately supported, especially in vertical runs, as specified in NFPA 70.

3.10.3.1 Vertical Runs. - Cable installed in vertical raceways shall be supported by basket-type cable grips, armor clamps, wedge clamps, or other suitable supports in order to relieve the cable terminations of the strain of supporting the cables. Such cable supports shall be installed at the intervals specified in the NFPA 70 section on supporting conductors in vertical raceways. In locations of high vibrational environment and wherever necessary to allow for cable thermal expansion and contraction, support shall be effected through suitable springs.

3.10.3.2 Wireways and Gutters. - All cable installed in wireways and gutters shall be laid in place, rather than being pulled into place, and shall be suitably supported, spaced, and held in place by hardware designed for that purpose strictly in accordance with the applicable requirements of NFPA 70. All cables installed in vertical runs in wireways shall be supported by suitable, basket-type cable grips, armor clamps, or other suitable supports. Such supports shall be provided in accordance with the requirements of the NFPA 70 section on supporting conductors in vertical raceways.

3.11 Cable Tray Raceway.

3.11.1 Preparation. - Prior to installation of cable in cable trays, the contractor shall verify, by field inspection or other means, that the installation of cable trays and required supporting hardware is complete and conforms to all applicable requirements of NFPA 70.

3.11.2 Rigging. - All necessary pulleys, sheaves, and other necessary temporary hardware shall be securely and firmly attached to the cable tray system at all points of change in direction of cable runs and at points along straight cable runs wherever necessary to prevent cable abrasion or scraping against the cable tray during the pulling process. They shall also prevent the minimum allowable bending radius for the type of cable being installed from being exceeded, as specified in table 2, and be placed so as to allow them to be removed following cable pulling without unduly moving or disturbing the cables in their laid positions.

3.11.3 Installation.

3.11.3.1 Spacing. Cable may be installed either with or without horizontal and vertical spacing maintained between adjacent cables. Irrespective of cable spacing, number of conductors per cable, and cable tray ventilation, the conductors of the cables installed shall conform to the requirements of the applicable section of NFPA 70 for the load current to be carried. Wherever power cables are installed in a common cable tray with cables of other electrical systems, the power cables shall be separated from those of the other systems in accordance with the requirements of NFPA 70 section on ampacities of cables installed in continuous rigid cable sup-

ports. If spacing between adjacent cables is maintained, allowance shall be made for thermal expansion and contraction of the cable.

3.11.3.2 Supporting - Horizontal and Vertical. - On horizontal runs, the cable shall be supported by the cable tray or by other cables lying underneath, if no vertical spacing between adjacent cables is to be maintained, or by approved clamps or other supporting hardware if such vertical spacing is to be maintained. On vertical runs, the cable shall be supported by being fastened securely to transverse members of the cable tray system in accordance with the NFPA 70 section on installation of continuous rigid cable supports. On vertical runs, where the length of the run is as great as 30 meters (100 ft), the cables shall be supported in accordance with the requirements of the NFPA 70 section on the supporting of conductors in vertical raceway.

3.11.3.3 Splicing and Branching. - Splicing and branching of cables laid in cable trays is prohibited except in junction boxes or other enclosures, suitable for the purpose, located at the ends of cable tray runs.

3.11.4 Cable Protection.

3.11.4.1 Bonding and Grounding. - The sheaths of all metallic-sheathed cables laid in cable trays shall be bonded at both ends to the frame of the metallic junction box or other metallic equipment enclosure at each end of the cable run in accordance with the requirements of the NFPA 70 section on grounding. There shall be a continuous electrical path from the metallic sheath of all such cable to ground.

3.11.4.2 Cable Turnouts. - Turnouts of all cables from cable trays shall be made only at horizontal T-sections intended for the purpose. Dropouts of all cables from cable trays shall be made only at vertical T-sections or through ladder-type with radius fitting intended for the purpose. In dropouts and turnouts, the minimum allowable bending radius for the type of cable being installed shall not be exceeded. (See table 2 for minimum bending radii). For mineral-insulated (Type MI) cable, the minimum bending radius of the inside edge of the bend shall not exceed five times the outside diameter of the cable.

3.11.4.3 Cable Tray Covers. - Cable tray covers shall be provided at all locations where the cables would otherwise be subject to physical damage by the impact of dropped objects, by the spillage of liquid propellants, or other cryogenic or corrosive liquids. All such cable tray covers shall be cable tray-matching types made by the same manufacturer as the cable trays with which they are used, and shall be attached and latched to the cable trays with hardware made by the cable tray manufacturer for the purpose.

3.12 Metallic-Sheathed, Mineral-Insulated Cable.

3.12.1 Preparation. - The length of cable needed for the run shall be measured with allowance made for the length of conductors needed at each end to properly make the desired terminations. The cable shall be cut to the desired length with a hack-saw. Cable cutters and other cutting tools which exert excessive pressure on the metallic sheath shall not be used. Immediately following cutting, the end of the unused portion of cable on the reel shall be sealed with tape or with the factory plastic shipping cap to prevent moisture penetration of the insulation. Cutting shall be done only immediately preceding installation.

3.12.2 Installation.

3.12.2.1 Training. - The cable shall be trained into place by hand wherever possible. It may be finally straightened into true position on straight runs by being tapped with a wooden mallet, block, or plank. Sharp bends and kinks shall be avoided during preliminary handling and training in order to avoid work hardening of the sheath. The cable shall be supported at least every 1 800 mm (6 feet) during handling and training. Bends shall be made by approved template or hand hickey. Minimum bending radius of the inside edge of any bend shall be five times the diameter of the cable. A loop or an offset shall be formed in the cable within 1 200 mm (4 ft) of cable terminations in all runs exceeding 9 m (30 ft). The loop or offset shall be of such a size as to provide a minimum of 300 mm (12 in) of excess cable to allow for retermination without replacing the cable run.

3.12.2.2 Removing Sheath. - Sheath material shall be stripped back a length necessary to leave sufficient conductor length to make termination. Sheath stripping shall be done only with diagonal cutters stripping rod, and copper tube cutters, or with rotary stripping tool and gland, and shall be done only in accordance with 79K06110. All insulation shall be removed from the conductors back to a distance of approximately 0.8 mm (1/32 in) inside the remaining sheath.

3.12.2.3 Sealing. - All threaded gland parts, all pots, insulation caps, and insulated "spaghetti" sleeving shall be installed on cables strictly in accordance with 79K06110.

3.12.2.4 Supports. - Cable shall be supported as shown on design drawings, except that intervals between supports shall be not more than 1 800 mm (6 ft) on both horizontal and vertical runs. Cable installed in ducts, raceways, conduits, cable trays, and direct buried cable shall be deemed adequately supported along horizontal runs.

3.12.3 Cable Protection.

3.12.3.1 Bonding and Grounding. - The metallic sheath shall be bonded at each end in accordance with the NFPA 70. All splices shall be made in junction boxes. The proper attachment of the cable to the metallic junction box or other type of metallic termination housing shall be deemed as adequate bonding. A continuous electrical path from every point on the metallic sheath to ground shall be provided.

3.13 Cable Splices.

3.13.1 General. - Space does not permit description of all the various types, sizes, and combinations of joints and splices which are available through building up or in kit form. Therefore, this specification will be limited to presentation of principles of construction that, when followed with manufacturer's dimensions and instructions, will result in a satisfactory installation.

3.13.2 Preparation. - In preparing to make a cable splice, all personnel shall give first attention to the requirements of 3.13.2.2.

3.13.2.1 Equipment. - All the necessary material and equipment shall be used to ensure the completion of a satisfactory splice.

3.13.2.2 Precautions. - For general safety procedures, the NASA/KSC regulations shall be consulted. Prior to working on a splice, every effort shall be made to ensure that the cable is not energized or charged. The environment in the area of the splice shall be clean and dry, and the cables shall be trained into position while avoiding sharp bends.

3.13.2.3 Removing Covering. - Extreme care shall be exercised in removing the covering to avoid damage to the insulation. Metallic and lead coverings shall be scored circumferentially at points of cutoff and then cut lengthwise from the end of the cable to the score. After this, the covering can be torn off at the score. Nonmetallic jackets shall be removed by splitting the covering lengthwise and then cutting away from the cable circumferentially at the point of cutoff.

3.13.2.4 Removing Insulation. - Insulation shall be removed the required distance and care shall be taken to avoid nicking the conductor. On single-conductor, paper-insulated cable, the insulation shall be removed from the conductor for the required distance by unwrapping and tearing off the inner layers of paper tapes. A wire weighted on each end and wrapped around the cable, at the point where the tapes are torn, will facilitate this operation. On multiconductor, belted, paper-insulated cable, the belt insulation shall be removed from the ends of the cable to the proper

position, indicated on the joint drawing, tearing rather than cutting the inner layers of belt insulation to avoid damaging the conductor insulation. The conductor insulation shall be removed as on a single-conductor cable.

3.13.2.5 Connecting Conductors. - Unless otherwise specified, compression-type connectors shall be used on all splices, and connector material shall be compatible with the conductor material. The conductor shall be thoroughly scraped and cleaned prior to installing the connection. Where sector-shaped cable conductors are to be joined, the sector conductor shall be rounded before inserting it into the connector. In all joints, and especially those operating at 2,500 volts and above, the installed connector shall be provided with a smooth outer surface to reduce the electrical stresses and facilitate taping. When using aluminum connectors, a suitable inhibitor shall be applied in the contact area to assure a low electrical resistance connection.

3.13.2.6 Insulating. - The proper thickness of required insulating material shall be applied as follows:

a. Varnished-Cambric Tape. - Apply drypacked varnished-cambric tape over varnished-cambric or paper insulation. Do not subject varnished-cambric tape to tensions greater than 1.75 newtons per millimeter (N/mm) [10 pounds per inch (lb/in)] of width for a 0.25-mm (10-mil) tape, as this will crack the varnish and destroy the dielectric strength of the tape.

b. Rubber Tape. - Before applying rubber tape to insulation, clean and roughen the insulation surface thoroughly with a small wood rasp, coat surfaces with rubber cement, and allow to dry until tacky. Before applying rubber tape to lead sleeves or sheaths, clean the lead thoroughly, apply adhesive coating, and allow to dry until tacky. Apply the tape smoothly and with tension to the required thickness at the connector, tapering off toward the ends of the joint. Do not stretch the tape to less than three-quarters of its original width.

c. Thermoplastic Tape. - Clean the surface of the insulation with a rag moistened with a petroleum-base, or other suitable base, cleaning fluid. Apply thermoplastic tape with the adhesive side down, using only sufficient tension to lay the tape smoothly over the joint. Keep the tension uniform to avoid the displacement of the underlying layers of tape or other soft insulating material which might be caused by the nonuniformity of tension in the tape turns. Relax the tension on the last turn so that the end of the tape will not pull back or loosen.

3.13.2.7 Covering. - Nonmetallic sheath cables should be wrapped with a protecting tape, such as neoprene tape, thermoplastic tape, or anhydrous tape.

3.13.3 Installation (5,000 Volts and Below). - Splices shall be made in a careful and workmanlike manner, following the instructions in 3.13.2 and the manufacturer's instructions.

3.13.4 Installation (5,000 to 7,500 Volts).

3.13.4.1 Construction. - Joints in this voltage range shall be made much the same as for the lower voltage with the exception of shielding, and all the requirements of 3.13.2 shall apply, in addition to the following:

3.13.4.2 Metallic Shielding. - Where metallic shielding is used, it shall be removed for a sufficient length to provide an adequate creepage distance. The metallic shielding shall be terminated in the form of a cone, either of a semi-shielded or fully shielded type of joint construction, to prevent damage to the cable insulation at the point of cable shielding termination.

3.13.4.3 Nonmetallic Shielding. - Where semiconducting neoprene jackets are used on single-conductor, rubber-insulated cable, the jacket shall be stripped from the insulation to provide sufficient creepage distance in the joint. Semiconducting tapes are occasionally used under the metallic shielding tapes. These are usually cotton fabric with a semiconducting rubber or neoprene compound calendared on the surface. A fabric tape containing carbon black is sometimes used. Any fabric tape, as well as semiconducting tapes, shall be removed to provide the proper creepage distance in the joint. The end of these tapes shall be secured with a wrapping of the insulating tape to be used on the joint. The surface of the insulation shall be thoroughly cleaned with a small rasp or nonconducting abrasive cloth to remove any particles of the conducting coating of the tape. Semiconducting carbon black and metallized paper tapes are also used over the conductor and over the insulation. Those over the conductor present no problem, as they are removed with the insulation to provide space for the connector. Those over the insulation shall be removed the same as the metallic shielding.

3.13.5 Installation (Above 7,500 Volts).

3.13.5.1 Contamination. - Every practicable means shall be employed to avoid contamination of the joint insulation from moisture, such as drippings, condensation, perspiration (especially from the splicer's hands), wiping rags, and any other materials or foreign matter. Since oil-impregnated paper quickly absorbs moisture from the damp atmosphere of the manhole, it should be exposed for as short a time as possible. Dehumidification of the manhole may be helpful under extreme conditions. The sheath should not be removed from the cable until all materials and tools are available and all the protective equipment is in place, so that, once started, the construction of the joint may proceed without interruption. A good

practice is to remove the sheath in steps. For cables with thermosetting insulating material, which are available up to 15 kilovolts (kV), moisture absorption problems, as stated in this section, are reduced but not eliminated.

3.13.5.2 Voids. - Formation of voids shall be prevented to eliminate the possibility of ionization damage to the insulation. Soft cotton yarn, which has been immersed in hot oil to remove moisture, shall be used to fill the corners in the insulation stepping and shall also be wrapped over each step to hold the paper tapes in place while the insulation is being applied. Every layer of tape shall be basted with cable oil to fill the spaces at the edges of the turns of tape. Use of the previously mentioned cables with thermosetting insulating material does not require this, since it has a penciled cut in lieu of a stepped cut.

3.13.5.3 Insulating. - When varnished-cambric tape is specified for joints in cable rated above 7.5 kV, it is furnished packed in oil in suitable containers. This tape has been carefully processed to prevent moisture absorption in the oil or cotton fibers of the cloth. This condition shall be maintained by ensuring that the container of tape is warm, dry, and clean when it is opened. The container shall not be opened until after all the splicing operations prior to the application of the tape have been completed, and shall be protected from contamination. It is extremely important in the application of the tape to maintain a correct and uniform tension. Too much tension will reduce the dielectric strength of the individual tapes, and uneven tension will produce a spongy wall of insulation with inferior dielectric properties. Cables with thermosetting insulating materials shall have splicing tape applied smoothly to the proper dimensions at the joint.

3.14 Cable Terminations.

3.14.1 Installation (600 Volts and Below). - Cables shall be terminated so as to provide good electrical circuit continuity for the conductors, to provide mechanical stress relief to the cable, and to prevent the charging of nearby grounded metallic objects.

3.14.1.1 Types. - For nonshielded types, which this normally includes, proper mechanical support, electrical connection of the conductor, and physical protection of the cable insulation shall be provided.

3.14.1.2 Methods. - These terminations shall be made in junction boxes, equipment connection compartments, or other enclosures designed to protect the termination and to protect personnel from exposure to live parts. The cable insulation shall be removed for a sufficient distance to permit attachment of a connector to the cable conductor. Sufficient distance shall be maintained between the live terminal and

the nearest ground surface to prevent creepage over the cable exterior. This distance varies from a 200-mm (8-in) minimum at 5,000 volts to 75 mm (3 in) at 600 volts.

3.14.2 Installation (5,000 to 15,000 Volts). - The same general requirements shall apply for terminations of cables for this voltage range as those outlined in 3.14.1.

3.14.2.1 Requirements. - Cable terminations of single-conductor construction meeting IEEE 48, Class 1 requirements shall be used for the termination of cables in this voltage rating.

3.14.2.2 Lead Cable Terminations. - These shall be of the capnut type with cast iron bells, grounding terminals and high-glazed porcelain insulators. Upon completion of termination, the termination shall be completely filled with insulation compound in accordance with manufacturer's recommendations and instructions. Unless otherwise specified, the voltage rating of terminations shall be 25 kV where exposed in switch yards, and 15 kV for others.

3.14.2.3 Extruded Cable Terminations. - Dry terminations with medium voltage pennants, preformed, and hand-wrapped stress cones may be used for terminating cables. Terminations shall be provided with adequate means for making external connections to the cable conductors of single-conductor cables (phase and concentric neutral); protecting the cable insulation against moisture, oil, or other contaminant; physically protecting and supporting cables, and maintaining the insulation level of the cable. Terminations shall be field fabricated from termination kits supplied by and in accordance with the termination manufacturer's recommendations for the type, size, and electrical characteristics of the cable. Installation shall include built-up or prefabricated heat- or cold-shrink stress-relief cones at the terminals of all shielded cables.

3.14.2.4 Compartment Type. - In the event that equipment is furnished with a connection compartment, it shall be used in conjunction with a separate termination if space permits. An alternative shall be with stress relief cones and the compartment preferably filled with insulating compound.

4. QUALITY ASSURANCE PROVISIONS

4.1 General. - All primary cables shall have dc voltage acceptance tests made by the contractor in accordance with 4.2 after the cable is installed and before it is placed in service. The applicable dc voltages shall be obtained from NEMA specifications covering the various types of insulation. For cables operating at 600 volts or

below, the insulation resistance test only shall be required. All tests shall be in accordance with the applicable NEMA cable standards. Records shall be made on forms similar to appendix A with leakage current being recorded after 15, 30, 45, and 60 seconds and then at 1-minute intervals.

4.2 Acceptance Test.

4.2.1 Rubber-Insulated Cables. - Tests shall be in accordance with NEMA WC 3, which requires 80 percent of the given factory dc test voltages. The duration of the dc test is 15 minutes for ozone-resisting insulations and 5 minutes for all others.

4.2.2 Thermoplastic-Insulated Cables. - Tests shall be the same as 4.2.1 except in accordance with NEMA WC 5 and WC 7.

4.2.3 Ethylene-Propylene-Rubber (EPR) Insulation. Tests shall be in accordance with NEMA WC 8. Duration of tests shall be 5 consecutive minutes using ac test voltage. For EPR insulated cables rated at 5,001 volts and above, the test shall be for 15 consecutive minutes using a dc voltage.

4.3 Insulation Resistance Test. - The insulation resistance shall be measured before any of the dc voltage tests. Single-conductor cables shall be tested between the conductor and ground, metallic sheath, or shield when used. Multiple conductor cables with unshielded conductors shall be tested between each conductor and all other conductors and ground. Multiple conductor cables with shielded conductors shall be tested between the conductor and shield. The conductor test shall be connected to the negative terminal, and readings shall be taken and recorded after an electrification of 1 minute. The test apparatus shall consist of a source of constant potential of 1,000 volts (2,500 volts for 5-kV and 15-kV cables). Each coil, reel, or length of wire or cable shall have an insulation resistance in megohms for 304.8 m (1,000 ft) at a temperature of 15.6 °C (60 °F) of not less than the value of R calculated as follows:

a. Single Conductor Cable

$$R = K \log_{10} \frac{D}{d}$$

Where: R = Megohms of 304.8 meters (1,000 feet) of cable
K = Constant for insulating material from applicable NEMA
D = Outside diameter of conductor insulation
d = Diameter of conductor

b. Multiconductor cable = Between conductors or conductor to sheath or shield

$$R = K \log_{10} \frac{D}{d}$$

Where: D = Diameter over insulation of equivalent single conductor cable = d + 2c + 2b
d = Diameter of conductor (for sector cables, d equals diameter of round conductor of same cross-section)
c = Thickness of conductor insulation
b = Thickness of jacket insulation
K = Constant for insulating material from applicable NEMA

4.4 Termination Tests. - Assembled terminations which are compound filled and ready for service are considered tested upon completion of the cable acceptance tests. The magnitude of the actual test voltage shall be determined by reference to the applicable NEMA cable specifications for the installed cable system. In no case shall this exceed the termination withstand voltages as listed in IEEE 48. Terminations to be tested shall be clean and dry. The high-voltage test connection shall leave the termination air terminal in a direction approximately parallel to the axis of the termination body for a distance of not less than the dry arcing distance over the insulator. No other object except the supporting structure shall be close enough to the termination to appreciably affect the test results. In addition, a radiographic examination shall be performed to determine if voids or foreign objects exist inside all compound filled terminations.

4.5 Splice Tests. - Assembled splices which are compound filled and ready for service are considered tested upon completion of the cable acceptance tests. The magnitude of the actual test voltage shall be determined by reference to the applicable NEMA cable specifications for the installed cable system. Splices to be tested shall be clean and dry. In addition, a radiographic examination shall be performed and evaluated by the contractor to determine if voids or foreign objects exist inside the splice. The radiographic records shall be submitted to the Contracting Officer for approval and retention. Unacceptable terminations shall be reworked by the contractor at no additional cost to the Government.

4.6 Sleeve Tests. - All joint sleeves on paper-insulated, lead-covered cables shall be pressure tested by applying a 41 kilopascals (kPa) [6 pounds per square inch (lb/in^2)] nitrogen gas pressure to the joint sleeve for 5 minutes, after which a check for gas leakage shall be made by applying a leak detector solution over the surface and around the fittings.

5. PREPARATION FOR DELIVERY

Not applicable.

6. NOTES

6.1 Intended Use. - This specification is intended to provide the requirements for installation and testing of 60-hertz ac power cables used at Kennedy Space Center.

6.2 Open-Wing and Building Wire Construction. - This document is not applicable to open-wire and building wire construction.

NOTICE. When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely related Government procurement operation, the United States Government thereby incurs no responsibility nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

Custodian:	Preparing Activity:
NASA - John F. Kennedy Space Center	John F. Kennedy Space Center Electrical Division Engineering Development Directorate

APPENDIX A

Primary Cable - DC Voltage Test

Location: _____
Description of Cable: _____
Rated Voltage: _____

TEST DATA

Set Leakage @ Test Voltage _____ mA Variac _____ Pri Voltage _____
Sphere Gap _____ mm (_____ inches)
Duct Temp. _____ Ambient Temp. _____ Weather _____
Cable Status 1 Hr. prior to test

Phase or Conductor	A	B	C	Remarks:
Starting Time:	___ mA	___ mA	___ mA	
0				
15 sec.				
30 sec.				
45 sec.				
1 min.				
2 min.				
3 min.				
4 min.				
5 min.				
6 min.				
7 min.				
8 min.				
9 min.				
10 min.				
11 min.				
12 min.				
13 min.				
14 min.				
15 min.				
Final Test Voltage	___	___	___	
Time Finish	___	___	___	
kV DC after 1 min.				

Test Procedure _____ No. of Terminals _____ Joints _____

Witnessed by: _____ Performed by: _____

SAMPLE

STANDARDIZATION DOCUMENT IMPROVEMENT PROPOSAL

INSTRUCTIONS

1. The preparing activity must complete blocks 1, 2, 3, and 8. In block 1, both the document number and revision letter should be given
2. The submitter of this form must complete blocks 4, 5, 6, and 7.
3. The preparing activity must provide a reply within 30 days from receipt of the form

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I RECOMMEND A CHANGE:	1 DOCUMENT NUMBER KSC-SPEC-E-0017C	2 DOCUMENT DATE October 28, 1996

3 DOCUMENT TITLE
Electrical Power Cable, Installation of, Specification for

4 NATURE OF CHANGE *(Identify paragraph number and include proposed rewrite, if possible Attach extra sheets as needed)*

5 REASON FOR RECOMMENDATION

6. SUBMITTER

a. NAME *(Last, First, Middle Initial)*	b ORGANIZATION	
c. ADDRESS *(Include Zip Code)*	d TELEPHONE *(Include Area Code)*	7. DATE SUBMITTED

8. PREPARING ACTIVITY

a NAME	d. TELEPHONE *(Include Area Code)*
Director of Engineering Development	(407) 867-2565

c ADDRESS *(Include Zip Code)* National Aeronautics and Space Admnistration, Mail Code DE
Kennedy Space Center, FL 32899

KSC FORM 21-610NS (2/94) (C/G 2/94)