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CABLES, ELECTRICAL,

GENERAL SPECIFICATION FOR

ENGINEERING DEVELOPMENT DIRECTORATE

National Aeronautics and
Space Administration

John F. Kennedy Space Center

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Approved:

Walter T. Murphy
Director of Engineering Development

JOHN F. KENNEDY SPACE CENTER, NASA

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ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
AWG	American wire gage
cmil	circular mil
dc	direct current
EPR	ethylene propylene rubber
FED	Federal
ft	foot
GSE	ground support equipment
Hz	hertz
in	inch
KSC	John F. Kennedy Space Center
kV	kilovolt
lb/in	pound per inch
m	meter
MIL	military
min	minimum
mm	millimeter
MPa	megapascal
N	newton
NASA	National Aeronautics and Space Administration
NEMA	National Electrical Manufacturer's Association
NHB	NASA handbook
OS	overall braided shield
OSDB	overall double-braided shield
OSDBI	overall double-braided shield insulated from conductor shields
OSI	overall braided shield insulated from conductor shields
psi	pound per square inch
PT	two conductors twisted
PTS	two conductors twisted and shielded
PTSI	two conductors twisted, shielded, and insulated
QT	four conductors twisted
QTS	four conductors twisted shielded
QTSI	four conductors twisted, shielded, and insulated
rms	root mean square
SC	single conductor unshielded
SS	single conductor shielded
SSI	single conductor shielded insulated
STD	standard
TT	three conductors twisted
TTS	three conductors twisted and shielded

ABBREVIATIONS AND ACRONYMS (cont)

TTSI	three conductors twisted, shielded, and insulated
XLPO	cross-linked polyolefin
°C	degree Celsius
µm	micrometer

CABLES, ELECTRICAL, GENERAL SPECIFICATION FOR

1. SCOPE

This specification establishes the general characteristic, construction, material, marking, inspection, test, and packaging requirements for flexible, multiconductor neoprene-jacketed electrical cables. These cables shall be used at the John F. Kennedy Space Center (KSC) for interconnecting various interior and exterior ground support equipment (GSE) network systems where voltages do not exceed 600 volts root mean square (rms).

NOTE

Neoprene-jacketed cables are not rated for riser or plenum use.

Cables covered by this specification are suitable for use in wet or dry locations in applications where they will not be subjected to severe mechanical abuse. The cables are designed to operate with a maximum continuous surface temperature of 75 degrees Celsius (°C) and at a maximum voltage of 600 volts rms. The cables are not recommended for use in applications where they will be subject to heavy impact or abrasive wear such as frequent foot or vehicle traffic or for direct burial as a permanent installation.

Exterior electrical cables are intended to interconnect various units of space vehicle ground networks, such as blockhouse to umbilical tower, propellant storage facilities to launcher, and launcher to vehicle.

NOTE

Cables manufactured to a previous revision of this specification shall not be considered obsolete by virtue of the release of this revision. This specification supersedes MSFC-SPEC-332 and includes requirements for cables procured for use at KSC. Cable type numbers remain the same.

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.

Federal

L-P-390	Plastic, Molding and Extrusion Material, Polyethylene and Copolymers (Low, Medium, and High Density)
QQ-S-571	Solder, Electronic

Military

MIL-C-12000	Cable, Cord, and Wire, Electric Packaging of
MIL-I-631	Insulation, Electrical, Synthetic-Resin Composition, Nonrigid

2.1.2 Standards.

Federal

FED-STD-228	Cable and Wire, Insulated; Methods of Testing

Military

MIL-STD-129	Marking for Shipment and Storage

2.1.3 Handbooks.

National Aeronautics and Space Administration (NASA)

NHB 5300.4(1C)	Inspection System Provisions for Aeronautical and Space System Materials, Parts, Components and Services

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

2.2 Non-Governmental.

American Society for Testing and Materials (ASTM)

ASTM B33	Standard Specification for Tinned Soft and Annealed Copper Wire for Electrical Purposes
ASTM D470	Standard Test Methods for Crosslinked Insulations and Jackets for Wire and Cable
ASTM D4066	Standard Specification for Nylon Injection and Extrusion Materials
ASTM G21	Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

National Electrical Manufacturers Association (NEMA)

WC 3	Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
WC 7	Cross-Linked-Thermosetting-Polyethylene-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
WC 8	Ethylene-Propylene-Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

(Application for copies should be addressed to the National Electrical Manufacturers Association, 2101 L Street NW, Suite 300, Washington, DC 20037.)

3. REQUIREMENTS

3.1 Product Requirements. - All cable furnished under this specification shall conform to all requirements specified herein and in the cable specification sheets in appendix A.

3.2 Test and Inspection Requirements. - Unless specifically waived by the procuring activity, the quality assurance and acceptance tests and inspections specified in 3.3 through 3.11 and in section 4 and in accordance with NHB 5300.4(1C) shall be performed on all cable furnished under this specification.

3.3 Materials. - The materials to be used in manufacturing cables to this specification shall be as specified in 3.3.1 through 3.3.8 and shall be virgin material (100 percent new material) processed one time only with only those processes necessary for manufacturing that material. The manufacturer of the cable shall obtain certifications from their suppliers to this effect, and the manufacturer shall certify that the materials supplied under these certifications are used in the manufacture of cable in conformance with the requirements specified herein.

3.3.1 Copper Strands. - Copper strands comprising the conductors and braided shields shall be tinned, soft-annealed, commercially pure copper conforming to the requirements of ASTM B33.

3.3.2 Polyethylene. - Polyethylene conforming to the requirements for type II, class L, grade 3 or 4 of L-P-390C, prior to extruding, shall be used as the primary insulation material for conductors 12 American wire gage (AWG) and smaller and when specified by the cable specification sheet (see appendix A) for shield insulation and insulation tapes.

3.3.3 Ethylene Propylene Rubber (EPR). - EPR or cross-linked polyolefin (XLPO) shall be used as the primary insulation on conductors 10 AWG and larger. EPR shall conform to all the requirements specified in WC 8.

3.3.4 Cross-Linked Polyolefin (XLPO). - Thermosetting irradiated XLPO may be used as primary insulation on conductor 10 AWG and larger and shall be capable of meeting all the requirements specified in WC 7.

3.3.5 Polyamide. - Polyamide conforming to the requirements for type III, grade E, of ASTM D4066 shall be used for insulation covering material.

3.3.6 Polyethylene Terephthalate (Mylar). - The polyethylene terephthalate used for barrier tape shall conform to the applicable requirements of MIL-I-631.

3.3.7 Polychloroprene (Neoprene). - Single- and double-layer sheaths shall consist of a polychloroprene compound having the characteristics specified in WC 3 and table 1.

3.3.8 Textiles. - Textiles used for separators and tape markers shall consist of fungus-resistant cotton, synthetic thread, or yarn, as applicable, conforming to the applicable fungus resistance requirements of ASTM G21.

3.4 Construction. - Construction of the cable shall be as specified herein and in the cable specification sheets (appendix A).

3.5 Conductors. - Conductors shall be formed by stranding tinned copper wire having a uniformly circular cross section. Finished conductor sizes are specified in table 2 by the AWG size approximating the finished conductor diameter (see 3.3.1).

3.5.1 Number of Strands. - Each conductor size shall contain the number of individual strands specified in table 2.

3.5.2 Strand Size. - The strands comprising each conductor size shall have the diameters specified in table 2.

3.5.3 Stranding and Length of Lay. - Conductor sizes 12 AWG and smaller shall be formed by concentric lay stranding. It is optional for the direction of lay for the successive layers to be alternately reversed (true concentric lay) or to be in the same direction (unidirectional lay). The strands shall be uniformly laid so as to produce a geometrically arranged conductor circular in cross section and free of any crossovers, high strands, or other irregularities. The direction of lay of the individual strands in the outer layer of the conductor shall be left hand. The length of lay of the strands in each layer shall be 8 to 16 times the diameter of that layer. Conductor size 10 AWG shall be bunch stranded. The length of lay shall be not more than 16 times the bunch conductor outside diameter. Conductor sizes 8 AWG and larger shall be rope lay construction. The length of lay of the wires comprising the stranded members shall be 8 to 16 times the diameter. The length of lay of the outer layer of the rope lay stranded conductors shall be not less than 8 nor more than 16 times the outside diameter of the completed conductor.

Table 1. Physical Requirements for Polychloroprene Sheath Material*

Physical Property	Value
Original requirements:	
Tear strength, minimum	3.5 N/mm (20 lb/in)
Tension set, maximum	9.5 mm (3/8 in)
Ultimate elongation [51mm (2 inches) to break] minimum	2 to 8
Tensile strength, minimum	12.4 MPa (1,800 psi)
Aging requirements after air oven:	
Ultimate elongation [51mm (2 inches) to break] minimum percent of original value	60%
Tensile strength, minimum percent of original value	50%

*See NEMA WC3 for detailed test requirements.

Table 2. Conductor Requirements

Approx-imate AWG No.	Conductor Size [mm² (cmil)]	Strand Requirements			Insulation Thickness [mm (in)]	Insulation Covering Thickness [µm (in)]	Maximum dc Resistance at 20 °C [ohms per 305 m (1000 ft)]
		No. of Strands	Strand AWG Size	Construction of Strands			
0000	110.24 (217,556)	427	23	7X61 Rope	1.40 (0.055)	Not required	0.0562
000	84.31 (166,382)	259	22	7X37 Rope	1.40 (0.055)	Not required	0.0718
00	66.87 (131,960)	259	23	7X37 Rope	1.40	Not required	0.0896
0	53.02 (104,636)	259	24	7X37 Rope	1.40 (0.055)	Not Required	0.113
2	33.35 (65,812)	259	26	7X37 Rope	1.14 (0.045)	Not required	0.180

Table 2. Conductor Requirements (cont'd)

Approximate AWG No.	Conductor Size [cmil (mm^2)]	Strand Requirements			Insulation Thickness [mm (in)]	Insulation Covering Thickness [µm (in)]	Maximum dc Resistance at 20 °C [ohms per 305 m (1000 ft)]
		No. of Strands	Strand AWG Size	Construction of Strands			
4	21.59 (42,613)	133	25	7X19 Rope	1.14 (0.045)	Not required	0.280
6*	13.58 (26,799)	133	27	7X19 Rope	1.14 (0.045)	Not required	0.444
7	10.72 (21,147)	133	28	7X19 Rope	1.14 (0.045)	Not required	0.585
8	8.54 (16,851)	133	29	7X19 Rope	1.14 (0.045)	Not required	0.701
10	5.30 (10,452)	104	30	Bunch	0.76 (0.030)	Not required	1.16
12**	3.08 (6,088)	19	25	Concentric	0.51 (0.020)	51 (0.002 min.)	1.92
14***	1.53 (3,028)	19	27	Concentric	0.51 (0.020)	51 (0.002 min.)	3.05
16	1.22 (2,407)	19	29	Concentric	0.38 (0.015)	51 (0.002 min.)	4.82
18	0.97 (1,909)	19	30	Concentric	0.38 (0.015)	51 (0.002 min.)	6.22
19	0.76 (1,504)	19	31	Concentric	0.25 (0.010)	51 (0.002 min.)	8.15
20	0.61 (1,201)	19	32	Concentric	0.25 (0.010)	51 (0.002 min.)	9.76
22	0.38 (755)	19	34	Concentric	0.25 (0.010)	51 (0.002 min.)	15.9
24	0.24 (475)	19	36	Concentric	0.25 (0.010)	51 (0.002 min.)	25.4

Notes: Due to critical maximum diameter requirements of these cable types (see appendix A), the following thickness requirements shall apply:

* For cable type 147, the insulation thickness shall be 1.02 mm (0.040 inch).
** For cable types 151 and 152, the insulation thickness shall be 0.38 mm (0.015 inch).
*** For cable types 145, 146, and 148, the insulation thickness shall be 0.38 mm (0.015 inch).

3.5.4 Splices. - In no case shall the whole conductor be spliced at one point. Splices in individual strands shall be butt-brazed. There shall not be more than one strand-splice in any 3-meter (m) (10-foot) length of conductor. Strand splices

shall be distributed throughout the conductor in such a manner that the physical and electrical properties of the conductor will not be adversely affected. There shall be a maximum of one joint per 300 millimeters (mm) (1 foot) of conductor 10 AWG and smaller. There shall be a maximum of one joint per 300 mm (1 foot) in each group comprising the conductors 8 AWG through 4 AWG. There shall be a maximum of one joint per 300 mm (1 foot) in each layer of each group comprising the conductors 2 AWG and larger.

3.5.5 Conductor Testing.

3.5.5.1 Elongation Test. - The elongation of seven strands from any one conductor or the sample shall be tested in accordance with ASTM B33. The elongation of the tested strands shall meet the requirements of ASTM B33. If the results of the elongation tests on the strands are found to be below the specified value, the remainder of the strands in the conductor shall be tested. The average of all the strands tested shall determine the acceptance or rejection of the lot.

3.5.5.2 Tin Coating (Individual Strands) Test. - A minimum of eight strand specimens from the sample shall be tested in accordance with ASTM B33 for continuity and adherence of tin coating. Cracking or parting of the tin coating on the strands, indicated by blackening of the copper, shall be cause for rejection. Blackening within 12 mm (0.5 inch) of the cut end is permissible.

3.5.5.3 Conductor Resistance Test. - Conductor resistance shall be measured in accordance with FED STD 228, method 6021. To determine the added length of conductor due to cabling, conductors shall be removed from a 1.5-m (5-foot) length of cable. The straightened length of conductors shall be measured, and the ratio of the straightened length of the conductor to the original length of the cable shall be computed. Every conductor in every cable shall be tested. The direct current resistance per 300 m (1000 feet) of conductor at 20 °C shall not exceed the values specified in table 2.

3.6 Conductor Insulation. - Polyethylene insulation materials, used on conductors 12 AWG and smaller, shall be extruded over each conductor or conductor separator, as applicable, in a continuous layer. EPR or XLPO insulation used on conductors 10 AWG and larger shall be extruded over each conductor or conductor separator, as applicable, in a continuous layer. The insulating materials shall form a close fit over the conductor without adhering to the conductor or adhering to the insulation of other conductors when fabricated into a cable and, when stripped, shall leave the conductor clean and in a condition for soldering. After application, the insulating material shall be seamless and free from foreign materials.

3.6.1 Insulation Wall Thickness. - The average insulation wall thickness shall be as specified in table 2. The minimum thickness shall be not less than 90 percent of the specified average thickness.

3.6.2 Conductor Insulation Testing.

3.6.2.1 Tensile Strength and Ultimate Elongation. - Tensile strength tests shall be made in accordance with method 3021 of FED-STD-228. Ultimate elongation tests shall be made in accordance with method 3031 of FED-STD-228.

3.6.2.2 Initial Requirement. - Before accelerated aging, the tensile strength and elongation at rupture shall conform to the original requirement specified in table 3.

3.6.2.3 Accelerated Aging. - Accelerated aging shall be in accordance with ASTM D470. Specimens of polyethylene shall be oven-aged for 48 hours at a temperature of 100 ±1 °C. After accelerated aging, the tensile strength and elongation at rupture shall conform to the aging requirement specified in table 3.

Table 3. Physical Requirements for Insulation Materials*

Physical Property	Polyethylene Value	EPR** Value	XLPO
Original requirements:			
Tensile strength, minimum	9.65 MPa (1,400 psi)	4.8 MPa (700 psi)	12.4 MPa (1,800 psi)
Elongation at rupture, minimum percent	350%	150%	150%
Aging requirement after air oven:		(168 hours at 121 °C)	
Tensile strength, minimum percent of original value	75%	75%	75%
Elongation at rupture, minimum percent of unaged value	75%	75%	75%

*See NEMA WC8 and NEMA WC7 for specific test details.
**Reference 3.3.3.

3.6.3 Insulation Shrinkage Test. - A 200-mm (8-inch) specimen shall be cut from a finished conductor, and the polyamide covering shall be removed. The specimen shall then be cut to 150 mm (6 inches), leaving the conductor flush with the insulation on each end. The specimen shall be heated in a forced convection air oven at 99 °C ±1 °C for 24 ±1 hour. The specimen shall be removed and allowed to cool to room temperature. Insulation shrinkback from conductor ends shall be measured. The shrinkback of insulation from either end of the conductor shall not exceed 1.6 mm (1/16 inch).

3.6.4 Insulation Stripping Test. - Three specimens 150 mm (6 inches) in length shall be cut from a finished conductor. A 130-mm (0.5-inch) length of insulation shall be stripped from one end of each specimen. The stripped end of each specimen shall be dipped in a solder pot containing SN-60 solder without flux, conforming to the requirements specified in QQ-S-571, at a temperature of 320 °C for 5 seconds. All insulation shall be easily removable without adhering to the conductor. The solder shall flow freely and shall produce an evenly tinned surface.

3.6.5 Insulation Water Absorption Test. - The increase in specific inductive capacity of the insulation material due to water absorption shall be measured in accordance with ASTM D470, Accelerated Water Absorption Test - EM1000. The insulation covering shall not be removed from the test specimen. The test shall be performed with a water bath temperature of 50 °C ±1 °C for a duration of 7 days. The increase in specific inductive capacity of the insulation material shall not exceed 3 percent when tested in this manner. Total capacitance of insulated conductors 18 AWG and smaller shall not exceed 360 picofarads per meter (110 picofarads per foot) at the completion of the 7-day test.

3.6.6 Insulation Electrode Spark Test. - After extrusion of the insulation material and before covering the insulation with polyamide, each length of finished conductor to be used in cable manufacture shall pass through an electrode spark device that will subject 100 percent of the insulation surface to the test voltage specified in table 4. Method 6211 of FED-STD-228 shall be used in conducting this test. Speed of travel through the device shall be adjusted so that every point on the insulation surface shall be in contact with the electrode for not less than 0.25 second. The conductor insulation shall exhibit no electrical breakdown. If insulation breakdown occurs at any point, the conductor insulation shall not be repaired, but the section of conductor containing the failure point shall be cut out and removed from production.

3.7 Insulation Covering. - Insulated conductors 12 AWG and smaller shall have an insulation covering concentrically applied over the primary insulation. The insulation covering material shall be extruded, clear, heat-stabilized polyamide with a nominal wall thickness of 0.05 mm (0.002 inch minimum).

Table 4. Conductor Test Specifications

Conductor Size	Spark Test Voltage (kV)	Inspection Test Voltage at 60 Hz (kV)		Minimum Resistance Primary Insulation at 20 °C [megohms per 305 m (1000 ft)]		
		EPR	Polyethylene	EPR	Polyethylene	XLPO
0000	15.6	7.0		1306		650
000	15.6	7.0		1484		742
00	15.6	7.0		1646		823
0	15.6	7.0		1830		915
2	8.0	5.5		1887		943
4	8.0	5.5		2290		1145
6	8.0	5.5		2799		1400
7	8.0	5.5		3098		1549
8	8.0	5.5		3393		1696
10	6.0	3.5		3194		1597
12	4.0		2.0		8070	
14	4.0		2.0		9265	
16	3.0		1.5		9235	
18	3.0		1.5		10205	
20	3.0		1.5		8805	
22	3.0		1.5		10610	
24	3.0		1.5		12765	

3.7.1 Insulation Covering Testing.

3.7.1.1 Polyamide Insulation Covering Test. - A specimen of finished conductor of sufficient length shall be wrapped for 2-1/2 turns around a metal mandrel of a diameter that is six times the outside diameter of the specimen, and secured in this position by tape or other means to prevent unwrapping during tests. The specimen and the mandrel shall be placed in a gravity convection type oven at a temperature of 94 °C ±5 °C for a period of 24 ±1 hour. The specimen and mandrel shall be removed from the oven and cooled to room temperature in a silica gel desiccator or equivalent for 1 hour minimum. The specimen shall be removed from the desiccator and straightened. When examined under five-power magnification, the specimen shall be free from any tears or cracks. Wrinkles shall not be cause for rejection.

3.8 Conductor Shield. - When the specification sheets specify a conductor shield, a tight-fitting, closely woven braid of tinned copper strands shall be applied directly over an individual insulated conductor or over two or more insulated conductors as specified. Strand sizes and shield angles shall be as specified in table 5. The braid shall be applied to provide a 90-percent minimum coverage over the construction. The braided strands shall be applied to preclude irregularities, breaks, or other discontinuities. There shall be no strands protruding through the insulation.

Table 5. Conductor Shield Strand Size and Shield Angle Requirements

Diameter Over Insulation Covering		Strand Size Diameter		Shield Angle (+5 Degrees, -10 Degrees)
mm	inch	mm	inch	
6.35 and under	0.250 and under	0.127	0.0050	30
6.36 to 8.89	0.251 to 0.350	0.160	0.0063	30
8.90 to 10.16	0.351 to 0.400	0.160	0.0063	35
10.17 to 13.97	0.401 to 0.550	0.160	0.0063	40
13.98 to 25.40	0.551 to 1.000	0.160	0.0063	50

The percent coverage (K) of all conductors and overall shields shall be calculated using one of the following equations as applicable for the appropriate measurement unit:

For metric measurements:

$$K = \left[2\left(\frac{F}{25.4}\right) - \left(\frac{F}{25.4}\right)^2\right]x100$$

F = NPd/(25.4 sin a)
N = number of strands per carrier
P = number of picks per 25.4 mm of wire length
d = diameter of one of the shield strands in millimeters
a = angle of shield with axis of wire (degrees)
tan a = 2π(D+2d)P/(25.4C)
D = diameter of wire (cable) under shield (millimeters)

NOTE

For two conductor cables, D is 1.63 x the diameter of one of the insulated conductors.

C = number of carriers

For nonmetric measurements:

$$K = (2F - F^2)x100$$

F = NPd/Sin a
N = number of strands per carrier
P = number of picks per inch of wire length
d = diameter of one of the shield strands in inches
a = angle of shield with axis of wire (degrees)
tan a = 2π (D + 2d) P/C
D = diameter of wire (cable) under shield (inches)

NOTE

For two conductor cables, D is 1.63 x the diameter of one of the insulated conductors.

C = number of carriers

For inspection purposes, the actual data used for the shield angle and overall coverage shall be documented.

3.9 Shield Insulation. - When the cable specification sheets (see appendix A) specify shield insulation, material conforming to the requirements specified in 3.3.2 shall be extruded over the shielded conductor or group. The minimum shield insulation thickness shall be as specified in table 6.

Table 6. Polyethylene Shield Insulation Thickness Requirements

Diameter Over Shield		Minimum Shield Insulation Thickness	
mm	inch	mm	inch
7.62 and under	0.300 and under	0.33	0.013
7.63 to 12.70	0.301 to 0.500	0.46	0.018
12.71 to 19.05	0.501 to 0.750	0.69	0.027
19.06 to 25.40	0.751 to 1.000	0.91	0.036

3.10 Cabling. - The requisite number, grouping, size, and diameter of conductors shall be as specified in table 2 and the cable specification sheets (see appendix A) and shall be cabled together with a suitable unidirectional lay and filler, where necessary, producing an essentially circular cross section.

3.10.1 Direction and Length of Lay. - The direction of lay of multiple groups of conductors shall be unidirectional right hand or left hand. The length of lay shall be 8 to 16 times the outside diameter of the applicable layer.

3.10.2 Binding. - Material conforming to the requirements specified in 3.3.6 may be used as a manufacturing aid, provided it does not adversely affect cable flexibility or geometry.

3.10.3 Overall Shield. - When specified in the cable specification sheets (see appendix A), a single- or double-braid shield consisting of tinned copper strands, constructed as specified in table 7, shall be applied over the assembled cabling, under the cabling separator and barrier tape so as to provide a 90-percent minimum coverage when calculated in accordance with the equation in 3.8.

Table 7. Overall Shield Strand Size and Shield Angle Requirements

Diameter Under Braid		Strand Size Diameter		Shield Angle (+5 degrees, -10 degrees)
mm	inch	mm	inch	
7.64 and under	0.300 and under	0.127	0.0050	35
7.65 to 25.40	0.301 to 1.000	0.160	0.0063	45
25.41 to 38.10	1.001 to 1.500	0.160	0.0063	50
38.11 to 50.80	1.501 to 2.000	0.203	0.0080	55
50.81 and over	2.001 and over	0.254	0.0100	60

3.10.4 Insulation Tapes. - When a single- or double-braid insulated overall shield [overall braided shield insulated from conductor shields (OSI) or overall double-braided shield insulated from conductor shields (OSDBI)] is specified in the cable specification sheets (see appendix A), two insulation tapes conforming to the requirements specified in 3.3.2 and having a minimum average thickness of 0.25 mm (0.001 inch) each shall be applied over the first barrier tape as follows:

a. The first tape shall be left-hand lay with a 25 percent minimum lap.

b. The second tape shall be right-hand lay with a 25 percent minimum lap.

3.10.5 Barrier Tape. - A barrier tape shall be applied over the cabled conductors, insulation tapes (when applicable), and overall shield (if any) and shall have a minimum thickness of 0.25 mm (0.001 inch) and a 25 to 50 percent overlap (see 3.3.6).

3.10.6 Tape Marker and Filler. - The tape marker shall be at least 3.18 mm (1/8 inch) wide and markings 300 mm (1 foot) apart and shall be placed under the cable separator. The year of manufacture and the name of the manufacturer shall be clearly printed on one side between each 300-mm (1-foot) marking. The markings shall be clearly visible upon removal of the tape from the cable. Unless otherwise specified in the cable specification sheets (see appendix A), cotton or polyolefin filaments shall be used for filler material. Cotton used for filler material shall be clean, dry, and free from all foreign particles or substances that impair the insulation of the conductor and shall be capable of passing the fungus resistance requirements of 3.3.8. Polyolefin filaments used for filler material shall

be oriented polyethylene or polypropylene multi-monofilaments capable of meeting all performance requirements specified herein. All fillers used shall be nonwicking to deter the flow of moisture.

3.10.7 Cable Separators. - A cable separator consisting of dry, soft, textile braid with a minimum of 80 percent coverage shall be applied over the assembled components under the sheath (see 3.3.8).

3.10.8 Sheath. - When specified in the cable specification sheets (see appendix A), a single- or double-layer of polychloroprene shall be extruded over the cable core to form a well-centered sheath (see 3.3.7). At any cross section, the minimum thickness of the sheath wall shall not be less than 90 percent of the thickness specified in the cable specification sheets (see appendix A). The outer layer of a double-layer sheath shall constitute at least 50 percent of the total thickness of the sheath. Application shall be such that the sheath is concentric with the cable conductors.

3.10.8.1 Reinforcement. - Where two layers are specified in the cable specification sheets (see appendix A), a reinforcement shall be provided between the two layers. The reinforcement shall consist of two serves of 423-mm (16.67-inch) cabled cotton, served in reverse, seven ends, with a 25-mm (1-inch) lay. Equivalent rayon or nylon tire cord may be substituted for the seinetwine serves.

3.10.8.2 Vulcanizing Rubber and Rubber-Like Materials. - The rubber or rubber-like sheath shall be vulcanized and cured in place over the cable core while contained in and restricted by a close-fitting mold. After vulcanizing, the rubber or rubber-like sheath shall be a firmly bound, strong, high-elastic, homogeneous mass. The rubber or rubber-like sheath shall not be over-vulcanized, sticky, or tacky. The sheath shall not be separable into layers without extreme difficulty, and shall pass the sheath spark test requirements of 4.8.7 and table 8.

3.10.8.3 Sheath Testing. - The polychloroprene (neoprene) sheaths on finished cable shall meet all of the requirements specified in 3.10.8.3.1 through 3.10.8.3.3. The tensile strength tests shall be performed in accordance with method 3021 of FED-STD-228.

3.10.8.3.1 Initial Requirement. - Before accelerated aging and oil immersion, the tensile strength and elongation at rupture shall conform to the original requirement specified in table 1.

3.10.8.3.2 Accelerated Aging. - Accelerated aging shall be in accordance with ASTM D470. After accelerated aging, the tensile strength and elongation at rupture shall conform to the aging requirement specified in table 1.

3.10.8.3.3 Oil Immersion. - The oil immersion procedure shall be in accordance with method 4221 of FED-STD-228. After immersion in oil, the tensile strength and elongation at rupture shall be not less than 60 percent of the original requirement specified in table 1.

3.11 Cable Marking. - The finished cable shall be identified by a printed marking applied to the outer surface of the sheath.

3.11.1 Cable Identification. - The cable identification marking applied to the outer surface of the sheath shall consist of the following:

a. KSC specification sheet number

b. Cable type designation (see 3.11.3)

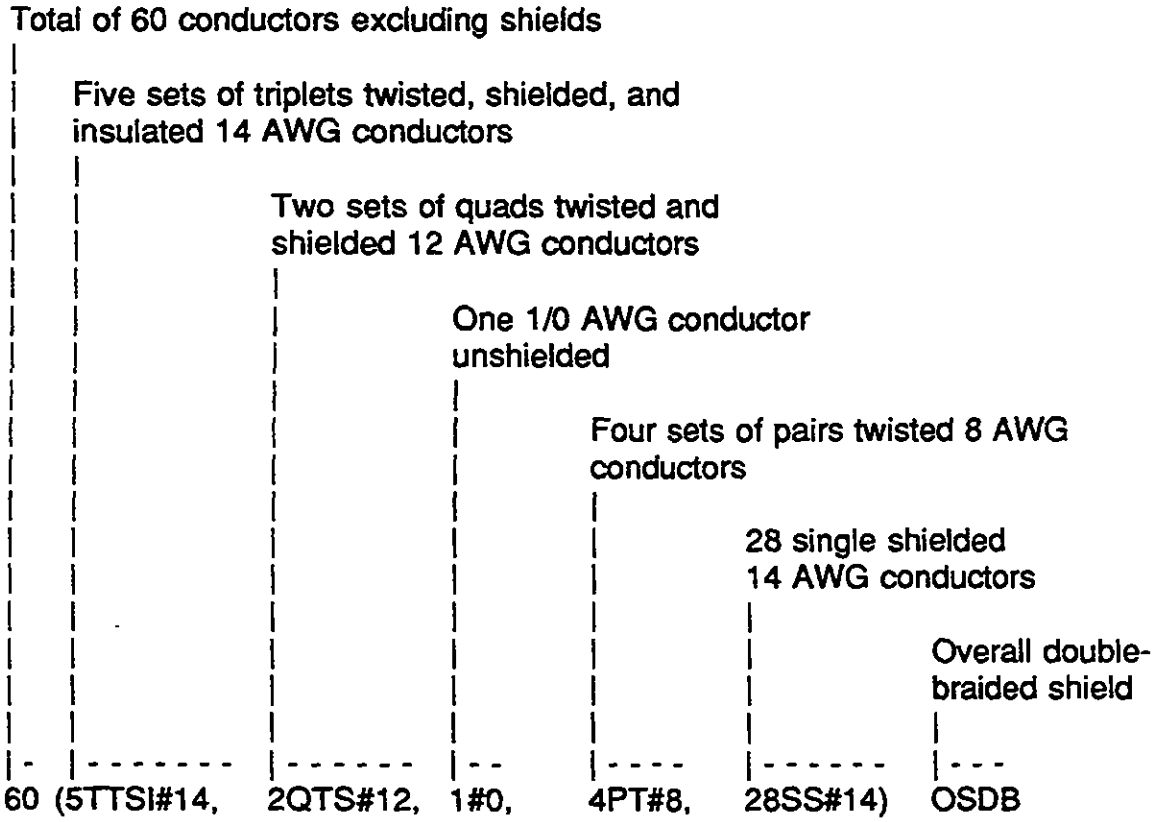
c. Manufacturer's name or code and the year manufactured

3.11.2 Method of Marking. - Either ink or hot stamp marking shall be employed. Hot stamping, if used, shall be performed prior to subjecting the cable to the sheath flaws and insulation resistance tests. Ink used for identification shall be of the best quality normally used in good commercial practice. Ink markings shall be repeated at intervals of not more than 600 mm (24 inches) and may be continuous.

3.11.3 Cable Type Designation Method. - Cables manufactured under this specification for delivery to the Government shall have the cable type designated as follows:

Example: 60 (5TTSI#14, 2QTS#12, 1#0, 4PT#8, 28SS#14) OSDB

Meaning of example:



4. QUALITY ASSURANCE PROVISIONS

4.1 Responsibility for Inspections. - The supplier is responsible for the performance of all inspection requirements specified herein. The procuring activity or its designated representative reserves the right to perform any or all the inspections set forth in this specification to ensure the end item conforms to all specified requirements.

4.2 Lot. - A lot shall consist of all cable of any one design produced under the same conditions and offered for acceptance inspection at any one time. One lot shall not be greater than 1 month's production or 3050 m (10,000 feet), whichever is smaller.

4.3 Samples. - Samples furnished for preproduction, quality assurance, and acceptance tests and inspections shall be finished cable in accordance with 4.3.1 through 4.3.3.

4.3.1 Preproduction Test Sample. - The preproduction test sample, when required, shall consist of one 30-m (100-foot) length of cable representative of the identical material and manufacturing processes to be used in production of cables covered by the specification.

4.3.2 Quality Assurance Test Sample. - The quality assurance test sample shall be selected at random from each production lot submitted for acceptance. The number and length of quality assurance test samples to be submitted shall be as required to perform all quality assurance tests and inspections specified herein.

4.3.3 Acceptance Test Sample. - Unless otherwise specified by the procuring activity, acceptance tests shall be performed on all cable submitted for acceptance. One 1.5-m (5-foot) sample from each production lot of cable shall be submitted for the visual and dimensional examinations. When specified in the contract, additional samples of the number and length specified in the contract shall be furnished to the procuring activity.

4.4 Visual and Mechanical Inspection Requirements. - Cable shall be examined to determine conformance with the requirements specified in 3.4, 3.5, 3.6, 3.7, and 3.8. When these examinations have been successfully completed, packaging, packing, and marking shall be examined to determine conformance with the requirements of section 5.

4.5 Testing Requirements. - Tests shall be performed as specified in 4.5.1 through 4.5.3. Test methods shall be as specified in 4.8. All cable submitted for testing shall have passed the visual and mechanical inspections specified in 4.4.

4.5.1 Preproduction Tests. - Preproduction tests, when required, shall consist of all the tests and inspections specified in 3.3 through 3.10. The preproduction test sample shall meet all requirements specified herein. Preproduction examinations and tests shall be performed by the contractor under Government surveillance or as directed by the procuring activity at the installation designated in the contract. Cables subjected to these tests shall be considered unserviceable but may be retained for examination by the procuring activity.

4.5.1.1 Preproduction Test Rejection. - If the preproduction sample fails to meet the requirements of any test or inspection specified herein, the preproduction sample shall be rejected. Before a new preproduction sample is submitted, a detailed report shall be forwarded to the procuring activity covering the rejection and the action taken to prevent recurrence of the defect causing failure. A reworked preproduction sample shall not be submitted. Production lots will not be considered for acceptance until the preproduction sample has been approved.

4.5.2 Quality Assurance Tests. - Unless otherwise specified in the contract, quality assurance tests and inspections shall be performed on samples from each production lot. The quality assurance tests shall consist of all the tests and inspections specified in 3.2 through 3.10. Cable subject to the quality assurance tests shall be considered unserviceable but may be retained for examination by the procuring activity. The Government reserves the right to waive specific test results at its discretion.

4.5.2.1 Workmanship. - When subjected to the inspections and tests specified herein, workmanship shall be such that the completed cable shall meet all requirements of this specification, the cable specification sheets (see appendix A), and other referenced documents.

4.5.2.2 Quality Assurance Test Rejection. - If a quality assurance sample fails any of the tests or inspections specified herein, the entire lot represented by the sample shall be rejected. Before the rejected lot or any subsequent lot of the same design can be resubmitted for acceptance, a detailed report shall be forwarded to the procuring activity covering the rejection and the action taken to prevent recurrence of the defect causing failure. The proposed corrective action on the lot represented by the rejected sample shall be the basis for permitting resubmittal. Any re-worked lot must be accompanied by a detailed report covering the previous rejection and corrective action taken.

4.5.3 Acceptance Tests. - Acceptance tests and inspections shall be performed on all cable in each lot. The electrode spark test shall be performed on all finished conductors prior to cabling. One sample from each lot of cable shall be inspected for visual and dimensional requirements.

4.5.3.1 Acceptance Test Rejection. - Any cable that fails any acceptance test or inspection shall be rejected. Rejected cable may be resubmitted at the discretion of the procuring activity, after corrective action has been taken. The number and type of defects shall be the basis for permitting resubmittal. Any reworked cable shall be accompanied by a detailed report concerning the previous rejection and corrective action taken. After rework, all previously rejected cable shall be subjected to all acceptance tests and inspections specified herein.

4.6 Test Reports and Certification. - Certification and reports of tests and inspections performed in accordance with the requirements of this specification shall be furnished to the procuring activity as specified in 4.6.1 and 4.6.2. Certifications and test reports shall be validated by the cognizant Government inspector. When such certifications or reports are required, no cable shall be accepted for delivery by the procuring activity prior to receipt of the certification or reports.

4.6.1 Component Materials Certification. - The supplier shall certify to the procuring activity that the component materials used in the manufacture of cables furnished under this specification are in accordance with the applicable referenced specifications and requirements. When requested, reports of tests verifying conformance with the applicable referenced specifications and requirements shall be furnished to the procuring activity.

4.6.2 Test and Inspection Certification. - The supplier shall certify to the procuring activity that all test and inspection requirements specified herein have been complied with and that all cable furnished conforms to all requirements specified herein. When requested, reports of tests and inspections shall be furnished to the procuring activity.

4.7 Reinspection. - The procuring activity reserves the right to reinspect and retest the cable for any necessary requirement after delivery and before final acceptance. Any or all of the inspections and tests specified herein may be performed to determine conformance to prescribed requirements. Final acceptance shall depend upon evaluation of test results.

4.8 Test Methods and Conditions. - All tests shall be performed in accordance with the methods and under the conditions specified in 4.8.1 through 4.8.7.

4.8.1 Test Conditions. - Unless otherwise specified, tests shall be performed at temperatures of 20 °C to 28 °C and a relative humidity of 80 percent maximum.

4.8.2 Cable Component Tests. - Unless otherwise specified, all tests shall be performed on cable components that have been removed from finished cables.

4.8.2.1 Conductor Tests. - Cable conductors shall be tested as specified in 3.5.5.

4.8.3 Electrical Tests. - Unless otherwise specified in the contract, every length of cable in every lot shall be subjected to the electrical tests specified in 4.8.5 through 4.8.7. The tests shall be performed on the completed cable in the sequence listed herein.

4.8.4 Test Equipment. - The contractor shall supply suitable bridge equipment, source of testing current, and other necessary equipment required for making accurate electrical measurements. The direct-current bridge measurements shall be made within an accuracy of 0.1 percent. The power source shall be capable of delivering a testing potential as specified in table 4 and shall be equipped with a variable control and meter for regulating and measuring output. The contractor shall make available to the NASA procuring activity a description, a wiring diagram, and operation instructions covering the equipment to be used. NASA

procuring activities shall check the equipment against calibrated standards to ensure accurate and satisfactory results are obtained.

4.8.5 Dielectric Strength. - Voltage shall be applied between adjacent conductors and between conductors and the conductor shield, if applicable, and the cable overall shield for a period of not less than 30 seconds on each completed length of cable. Conductors may be tested singly against all other conductors or arranged in two or more groups, provided that full voltage is impressed between adjacent conductors and each conductor and the shield. The test voltage shall be attained by raising the inspection test voltage from zero to the value specified in table 4 within 20 seconds. The conductor insulation shall exhibit no electrical breakdown. If conductor shields are insulated, the shields shall be tested in a like manner.

4.8.6 Insulation Resistance. - Immediately after the dielectric strength test, the cable shall be tested for insulation resistance in accordance with ASTM D470. The test potential shall be 500 volts direct current minimum, and the temperature correction factors shall be supplied and certified by the contractor. Conductors may be tested singly or in groups in accordance with the connections used in the dielectric strength test specified in 4.8.5. The insulation of the completed cable shall have resistance values not less than the values of R as shown in table 4.

4.8.7 Sheath Flaws. - The finished cable shall pass through a spark test device that will subject 100 percent of the sheath surface to the test voltage (specified in table 8) applied between the sheath and the cable shield. The speed of travel through the device shall be adjusted so every point on the sheath surface shall be in contact with the test voltage for not less than 0.25 second. The sheath shall exhibit no electrical breakdown. If sheath breakdown occurs at any point, the sheath shall not be repaired, but the section of cable containing the failure point shall be cut out and removed from production. Method 6211 of FED-STD-228 shall be used.

5. PREPARATION FOR DELIVERY

5.1 Packaging, Packing, and Marking. - Packaging, packing, and marking shall be in accordance with MIL-C-12000 and as specified herein.

5.1.1 Packaging. - Packaging shall be accordance with the level A requirements of MIL-C-12000 and as follows.

5.1.1.1 Reels and Spools. - Cable shall be delivered on reels or spools. The cable shall be wound on the reel or spool in a manner such that both ends are accessible for testing.

Table 8. Sheath Spark Test Voltages
(For Shielded and Jacketed Cables)

Jacket Thickness		AC Spark Test Voltage (kV)
mm	mil	
0 to 0.23	0 to 9	1 to 2
0.24 to 0.51	10 to 20	2.5
0.52 to 0.76	21 to 30	3
0.77 to 1.02	31 to 40	3.5
1.03 to 1.40	41 to 55	4
1.41 to 1.65	56 to 65	5.5
1.66 to 2.03	66 to 80	7
2.04 to 2.54	81 to 100	8.5
2.55 and up	101 and up	10

5.1.1.2 Cable Lengths. - Cable cutting lengths shall be as specified in the contract. Each individual continuous length of cable shall be packaged on a separate reel or spool.

5.1.2 Packing. - Unless otherwise specified in the contract, packing shall be in accordance with the level temperature requirements specified in MIL-C-12000.

5.1.3 Marking. - Cable reels or spools and exterior shipping containers shall be marked in accordance with MIL-C-12000 and MIL-STD-129. The identification shall include the following information:

a. Cable part number

b. Specification KSC-SPEC-E-0031

c. Length ( ) meters [or ( ) feet]

d. Date of manufacture

e. Name of manufacturer

6. NOTES

6.1 Intended Use. - This specification is intended to be used for the procurement of flexible multiconductor neoprene-jacketed cable used for instrumentation and control systems and GSE used to support the test, checkout, servicing, and launch of space vehicles and payloads at KSC.

6.2 Ordering Data. - Procurement documents should specify the following:

a. Title, number, and date of this specification and the applicable cable specification number

b. Cable part number

c. Total length of cable required

d. Minimum cutting lengths

e. If a preproduction sample is required (see 4.3.1)

f. Where preproduction and quality assurance tests will be accomplished (see 4.5.1)

g. If acceptance inspection samples are required to be furnished to the procuring activity (see 4.3.3)

h. Number and length of inspection samples (see 4.3.3)

i. If special packing is required (see 5.1.2)

j. If an inspection plan is required

k. If empty reels will be returned to the contractor at his expense

l. Test reports and certification

m. If a pulling eye is required at the free end of the cable and if both ends of the cable must be sealed with a cable boot

6.3 Definitions. - The following is a list of terms and their definitions as they apply to this document.

a. Barrier tape: a tape made of polyethylene terephthalate (Mylar) applied over the cable core and the cable separator.

b. Binding: binding is made of fungus-resistant cotton, synthetic thread yarn, or polyethylene terephthalate and is used as an aid in the fabrication of cables.

c. Bunched lay: a conductor with the strands twisted together in the same direction without regard to geometrical arrangement.

d. Cable: two or more conductors (solid or stranded) insulated from each other and contained in a common covering; two or more conductors insulated from each other and twisted or molded together without a common covering; or one insulated conductor with a metallic covering, shield, or outer conductor.

e. Carrier: yarn or a combination of several yarns laid parallel in the braid by a single bobbin of the braiding machine.

f. Completed cable: cable on which all manufacturing operations have been completed and that is ready to be submitted for inspection.

g. Concentric lay: a conductor or cable composed of a central core surrounded by one or more layers of helically wound strands of insulated conductors. Successive layers are laid in a reverse direction.

h. Conductor: a wire or combination of wires not insulated from each other, suitable for carrying an electric current. A conductor may be bare or insulated.

i. Denier: a unit of fineness for yarn. A denier is equal to the fineness of a yarn weighing 0.05 grams for each 450 meters of length or 1 gram for each 9000 meters.

j. Direction of lay: the lateral direction, either right hand or left hand, in which a strand or insulated conductor passes over the top as it recedes from an observer looking along the axis of the conductor or cable.

k. Elongation: extension between bench marks produced by a tensile force applied to a specimen and expressed as a percentage of the original distance between the marks on the unstretched specimen. Ultimate elongation is the elongation at the moment of rupture.

l. End: individual warp yarn.

m. Filler: materials used in the interstices of cables where necessary to give the completed assembly a substantially circular cross section.

n. Finished conductor: the metal conductor with insulation and any covering present before assembling into a completed cable.

o. Insulation: materials or compounds molded or extruded onto conductors or conductor and offering very high resistance to current flow.

p. Insulation covering: a covering applied over the insulation for the purpose of protecting the insulation.

q. Insulation resistance: the electrical resistance offered by insulation to an impressed direct-current potential, tending to produce a leakage of current through the same.

r. Length of lay: the axial length of one complete turn of the helix or any helically wound strand or insulated conductor, usually expressed in millimeters or inches.

s. Mold: a container to hold the sheath in shape during vulcanizing and curing processes.

t. Picks per 25 millimeters or picks per inch: the number of filling yarns per 25 millimeters or 1 inch of braid measured parallel to the axis of the finished wire or cable.

u. Ply: the number of single yarns twisted together to form a plain yarn; also, the number of plaid yarns twisted together to form a cord.

v. Rope lay: a single conductor cable composed of a central core surrounded by one or more layers of helically laid groups or wires.

w. Separator: a material applied between the conductor and insulation or between the cable core and sheath, used to prevent the insulation or sheath from adhering to the conductor or cable core.

x. Sheath: outer covering or jacket placed over cable primarily for mechanical protection.

y. Shielded pair: a twisted pair over which a close braid of copper wire has been applied.

z. Stranded conductor: a conductor composed of more than one wire.

aa. Tear strength: the ratio of maximum force applied during tear of a specimen to the thickness of the unstretched specimen.

ab. Tension set: elongation remaining after a specimen has been stretched, held at a specified elongation for a given period of time, and then relieved of the force and allowed to reset for a definite period of time.

ac. Twisted pair: two insulated conductors twisted together.

ad. Unidirectional lay: a conductor or cable, composed of a central core surrounded by one or more layers of helically wound strands or insulated conductors. Successive layers are laid in the same direction. The length of lay shall increase with each successive layer.

ae. Wire: a slender rod or filament of drawn metal capable of carrying current in an electrical circuit. A wire may be bare or insulated but does not have a metallic covering, sheath, or shield.

af. Yarn: the product formed by two or more single continuous filament threads twisted together.

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:

NASA - John F. Kennedy Space Center

Preparing Activity:

John F. Kennedy Space Center
Electrical Division
Engineering Development Directorate

APPENDIX A

CABLE SPECIFICATION SHEETS

Table A-1. Cable Specification Sheets

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
2	20	2	SC	PE		Single	1.57 (0.062)	8.26 (0.325)	7.75 (0.305)
87	20	2	SC	PE	OS	Single	1.57 (0.062)	9.27 (0.365)	8.51 (0.335)
5	20	3	SC	PE		Single	1.57 (0.062)	8.64 (0.340)	7.87 (0.310)
88	20	3	SC	PE	OS	Single	2.39 (0.094)	9.40 (0.370)	8.64 (0.340)
10	20	4	SC	PE		Single	1.57 (0.062)	9.27 (0.365)	8.51 (0.335)
156	20	6	3 PTSI	PE		Single	1.57 (0.062)	15.37 (0.605)	14 61 (0.575)
163	20	6	3 PTSI	PE	OS	Single	1.57 (0.062)	16.26 (0.640)	15.24 (0.600)
81	20	7	SC	PE	OS	Single	1.57 (0 062)	11.81 (0.465)	11.05 (0.435)
35	20	8	SC	PE	OS	Single	1.57 (0.062)	12.07 (0.475)	11.30 (0.445)
161	20	10	SC	PE	OS	Single	1.57 (0.062)	12.70 (0.500)	11.94 (0.470)
11	20	10	SS	PE		Single	1.57 (0.062)	14.86 (0.585)	14.10 (0.555)
97	20	10	SC	PE		Single	1 57 (0.062)	12.07 (0.475)	11.30 (0.445)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
157	20	12	6 PTSI	PE		Single	1.93 (0.076)	20.57 (0.810)	19.30 (0.760)
164	20	12	6 PTSI	PE	OS	Single	1.98 (0.078)	21.34 (0.840)	20.07 (0.790)
74	20	13	SC	PE		Single	1.57 (0.062)	12.83 (0.505)	12.07 (0.475)
12	20	18	SS	PE		Single	1.57 (0.062)	17.78 (0.700)	16.76 (0.660)
75	20	18	SC	PE	OS	Single	1.57 (0.062)	14.61 (0.575)	13.72 (0.540)
165	20	18	SSI	PE	OS	Single	1.98 (0.078)	22.35 (0.880)	21.08 (0.830)
13	20	19	SC	PE		Single	1.57 (0.062)	14.86 (0.585)	14.10 (0.555)
119	20	30	SSI	PE		Single	2.39 (0.094)	28.07 (1.105)	26.54 (1.045)
99	20	30	SSI	PE	OS	Double	2.77 (0.109)	29.85 (1.175)	28.07 (1.105)
84	20	32	SC	PE		Single	1.57 (0.062)	17.27 (0.680)	16.26 (0.640)
121	20	32	16 PTS	PE		Single	1.98 (0.078)	23.75 (0.935)	22.35 (0.880)
15	20	39	SC	PE		Single	1.57 (0.062)	18.54 (0.730)	17.53 (0.690)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
100	20	40	20 PTSI	PE	OS	Double	2.77 (0.109)	34.29 (1.350)	32.26 (1.270)
101	20	45	15 TTSI	PE	OS	Double	2.77 (0.109)	34.54 (1.360)	32.51 (1.280)
103	20	48	12 QTSI	PE	OS	Double	2.77 (0.109)	33.02 (1.300)	30.99 (1.220)
117	20	60	15 QTS	PE		Single	2.39 (0.094)	30.99 (1.220)	29.21 (1.150)
17	20	60	SS	PE		Double	2.77 (0.109)	29.85 (1.175)	28.07 (1.105)
61	20	60	30 PTS	PE		Double	2.77 (0.109)	33.53 (1.320)	31.50 (1.240)
77	20	60	SC	PE	OS	Single	1.98 (0.078)	23.50 (0.925)	22.23 (0.875)
18	20	61	SC	PE		Single	1.98 (0.078)	23.11 (0.910)	21.84 (0.860)
162	20	61	SC	PE	OS	Single	1.98 (0.078)	23.50 (0.925)	22.10 (0.870)
16	20	60	20 TTS	PE		Double	2.77 (0.109)	32.39 (1.275)	30.61 (1.205)
19	18	2	SC	PE		Single	1.98 (0.078)	10.41 (0.410)	9.53 (0.375)
20	18	3	SC	PE		Single	1.98 (0.078)	10.67 (0.420)	9.91 (0.390)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
22	18	4	SC	PE		Single	1.98 (0.078)	11.30 (0.445)	10.54 (0.415)
29	18	5	SC	PE		Single	1.98 (0.078)	11.94 (0.470)	11.18 (0.440)
30	18	6	SC	PE		Single	1.98 (0.078)	12.83 (0.505)	12.07 (0.475)
70	18	6	SC	PE	OS	Single	1.98 (0.078)	13.59 (0.535)	12.83 (0.505)
31	18	7	SS	PE		Single	1.98 (0.078)	15.88 (0.625)	14.86 (0.585)
34	18	8	SC	PE	OS	Single	1.98 (0.078)	14.99 (0.590)	14.10 (0.555)
66	18	8	SC	PE		Single	1.98 (0.078)	14.35 (0.565)	13.59 (0.535)
38	18	10	SC	PE		Single	1.98 (0.078)	15.11 (0.595)	14.22 (0.560)
71	18	10	SC	PE	OS	Single	1.98 (0.078)	16.26 (0.640)	15.24 (0.600)
73	18	13	SC	PE	OS	Single	1.98 (0.078)	17.27 (0.680)	16.26 (0.640)
72	18	15	SC	PE	OS	Single	1.98 (0.078)	17.78 (0.700)	16.76 (0.660)
39	18	19	SS	PE		Single	1.98 (0.078)	21.97 (0.865)	20.70 (0.815)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
107	18	30	SSI	PE	OS	Double	3.18 (0.125)	34.29 (1.350)	32.26 (1.270)
42	18	36	SS	PE		Single	2.39 (0.094)	27.81 (1.095)	26.29 (1.035)
41	18	37	SC	PE		Single	2.39 (0.094)	24.00 (0.945)	22.61 (0.890)
44	18	40	20 PTSI	PE		Double	3.56 (0.140)	40.64 (1.600)	38.23 (1.505)
105	18	40	20 PTSI	PE	OS	Double	3.56 (0.140)	41.66 (1.640)	39.12 (1.540)
106	18	45	15 TTSI	PE	OS	Double	3.56 (0.140)	41.66 (1.640)	39.12 (1.540)
104	18	48	12 QTSI	PE	OS	Double	3.56 (0.140)	40.26 (1.585)	37.97 (1.495)
69	18	54	SC	PE		Double	3.18 (0.125)	28.83 (1.135)	27.05 (1.065)
48	18	60	SC	PE		Double	3.18 (0.125)	29.72 (1.170)	27.94 (1.100)
49	18	60	SS	PE		Double	3.18 (0.125)	35.69 (1.405)	33.66 (1.325)
52	18	60	15 SS, 18 PTS, 3 TTS	PE		Double	3.96 (0.156)	43.18 (1.700)	40.64 (1.600)
53	18	60	SC	PE	OSDB	Double	3.18 (0.125)	31.62 (1.245)	29.85 (1.175)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
153	18	100	50 PT	PE	OS	Double	3.56 (0.140)	42.67 (1.680)	40.26 (1.585)
92	16	2	SC	PE		Single	1.98 (0.078)	10.67 (0.420)	9.91 (0.390)
91	16	3	SC	PE		Single	1.98 (0.078)	11.18 (0.440)	10.41 (0.410)
158	16	3	SC	PE	OS	Single	1.57 (0.062)	10.80 (0.425)	9.78 (0.385)
94	16	4	SC	PE		Single	1.98 (0.078)	11.94 (0.470)	11.05 (0.435)
93	16	6	SC	PE		Single	1.98 (0.078)	13.21 (0.520)	12.45 (0.490)
159	16	6	3 PTSI	PE	OS	Single	1.98 (0.078)	20.19 (0.795)	18.92 (0.745)
129	16	6	SC	PE	OS	Single	1.57 (0.062)	12.83 (0.505)	12.07 (0.475)
79	16	7	3 PTS, 1 S	PE		Single	1.98 (0.078)	19.05 (0.750)	18.03 (0.710)
80	16	7	SC	PE	OS	Single	1.98 (0.078)	14.86 (0.585)	14.10 (0.555)
36	16	10	SC	PE	OS	Single	1.98 (0.078)	17.12 (0.670)	16.00 (0.630)
67	16	10	SC	PE		Single	1.98 (0.078)	16.00 (0.630)	14.73 (0.580)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
96	16	10	2 PTS, 6 SC	PE		Single	1.98 (0.078)	18.80 (0.740)	17.78 (0.700)
160	16	12	6 PTSI	PE	OS	Double	2.77 (0.109)	27.18 (1.070)	25.65 (1.010)
155	16	15	1 PTSI, 13 SC	PE	OS	Single	1.57 (0.062)	21.08 (0.830)	19.05 (0.750)
83	16	20	SC	PE	OS	Single	1.98 (0.078)	20.32 (0.800)	19.18 (0.755)
111	16	30	SSI	PE	OS	Double	3.18 (0.125)	35.31 (1.390)	33.27 (1.310)
95	16	37	SC	PE	OSDB	Double	3.18 (0.125)	29.08 (1.145)	27.31 (1.075)
115	16	37	SC	PE	OS	Double	3.18 (0.125)	28.45 (1.120)	26.67 (1.050)
109	16	40	20 PTSI	PE	OS	Double	3.56 (0.140)	44.20 (1.740)	41.66 (1.640)
110	16	45	15 TTSI	PE	OS	Double	3.56 (0.140)	43.43 (1.710)	40.89 (1.610)
108	16	48	12 QTSI	PE	OS	Double	3.96 (0.156)	43.05 (1.695)	40.51 (1.595)
50	16	60	SC	PE		Double	3.18 (0.125)	31.67 (1.235)	29.59 (1.165)
51	16	60	SS	PE		Double	3.56 (0.140)	38.35 (1.510)	36.07 (1.420)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
118	16	60	20 TTS	PE		Double	3.56 (0.140)	42.29 (1.665)	39.75 (1.565)
120	16	60	15 QTS	PE		Double	3.56 (0.140)	41.53 (1.635)	39.24 (1.545)
122	16	60	30 PTS	PE		Double	3.56 (0.140)	41.40 (1.630)	38.99 (1.535)
130	16	60	SC	PE	OS	Single	1.57 (0.062)	27.94 (1.100)	26.29 (1.035)
131	16	60	60 SS	PE	OSI	Single	1.98 (0.078)	36.70 (1.445)	34.67 (1.365)
132	16	60	30 PTSI	PE	OS	Single	2.39 (0.094)	36.96 (1.455)	34.42 (1.355)
133	16	60	20 TTSI	PE	OS	Single	2.39 (0.094)	43.56 (1.715)	41.02 (1.615)
134	16	60	15 QTSI	PE	OS	Single	2.39 (0.094)	42.29 (1.665)	39.75 (1.565)
135	16	60	60 SSI	PE	OS	Single	2.39 (0.094)	42.55 (1.675)	40.01 (1.575)
113	14	3	SC	PE		Single	1.98 (0.078)	12.57 (0.495)	11.81 (0.465)
40	14	30	SSI	PE	OS	Double	3.56 (0.140)	41.40 (1.630)	38.86 (1.530)
98	14	40	20 PTSI	PE	OS	Double	3.96 (0.156)	53.98 (2.125)	51.44 (2.025)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
45	14	45	15 TTSI	PE	OS	Double	3.96 (0.156)	52.83 (2.080)	50.29 (1.980)
102	14	48	12 QTSI	PE	OS	Double	3.96 (0.156)	51.69 (2.035)	49.15 (1.935)
37	14	60	20 TTS	PE	OSI	Double	3.96 (0.156)	53.85 (2.120)	51.31 (2.020)
57	14	60	30 PTS	PE	OSI	Double	3.96 (0.156)	59.18 (2.330)	56.64 (2.230)
58	14	60	SS	PE	OSI	Double	3.96 (0.156)	47.75 (1.880)	45.21 (1.780)
59	14	60	SC	PE	OS	Double	3.56 (0.140)	39.24 (1.545)	36.96 (1.455)
60	14	60	15 QTS	PE	OSI	Double	3.96 (0.156)	53.34 (2.100)	50.80 (2.000)
136	14	60	2 TTSI, 48 SC, 3 PTSI	PE	OS	Single	1.98 (0.078)	41.66 (1.640)	38.10 (1.500)
137	14	60	3 PTSI, 45 SSI, 3 TTSI	PE	OS	Single	2.39 (0.094)	50.80 (2.000)	48.26 (1.900)
138	14	60	30 PTSI	PE	OS	Single	2.39 (0.094)	44.58 (1.755)	42.04 (1.655)
139	14	60	20 TTSI	PE	OS	Single	2.39 (0.094)	51.94 (2.045)	49.40 (1.945)
140	14	60	15 QTSI	PE	OS	Single	2 39 (0.094)	51.82 (2.040)	49.28 (1.940)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
145	14	60	5 PTSI, 50 SSI	PE	OS	Single	2.39 (0.094)	48.39 (1.905)	45.85 (1.805)
148	14	60	6 TTSI, 8 SSI, 17 PTSI	PE	OS	Single	2.39 (0.094)	49.28 (1.940)	46.99 (1.850)
149	14	60	5 PTSI, 50 SC	PE	OS	Single	1.98 (0.078)	40.26 (1.585)	37.97 (1.495)
150	14	60	24 SSI, 4 TTSI, 12 PTSI	PE	OS	Single	1.98 (0.078)	51.44 (2.025)	48.90 (1.925)
154	14	60	60 SSI	PE	OS	Single	1.98 (0.078)	50.29 (1.980)	45.34 (1.785)
66	12	3	SC	PE		Single	1.98 (0.078)	13.59 (0.535)	12.83 (0.505)
166	12	3	SC	PE	OS	Single	1.57 (0.062)	13.21 (0.520)	12.32 (0.485)
7	12	4	SC	PE	OSDB	Single	1.98 (0.078)	16.51 (0.650)	15.75 (0.620)
24	12	4	SC	PE		Single	1.98 (0.078)	14.61 (0.575)	13.84 (0.545)
167	12	4	SC	PE	OS	Single	1.98 (0.078)	15.62 (0.615)	14.61 (0.575)
65	12	5	SC	PE	OS	Single	1.98 (0.078)	17.02 (0.670)	16.00 (0.630)
143	12	5	SC	PE		Single	1.57 (0.062)	14.48 (0.570)	13.72 (0.540)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
43	12	37	SC	PE		Double	3.56 (0.140)	36.58 (1.440)	34.54 (1.360)
4	10	3	SC	EPR/XLPO		Single	1.98 (0.078)	16.00 (0.630)	15.11 (0.595)
8	10	4	SC	EPR/XLPO		Single	1.98 (0.078)	17.40 (0.685)	16.38 (0.645)
89	8	2	SC	EPR/XLPO		Single	2.39 (0.094)	21.21 (0.835)	19.94 (0.785)
21	8	3	SC	EPR/XLPO		Single	1.57 (0.062)	21.46 (0.845)	20.19 (0.795)
126	8	3	SC	EPR/XLPO	OS	Single	1.57 (0.062)	22.23 (0.875)	20.96 (0.825)
6	8	4	SC	EPR/XLPO		Single	2.39 (0.094)	23.37 (0.920)	21.97 (0.865)
28	8	4	SC	EPR/XLPO	OS	Single	2.39 (0.094)	24.13 (0.950)	22.61 (0.890)
125	8	5	SC	EPR/XLPO	OS	Double	3.18 (0.125)	26.92 (1.060)	25.27 (0.995)
141	8	6	SC	EPR/XLPO	OS	Double	2.77 (0.109)	28.96 (1.140)	27.31 (1.075)
33	8	7	SC	EPR/XLPO	OS	Double	3.56 (0.140)	31.50 (1.240)	29.59 (1.165)
32	8	7	1 SC, 3 PTS	EPR/XLPO		Double	3.96 (0.156)	44.45 (1.750)	41.91 (1.650)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
63	8	21	SC	EPR/XLPO	OSDB	Double	3.56 (0.140)	51.44 (2.025)	48.90 (1.925)
3	6	3	SC	EPR/XLPO		Single	2.39 (0.094)	23.88 (0.940)	22.48 (0.885)
9	6	4	SC	EPR/XLPO		Double	3.18 (0.125)	26.80 (1.055)	25.27 (0.995)
27	6	4	SC	EPR/XLPO	OS	Double	2.77 (0.109)	27.56 (1.085)	26.04 (1.025)
1	4	2	SC	EPR/XLPO		Double	3.18 (0.125)	26.42 (1.040)	24.89 (0.980)
112	4	3	SC	EPR/XLPO		Double	3.18 (0.125)	27.81 (1.095)	26.16 (1.030)
168	4	3	SC	EPR/XLPO	OS	Double	2.77 (0.109)	28.58 (1.125)	26.92 (1.060)
26	4	4	SC	EPR/XLPO	OS	Double	2.77 (0.109)	31.12 (1.225)	29.34 (1.155)
123	4	4	SC	EPR/XLPO		Double	3.18 (0.125)	30.33 (1.194)	28.55 (1.124)
127	4	5	SC	EPR/XLPO	OS	Double	3.56 (0.140)	34.67 (1.365)	32.64 (1.285)
114	2	3	SC	EPR/XLPO		Double	3.56 (0.140)	31.50 (1.240)	29.72 (1.170)
90	1/0	2	SC	EPR/XLPO		Double	3.56 (0.140)	36.45 (1.435)	34.29 (1.350)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
169	1/0	3	SC	EPR/XLPO	OS	Double	3.56 (0.140)	39.37 (1.550)	37.08 (1.460)
25	1/0	4	SC	EPR/XLPO	OS	Single	3.96 (0.156)	43.79 (1.724)	41.25 (1.624)
64	1/0	4	SC	EPR/XLPO	OSDB	Double	3.96 (0.156)	45.59 (1.795)	43.05 (1.695)
128	1/0	5	SC	EPR/XLPO	OS	Double	3.96 (0.156)	48.64 (1.915)	46.10 (1 815)
116	2/0	3	SC	EPR/XLPO		Double	3.96 (0.156)	42.29 (1.665)	39.88 (1.570)
170	4/0	3	SC	EPR/XLPO	OS	Double	3.96 (0.156)	51.56 (2.030)	49.02 (1.930)
23	4/0	4	SC	EPR/XLPO	OS	Double	3.96 (0.156)	56.39 (2.220)	53.85 (2.120)
14	16, 20	39	2#16 SC, 37#20 SC	PE	OS	Single	1.57 (0.062)	18.54 (0.730)	17.53 (0.690)
47	8, 12, 16	47	1#8 SC, 22#12 SC, 24#16 SC	EPR/XLPO	OSDB	Double	3.56 (0.140)	38.74 (1.525)	36.45 (1.435)
46	8, 12, 18	47	1#12 PTSI, 1#8 S, 24#18 S, 4#12 S, 4#12 QTSI	EPR/XLPO		Double	3.96 (0.156)	45.72 (1.800)	43.18 (1.700)
142	8, 16	4	3#8 SC, 1#16 SC	EPR/XLPO	OS	Single	1.57 (0.062)	19.43 (0.765)	18.42 (0.725)

Table A-1. Cable Specification Sheets (cont)

Cable Type No.	Conductor				Completed Cable				
	AWG	No.	Construction	Insulation Type	Shield	Sheath Type	Sheath Thickness [mm (inch)]	Maximum Diameter [mm (inch)]	Minimum Diameter [mm (inch)]
146	0, 7, 14	35	3#0 SC, 6#7 SC, 13#14 PTSI	PE/EPR/XLPO	OS	Single	2.39 (0.094)	54.23 (2.135)	50.80 (2.000)
147	2, 6, 14	29	4#2 SC, 9#6 SC, 16#14 SC	PE/EPR/XLPO	OS	Single	2.39 (0.094)	52.07 (2.050)	49.53 (1.950)
151	12, 16	10	1#12 PTSI, 4#16 PTSI	PE	OS	Single	1.98 (0.078)	19.05 (0.750)	17.78 (0.700)
152	12, 16	8	1#12 PT, 3#16 PTSI	PE	OS	Single	1.98 (0.078)	20.22 (0.910)	15.24 (0.840)
144	10, 14	40	5#10 QTSI, 20#14 SC	PE/EPR/XLPO	OS	Single	2.39 (0.094)	44.20 (1.740)	41.66 (1.640)
124	8, 12	9	3#8 SC, 6#12 SC	PE/EPR/XLPO	OS	Single	2.39 (0.094)	28.19 (1.110)	26.67 (1.050)

Notes:

1. For conductors:

PT	=	two conductors twisted
PTS	=	two conductors twisted and shielded
PTSI	=	two conductors twisted, shielded, and insulated
*QT	=	four conductors twisted
*QTS	=	four conductors twisted and shielded
*QTSI	=	four conductors twisted, shielded, and insulated
SC	=	single conductor unshielded
SS	=	single conductor shielded
SSI	=	single conductor shielded and insulated
TT	=	three conductors twisted
TTS	=	three conductors twisted and shielded
TTSI	=	three conductors twisted, shielded, and insulated

Table A-1. Cable Specification Sheets (cont)

Notes: (cont)

2. For shielded cables:

OS	=	overall braided shield
OSDB	=	overall double-braided shield
OSDBI	=	overall double-braided shield insulated from conductor shields
OSI	=	overall braided shield insulated from conductor shields

* For five or more conductors, substitute the number of conductors for the Q. For example, six conductors twisted and shielded would be abbreviated as 6TS.