INCH-POUND
MIL-DTL-24640C
8 November 2011
SUPERSEDING
MIL-DTL-24640B
22 August 2002

DETAIL SPECIFICATION

CABLES, LIGHTWEIGHT, LOW SMOKE, ELECTRIC, FOR SHIPBOARD USE, GENERAL SPECIFICATION FOR

This specification is approved for use by all Departments and Agencies of the Department of Defense.

1. SCOPE

1.1 Scope. This specification covers lightweight, low smoke, electric cables for Navy shipboard applications. These cables are not meant to be exposed to or submerged in fresh, potable, seawater, or saltwater.

1.2 Classification. Cables covered by this specification should be classified as watertight, watertight with circuit integrity, and non-watertight constructions, with or without overall shields and further classified for flexing and non-flexing service for low power, lighting, control, communications, instrumentation and electronic applications (see supplement). A part or identifying number for cable should be as specified in 1.3 and the applicable specification sheet.

1.3 Part or identifying number (PIN). The part number should be a combination of numbers and letters in accordance with the following:

M 24640	**/XX**	**-XX**	**A or U**	**O or D or N**
Prefix Specification number	Slant Sheet Number	See Specification Sheets	A = Armored U = Unarmored or blank	O = Overall shielded D = Double overall shielded N = Not shielded or blank

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed in this section are specified in sections 3, 4, or 5 of this specification. This section does not include documents cited in other sections of this specification or recommended for additional information or as examples. While every effort has been made to ensure the completeness of this list, document users are cautioned that they must meet all specified requirements of documents cited in sections 3, 4, or 5 of this specification, whether or not they are listed.

2.2 Government documents.

2.2.1 Specifications, standards, and handbooks. The following specifications, standards, and handbooks form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

FEDERAL STANDARDS

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

Comments, suggestions, or questions on this document should be addressed to: Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil, with the subject line "Document Comment". Since contact information can change, you may want to verify the currency of this address information using the ASSIST Online database at https://assist.daps.dla.mil.

DEPARTMENT OF DEFENSE SPECIFICATIONS

(See supplement 1 for list of specification sheets.)

MIL-I-631	-	Insulation, Electrical, Synthetic-Resin Composition, Nonrigid
MIL-DTL-5624	-	Turbine Fuel, Aviation, Grades JP-4 and JP-5
MIL-DTL-16884	-	Fuel, Naval Distillate
MIL-PRF-17331	-	Lubricating Oil, Steam Turbine and Gear, Moderate Service
MIL-PRF-17672	-	Hydraulic Fluid, Petroleum, Inhibited
MIL-PRF-23699	-	Lubricating Oil, Aircraft Turbine Engine, Synthetic Base, NATO Code Number O-156
MIL-DTL-81381	-	Wire, Electric, Polyimide-Insulated, Copper or Copper Alloy
MIL-PRF-83282	-	Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon Base, Metric, NATO Code Number H-537
MIL-PRF-87257	-	Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile

DEPARTMENT OF DEFENSE STANDARDS

MIL-STD-104	-	Limits for Electrical Insulation Color

(Copies of these documents are available online at https://assist.daps.dla.mil/quicksearch/ or https://assist.daps.dla.mil.)

2.3 Non-Government publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents are those cited in the solicitation or contract.

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI B46.1	-	Surface Texture (Surface Roughness, Waviness, and Lay)

(Copies of this document are available from the American National Standards Institute, 25 W. 43rd St, 4th Floor, New York, NY 10036 or online at http://webstore.ansi.org/.)

ASTM INTERNATIONAL

ASTM B3	-	Standard Specification for Soft or Annealed Copper Wire
ASTM B8	-	Standard Specification for Concentric-Lay-Stranded Copper Conductors, Hard, Medium-Hard, or Soft
ASTM B33	-	Standard Specification for Tin-Coated Soft or Annealed Copper Wire for Electrical Purposes
ASTM B193	-	Standard Test Method for Resistivity of Electrical Conductor Materials
ASTM B258	-	Standard Specification for Standard Nominal Diameters and Cross-Sectional Areas of AWG Sizes of Solid Round Wires Used as Electrical Conductors
ASTM B286	-	Standard Specification for Copper Conductors for Use in Hookup Wire for Electronic Equipment

ASTM D470	-	Standard Test Methods for Crosslinked Insulations and Jackets for Wire and Cable
ASTM D770	-	Standard Specification for Isopropyl Alcohol
ASTM D1141	-	Standard Practice for the Preparation of Substitute Ocean Water
ASTM D2240	-	Standard Test Method for Rubber Property - Durometer Hardness
ASTM D5213	-	Standard Specification for Polymeric Resin Film for Electrical Insulation and Dielectric Applications
ASTM G21	-	Standard Practice for Determining Resistance of Synthetic Polymeric Materials to Fungi

(Copies of these documents are available from ASTM International, 100 Barr Harbor Dr., P.O. Box C700, West Conshohocken, PA 19428-2959 or online at www.astm.org.)

DEFENCE STANDARDS (DEF STAN)

DEF STAN 02-711	-	Determination of the Smoke Index of the Products of Combustion from Small Specimens of Materials, Issue 2 (1/1981)
DEF STAN 02-713	-	Determination of the Toxicity Index of the Products of Combustion from Small Specimens of Material, Issue 3 (3/1985)

(Copies of these documents are available from the Procurement Executive, Ministry of Defence, Ship Department, Section TE112, Block G, Foxhill, Bath 5AB England.)

INSULATED CABLE ENGINEERS ASSOCIATION (ICEA)

ICEA T-28-562	-	Test Method for Measurement of Hot Creep of Polymeric Insulation

(Copies of this document are available from Insulated Cables Engineers Association, P.O. Box 440, South Yarmouth, MA 02664 or online at www.icea.net.)

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

NEMA WC 26	-	Binational Wire and Cable Packaging Standard
NEMA WC 61	-	Transfer Impedance Testing
NEMA WC 27500	-	Standard for Aerospace and Industrial Electrical Cable

(Copies of these documents are available from the National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, VA 22209 or online at www.nema.org.)

SAE INTERNATIONAL

SAE-AS81044	-	Wire, Electrical, Crosslinked Polyalkene, Crosslinked Alkane-Imide Polymer, or Polyarylene Insulated, Copper or Copper Alloy
SAE-AS81044/9		Wire, Electric, Crosslinked Polyalkene Insulated, Tin-Coated Copper, Medium Weight, 600-Volt, 150 °C
SAE-AS81044/12	-	Wire, Electric, Crosslinked Polyalkene Insulated, Tin-Coated Copper, Light-Weight, 600-Volt, 150 °C

(Copies of these documents are available from SAE World Headquarters, 400 Commonwealth Drive, Warrendale, PA 15096-0001 or online at www.sae.org.)

UNDERWRITERS LABORATORES INC. (UL)

UL 1581	-	Reference Standard for Electrical Wires, Cables, and Flexible Cords
UL 1685		Standard for Vertical-Tray Fire-Propagation and Smoke-Release Test for Electrical and Optical-Fiber Cables

(Copies of these documents are available from COMM 2000, 1414 Brook Drive, Downers Grove, IL 60515 or online at www.ul.com.)

2.4 Order of precedence. Unless otherwise noted herein or in the contract, in the event of a conflict between the text of this document and the references cited herein (except for related specification sheets), the text of this document takes precedence. Nothing in this document, however, supersedes applicable laws and regulations unless a specific exemption has been obtained.

3. REQUIREMENTS

3.1 Specification sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheet. In the event of any conflict between the requirements of this specification and the specification sheet, the latter shall govern.

3.2 Qualification. Cables furnished under this specification shall be products that are authorized by the qualifying activity for listing on the applicable qualified products list before contract award (see 4.3 and 6.5).

3.3 Materials. Materials used in construction of those cables furnished under this specification shall be in accordance with the requirements shown in the applicable specification sheets and as follows.

3.3.1 Conductors. Conductor material shall be copper and shall be as specified in 3.3.1.1 through 3.3.1.3.

3.3.1.1 Uncoated copper. Copper conductors shall be soft or annealed in accordance with ASTM B3.

3.3.1.2 Coated conductor. Coated copper conductors shall be tinned in accordance with ASTM B33.

3.3.1.3 Conductor stranding. The size and quantity of individual conductor strands shall be in accordance with ASTM B8 or ASTM B286 as specified in the specification sheet. Strands shall be free from lumps, kinks, splits, scraped or corroded surfaces, and skin impurities.

3.3.2 Insulation. Insulation shall be in accordance with MIL-DTL-81381, SAE-AS81044/9, or SAE-AS81044/12 as specified in the applicable specification sheet. All physical and electrical properties shall be as specified by the specification sheet.

3.3.3 Jackets. The material used for the cable jacket shall be crosslinked polyolefin which shall have the physical and electrical properties as required by the applicable specification sheet and as specified herein. The color of the cable jacket shall be black or white, as specified (see 6.2).

3.3.4 Shields. Conformance to the materials, constructions, and coverage for shields of insulated conductors, groups of insulated conductors, and overall cable and cord shall be as specified in the specification sheet. When AWG sizes are specified for wire shields, they shall be in accordance with ASTM B258.

3.3.5 Fillers. Unless otherwise specified in the applicable specification sheet, fillers for cables intended for flexing applications, only fibrous or paper fillers shall be used. For non-flexing types, solid or fibrous filler materials shall be acceptable.

3.3.5.1 Fibrous or paper fillers. Fibrous and paper fillers shall be treated for flame or moisture resistance, or a combination of both, to meet the requirements for the particular type of cable.

3.3.5.2 Nonfibrous fillers (solids). Nonfibrous fillers shall consist of elastomeric material which is removable from insulation of conductors and insulating coverings over the shields. The acceptability of the material shall be in accordance with 4.7.2 and 4.7.3.

3.3.5.3 Water-blocking filler materials (watertight). Water-blocking materials used in cable and shield interstices shall be compatible with all other cable materials. The materials shall be clean, non-tacky to the touch, and shall leave no residue on the installers' hands. The materials shall be free stripping from the cable components and shield by hand and shall not require the use of chemicals or other mechanical means of removal. The materials shall not interfere with any termination technique used with finished cable, shields, or components. The compatibility of the materials shall be in accordance with 4.7.2 and 4.7.3.

3.3.5.4 Water-swelling fillers (watertight). Water-swelling fillers used to water-block cable voids and shield interstices shall be compatible with all other cable materials in accordance with 4.7.2 and 4.7.3. The fillers shall be clean and non-tacky to the touch. They shall be readily removable from the cable components and shields. The fillers shall not interfere with any termination technique used with finished cable, shields, or components. Cables manufactured with these types of fillers shall be tested for water-tightness with seawater in accordance with ASTM D1141, and shall pass the limits for allowable water-leakage.

3.3.6 Tapes. Tapes shall be of a material compatible with the other cable materials in accordance with 4.7.2 and 4.7.3. Polyester tapes shall be Type G in accordance with MIL-I-631, and polyimide tapes shall be in accordance with ASTM D5213. Tapes applied over shield braids for singles, twisted pairs, and triads, shall be sealed or set to prevent unwinding freely, but shall be easily removable for wire and/or shield termination.

3.3.6.1 Water-swelling tapes (watertight). Water-swelling tapes used to water-block cable voids and shield interstices shall be compatible with all other cable materials in accordance with 4.7.2 and 4.7.3. The tapes shall be clean and non-tacky to the touch. They shall be readily removable from the cable components and shields. The tapes shall not interfere with any termination technique used with finished cable, shields, or components. Cables, manufactured with these types of tapes must be tested for water-tightness with seawater in accordance with ASTM D1141, and shall pass the limits for allowable water-leakage.

3.3.7 Separators. Separators may be used at manufacturer's option where required to meet insulation removability requirements and shall be of a material that is compatible with other cable materials. The compatibility of the material shall be in accordance with 4.7.2 and 4.7.3.

3.3.8 Binders. Binders shall be of a material compatible with the other cable materials. The compatibility of the material shall be in accordance with 4.7.2.

3.3.9 Fungus resistance. All nonmetallic materials shall be fungus inert and shall be certified that they meet the requirements of ASTM G21 with a growth rate of 1 or less.

3.3.10 Armor wires. The armor wires shall consist of Alclad 5056 or 5154 aluminum alloy having a diameter of 0.0126±0.0005 inch with a minimum tensile strength of 50,000 pounds per square inch (lb/in^2) and a minimum elongation (before application to the cable) of 2 percent in 10-inch length.

3.3.11 Hazardous items and toxic materials. The material shall have no adverse effect on the health of personnel when used for its intended purpose. Questions pertinent to this effect shall be referred by the contracting activity to the appropriate departmental medical service who will act as an advisor to the contracting agency. Regardless of any other requirements, materials and parts containing polyvinylchloride (PVC), asbestos, mercury, or mercury compounds shall not be used.

3.3.12 Materials control. All materials included in the construction of the cable shall be examined and tested to ensure conformance to this specification and applicable specification sheet. Once a cable construction has been fully qualified, no materials may be added, deleted, or modified. Any addition, deletion, or modification of materials within a cable construction or the processes used for cable construction shall require notification to NAVSEA and possibly requalification.

3.3.13 Recycled, recovered, or environmentally preferable materials. Recycled, recovered, or environmentally preferable materials should be used to the maximum extent possible, provided that the material meets or exceeds the operational and maintenance requirements, and promotes economically advantageous life cycle costs.

3.4 Design and construction.

3.4.1 Component wire. Unless otherwise specified in the applicable specification sheet, finished component wire shall be in accordance with SAE-AS81044, SAE-AS 81044/9, and SAE-AS81044/12. When specified in the specification sheet, the color shall be in accordance with MIL-STD-104.

3.4.2 Separators. Separators employed directly over conductors shall be applied to give not less than 100 percent coverage to the conductors.

3.4.3 Insulation. The insulation shall be as specified in the applicable specification sheet. Conductor insulation shall be readily removable by conventional wire stripping devices without damage to the conductor.

3.4.4 Tapes. Tape wraps over the cable core, shield, and other locations shall be as specified in the applicable specification sheet. Tapes shall be applied helically with an overlap of not less than 25 percent. From a design standpoint (Galvanic corrosion), copper foil shall be used where aluminum foils have been used.

3.4.5 Fillers and binders. Fillers and binders may be used to provide firmness and roundness of completed cables and to provide watertightness when required by the specification sheet. Filler and binder material shall be compatible with all other cable components. Compatibility of components shall be determined in accordance with 4.7.2 and 4.7.3.

3.4.6 Shields.

3.4.6.1 Component shields. When specified in the applicable specification sheet, shall be of the push back type and shall be constructed to conform to the physical and electrical requirements specified in the applicable specification sheet. The shield shall be of a close fitting braid construction and shall be free from irregularities and discontinuities. Individual wire strands may be spliced, but not more than one carrier may be spliced at any one point. When the braided shield is cut, it shall be capable of sliding back not less than 4 inches on an exposed 24-inch length of component wire or cable with the opposite end clamped. When specified in the applicable specification sheet, braid angle and shield coverage calculations shall be in accordance with NEMA WC 27500.

3.4.6.1.1 Component shield insulation. Shield insulation shall consist of two polyester tapes, Type G in accordance with MIL-I-631, sealed. Alternate shield insulation may consist of one polyester tape, plus an extruded jacket of a suitable translucent material, minimum average thickness of the transparent material 0.003 inch. The standard identification code shall be applied by Method 2 on the inner tape.

3.4.6.2 Overall shields. Overall shields shall be applied to the cable when specified in the applicable specification sheet. The shield shall be of a close fitting braid construction and shall be free from irregularities and discontinuities. Individual wire strands may be spliced, but not more than one carrier may be spliced at any one point. The braid angle shall be no less than 30 degrees, and no greater than 50 degrees. Conformance of the shield shall be verified by the surface transfer impedance and EMP response requirements of the applicable specification sheet.

3.4.6.3 Foil shields. When specified in the applicable specification sheet, shall be of the copper/polyester type. The percent overlap shall be as specified in the applicable specification sheet.

3.4.7 Watertightness. Where watertight cable construction is specified (see 3.1), voids within the cable construction shall be filled to prevent the passage of water longitudinally through the cable.

3.4.8 Cable jacket. A well-centered jacket shall be applied over the cable core. The jacket shall conform to the applicable specification sheet and shall be removable without damage to the underlying shield or components.

3.4.9 Finished cable. Finished cable shall conform to the applicable specification sheet. Cable dimensions shall be measured as specified in 4.6.2.

3.4.9.1 Cabling. The number of component wires shall be as specified in the applicable specification sheet. The outer layer shall be left hand and in cables with multiple layers of components, the inner layer or layers may be either right hand or left hand lay. The lay length shall be not less than 8 times nor more than 16 times the diameter over each individual layer of components.

3.4.9.2 Concentricity. Concentricity shall not be less than 70 percent and shall apply to both the finished wires and finished cable (see 4.7.1).

3.4.10 Braid armor. The armor shall be applied in the form of a braid. The weave of the braid shall be of either the "one over - one under" or the "two over - two under" type. The weave shall be such that the wires of a carrier are laid closely together, flat and parallel. The braid shall be applied with maximum tension possible so as to prevent loosening and creeping but not to cause broken ends. Splices in the braid strands shall be infrequent, staggered, and inconspicuous so as not to increase the nominal diameter of the cable or result in rough spots. Broken ends shall be neatly tucked under the braid so they do not protrude. No greater than 10 end breaks are allowed in a 50-foot section of cable. This does not include changes in carriers. When a full carrier is changed, the ends of the carrier shall also be neatly tucked under the braid so they do not protrude. No more than one carrier changes is allowed within 10 feet of cable. If more than one change is required a length shall be created. The braid shall remain snug to the cable jacket and not spring away when cut. The selection of the number of wires per carrier and the number of carriers per braid shall be such as to produce a basket weave to give a minimum of 88 percent coverage and a braid angle within the limits as specified in table I. The number of wires per carrier shall be not more than as specified in table II.

TABLE I. Armor braid angle.

Diameter over jacket (inches)	**Braid angle**	
	Minimum (degrees)	**Maximum (degrees)**
0.100 - 0.600	30	60
0.601 - 1.000	35	60
1.001 - 1.500	40	70

TABLE II. Wires per carrier.

Diameter under braid (inches)	**Maximum number of ends/carrier**	
	One over One under	**Two over Two under**
0.100 - 0.400	8	5
0.401 - 0.800	12	10
0.801 - 1.500	16	10

3.4.10.1 Braid angle and coverage. The braid angle and coverage shall be as determined by the following formulas:

Braid angle = Tan (a) = $2 \times 3.14159 (D+2d)P/C$

Percent coverage = $100 (2F-F^2)$

Where:
- F = NPd/Sin (a)
- a = acute angle of braid with axis of cable
- d = diameter (inch) of individual braid wires
- D = diameter (inch) of cable under braid
- N = number of wires per carrier
- C = number of carriers
- P = picks per inch of cable length

3.5 Electrical properties. Electrical properties of the completed cable shall be as specified by the specification sheet.

3.6 Physical properties. Physical properties of the completed cable and cable components shall be as specified by the specification sheet.

3.7 Identification codes and methods. Individual conductors and groups of conductors shall be separately identified in accordance with 3.7.1, 3.7.2, and 3.7.3.

3.7.1 Identification codes. Unless otherwise specified (see 6.2), the standard identification code and where applicable, twisted pair and triad identification codes shall be used.

3.7.1.1 Standard identification code. Standard identification code shall be in accordance with table III.

TABLE III. Standard identification code.

Color, conductor, or group no.	**Background or base color**	**First tracer color**	**Second tracer color**
1	Black	----	----
2	White	----	----
3	Red	----	----
4	Green	----	----
5	Orange	----	----
6	Blue	----	----
7	White	Black	----
8	Red	Black	----
9	Green	Black	----
10	Orange	Black	----
11	Blue	Black	----
12	Black	White	----
13	Red	White	----
14	Green	White	----
15	Blue	White	----
16	Black	Red	----
17	White	Red	----
18	Orange	Red	----
19	Blue	Red	----
20	Red	Green	----
21	Orange	Green	----
22	Black	White	Red
23	White	Black	Red
24	Red	Black	White
25	Green	Black	White
26	Orange	Black	White
27	Blue	Black	White

TABLE III. Standard identification code - Continued.

Color, conductor, or group no.	Background or base color	First tracer color	Second tracer color
28	Black	Red	Green
29	White	Red	Green
30	Red	Black	Green
31	Green	Black	Orange
32	Orange	Black	Green
33	Blue	White	Orange
34	Black	White	Orange
35	White	Red	Orange
36	Orange	White	Blue
37	White	Red	Blue
38	Brown	----	----
39	Brown	Black	----
40	Brown	White	----
41	Brown	Red	----
42	Brown	Green	----
43	Brown	Orange	----
44	Brown	Blue	----
45	White	Black	Blue
46	Red	White	Blue
47	Green	Orange	Red
48	Orange	Red	Blue
49	Blue	Red	Orange
50	Black	Orange	Red
51	White	Black	Orange
52	Red	Orange	Black
53	Green	Red	Blue
54	Orange	Black	Blue
55	Blue	Black	Orange
56	Black	Orange	Green
57	White	Orange	Green
58	Red	Orange	Green
59	Green	Black	Blue
60	Orange	Green	Blue
61	Blue	Green	Orange
62	Black	Red	Blue
63	White	Orange	Blue
64	Red	Black	Blue

TABLE III. Standard identification code - Continued.

Color, conductor, or group no.	Background or base color	First tracer color	Second tracer color
65	Green	Orange	Blue
66	Orange	White	Red
67	Blue	White	Red
68	Black	Green	Blue
69	White	Green	Blue
70	Red	Green	Blue
71	Green	White	Red
72	Orange	Red	Black
73	Blue	Red	Black
74	Black	Orange	Blue
75	Red	Orange	Blue
76	Green	Red	Black
77	Orange	White	Green
78	Blue	White	Green
79	Red	White	Orange
80	Green	White	Orange
81	Blue	Black	Green
82	Orange	White	----
83	Green	Red	----
84	Black	Green	----
85	White	Green	----
86	Blue	Green	----
87	Black	Orange	----
88	White	Orange	----
89	Red	Orange	----
90	Green	Orange	----
91	Blue	Orange	----
92	Black	Blue	----
93	White	Blue	----
94	Red	Blue	----
95	Green	Blue	----
96	Orange	Blue	----
97	Yellow	----	----
98	Yellow	Black	----
99	Yellow	White	----
100	Yellow	Red	----
101	Yellow	Green	----

TABLE III. Standard identification code - Continued.

Color, conductor, or group no.	Background or base color	First tracer color	Second tracer color
102	Yellow	Orange	----
103	Yellow	Blue	----
104	Black	Yellow	----
105	White	Yellow	----
106	Red	Yellow	----
107	Green	Yellow	----
108	Orange	Yellow	----
109	Blue	Yellow	----
110	Black	Yellow	Red
111	White	Yellow	Red
112	Green	Yellow	Red
113	Orange	Yellow	Red
114	Blue	Yellow	Red
115	Black	Yellow	White
116	Red	Yellow	White
117	Green	Yellow	White
118	Orange	Yellow	White
119	Blue	Yellow	White
120	Black	Yellow	Green
121	White	Yellow	Green
122	Red	Yellow	Green
123	Orange	Yellow	Green
124	Blue	Yellow	Green
125	Black	Yellow	Blue
126	White	Yellow	Blue
127	Red	Yellow	Blue

3.7.1.2 Telephone and special identification code. Conductor identification code for telephone cables and special cables shall be in accordance with table IV.

TABLE IV. Telephone and special identification.

Color or conductor no.	Color	Color or conductor no.	Color
1	Black	7	Brown
2	White	8	Gray
3	Red	9	Yellow
4	Green	10	Purple
5	Orange	11	Tan
6	Blue	12	Pink

3.7.1.3 Pairing of conductors for telephone cables. The paring of conductors for forming pairs for telephone cables shall be in accordance with table V.

TABLE V. Pairing of conductors for telephone cables.

Conductor no.	Paired with conductor nos.	Quantity of possible pairs
1	2 – 12	11
2	3 – 12	10
3	4 – 12	9
4	5 – 12	8
5	6 – 12	7
6	7 – 12	6
7	8 – 12	5
8	9 – 12	4
9	10 – 12	3
10	11 – 12	2
11	12	1

3.7.1.4 Twisted pair identification code. This code shall consist of the numbers in sequence running from 1 through the number corresponding to the total number of twisted pairs in the cable. Both conductors in each pair shall be numbered the same, denoting the sequence number of the pair. Distinction between the two conductors is provided by different colored insulation. Conductors of a cable with a single pair need not be numbered.

3.7.1.5 Twisted triad identification code. This code shall consist of the numbers in sequence running from 1 through the number corresponding to the total quantity of twisted triads in the cable. Three conductors shall be numbered the same, denoting the sequence number of the triad. Distinction between the three conductors is provided by different colored insulation. Conductors of a cable with a single triad need not be numbered.

3.7.2 Identification methods. Unless otherwise specified (see 6.2), identification Method 1 or Method 3 shall be used.

3.7.2.1 Method 1. Identification Method 1 shall be surface printing of both number and color designations. The legend shall be printed in contrasting color: preferably white ink on black or dark background or black ink on white or light background. The legend shall be repeated at intervals not exceeding 3 inches and alternate legends shall be inverted. For example, 10 ORANGE BLACK 10 ORANGE BLACK. Unless otherwise specified (see 3.1), the axis of the characters shall be perpendicular to the longitudinal axis of the wire. The character type shall be block and shall have a height in accordance with the diameter over which it is applied in accordance with table VI.

TABLE VI. Method 1 character height.

Diameter range (inch)	Height of character approximate (inch)
0.045 to 0.070	0.025
0.070 to 0.095	0.031
0.095 to 0.115	0.047
0.115 to 0.200	0.062
0.190 to 0.250	0.078
0.235 to 0.325	0.094
0.330 and larger	0.125

3.7.2.2 Method 2. Identification Method 2 shall use translucent (opaque) polyester tapes (see 3.3.6) which have been printed with both the number and the color designation. The legend shall be printed with black ink and shall be repeated at intervals not exceeding 3 inches and alternate legends shall be inverted. The character type shall be block and shall be approximately 3/32 inch in height.

3.7.2.3 Method 3. Identification Method 3 shall be the use of solid base colors or solid base colors with tracers as required. The base color may be either the color of the insulation or the color of a coating applied to the insulation. The tracers shall be approximately 1/32 inch wide ink stripes of the required color applied helically with 1 ½±¼ inch lay. If two tracers are required, the second shall be half the width of the first.

3.7.2.4 Method 6. Identification Method 6 shall consist of numerals printed in ink on the conductor insulation. For conductors having a jacket directly over the insulation, the numerals may be printed in ink on the jacket, at the manufacturer's option. White ink shall be used for a red or black background; black ink shall be used for a white background. Numerals may be perpendicular or parallel to the longitudinal axis of the conductor (see figure 1). Numeral width shall be proportional to conductor outside diameter (O.D.) range as shown in Method 1 (see 3.7.2.1).

Numeral height shall be 2½ to 3 times numeral width. Each numeric legend shall be underlined. Two digit legends which are parallel to the longitudinal axis shall have the bottom numeral underlined. Legends shall be alternately inverted and shall be repeated at intervals not greater than 1½ inches.

3.7.3 Manufacturer's identification tape. Unless otherwise indicated on the specification sheet, all cables with a core diameter of 0.250 inch or greater shall contain continuous, thin, moisture resistant marker tape, not less than 1/10 inch wide. Cables with core diameters less than 0.250 inch shall either contain a manufacturer's identification tape, or a marker thread in accordance with 3.7.3.1. The marker tape or threads shall be placed directly under the cable binder tape or jacket. The tape shall be printed to show the following information at intervals not greater than 1 foot.

a. Name and location of manufacture

b. Year of manufacture

c. Specification number (MIL-DTL-24640)

d. Progressive serial number

The serial number is not necessarily a footage marker. A serial number shall not be repeated by a manufacture in any one year for any one type and size of cable.

3.7.3.1 Marker threads. Marker threads may be used on cables as an alternative to a manufacturer's identification tape, as specified in 3.7.3, for cables with a core diameter of less than 0.250 inch. Marker threads shall be in accordance with those assigned by Underwriters Laboratory (UL) Incorporated to indicate the manufacture of the cable. When UL marker threads are used, a yearly marker shall also be used to indicate the year of manufacture in accordance with table VII.

TABLE VII. Yearly marker thread colors.

Year	Thread 1	Thread 2
2009	Red	Yellow
2010	Orange	Green
2011	Orange	Brown
2012	Orange	Black
2013	Orange	Yellow
2014	Blue	Green
2015	Blue	Brown
2016	Blue	Black
2017	Blue	Yellow
2018	White	Green
2019	White	Brown
2020	White	Black
2021	White	Yellow
2022	Red	Green
2023	Red	Brown
2024	Red	Black
2025	Red	Yellow
2026	Orange	Green
2027	Orange	Brown
2028	Orange	Black

3.7.4 Cable or surface marking. Unless otherwise specified (see 3.1), ink marking shall be used for overall cable jacket surface marking. The legend shall be printed in contrasting color: white ink on black background, or black ink on white background. The legend shall consist of the manufacturer's name, the cable type and size designation, specification sheet number, the year of manufacture, and jacket type. The legend shall be repeated at intervals not exceeding 1 foot from the ending of one legend to the beginning of the next legend. The year of manufacture need not be in line with the balance of the legend.

The character type shall be block and shall have a minimum height in accordance with the diameter over which it is applied in accordance with table VIII.

Jacket material name shall be abbreviated as follows: XLPOLYO

For example: "Manufacturer's name – DX-3 M24640/1-01UN 2009 XLPOLYO"
or "Manufacturer's name – DX-3 M24640/1-01UN XLPOLYO 2009"

TABLE VIII. Surface marking character height.

Diameter range (inch)	Height of character approximate (inch)
0.125 to 0.200	0.047
0.200 to 0.285	0.063
0.285 to 0.350	0.078
0.350 to 0.500	0.094
0.500 and larger	0.125

3.7.5 Completed cables. Unless otherwise specified in the specification sheet (see 3.1) or in the ordering document (see 6.2), completed cables covered by this specification shall be placed on reels. Cable placement on reels shall be in accordance with NEMA WC 26. The cable on each reel shall be one continuous length and shall have both ends readily available for testing without un-spooling.

3.7.5.1 Year marking. In addition to any other required marking, reels shall be marked with a keyed series of colors to indicate the year of manufacture. The cycle of colors shall be repeated every fifth year. The reel marking shall consist of a stripe of one coat of commercial quality outside paint approximately 2 inches wide, colored to designate the particular year of manufacture in accordance with table IX.

TABLE IX. Reel year color marking.

Year of manufacture	Identifying color
2009	Blue
2010	White
2011	Red
2012	Green
2013	Orange
2014	Blue
2015	White
2016	Red
2017	Green
2018	Orange

3.7.5.2 Location of year marking. The colored stripe on reels shall be applied circumferentially over the lagging or the alternative to lagging and midway between the flanges. The stripe shall consist of one coat of commercial quality outside paint of the appropriate color. In addition to the stripe, both flanges of the reel shall be stenciled with 4-inch high figures to show the year of manufacture.

3.7.5.3 Standard reel markings. Each reel shall be plainly marked on both flanges with the following information:

a. Reel number.

b. Type and size of cable.

c. Footage.

d. Contract or order number.

e. Contractor's name.

f. Manufacturer's name (if other than contractor).

g. Gross weight.

h. One continuous length or the sequence of lengths on the reel indicated in feet, whichever is applicable.

3.7.5.4 Coils. Coils shall contain one continuous length of cable (standard length, see table X).

TABLE X. Cable lengths.

Type of package	Nominal length (feet)	Standard lengths no price reduction (feet)	Random lengths no price reduction (feet)	Remnant lengths price reduction		Scrap lengths not acceptable (feet)
				5 percent (feet)	10 percent (feet)	
Coil	250	300 to 200	199 to 100	99 to 75	74 to 50	49 to 0
Coil	500	550 to 450	449 to 150	149 to 100	99 to 50	49 to 0
Reel	250	300 to 200	199 to 100	99 to 75	74 to 50	49 to 0
Reel	500	550 to 450	449 to 150	149 to 100	99 to 50	49 to 0
NOTE: For orders greater than 2500 feet, no more than 10% of the total length shall be random lengths.						

3.7.5.5 Year marking. In addition to any other required marking, coils shall be marked with a keyed series of colors to indicate the year of manufacture. This marking shall consist of a stripe approximately 2 inches wide and colored for the particular year of manufacture. The cycle of colors shall be the same as those used for year marking of reels (see 3.7.5.1).

3.7.5.6 Identification. Two shipping tags shall be securely attached to each coil, one inside and one outside the wrapping, and marked with the following information.

a. Type and size of cable.

b. Footage.

c. Contract or order number.

d. Contractor's name.

e. Manufacturer's name (if other than contractor).

f. Gross weight.

4. VERIFICATION

4.1 Classification of inspections. The inspection requirements specified herein are classified as follows:

a. Qualification inspection (see 4.3).

b. Conformance inspection (see 4.4).

4.2 Inspection conditions. Unless otherwise specified (see 6.2), all inspections shall be performed in accordance with the test conditions specified in 4.5.

4.3 Qualification inspection. Qualification inspection shall consist of the examination and tests specified in tables XI and XIII and in accordance with the applicable specification sheet.

TABLE XI. Qualification inspection.

Examination or test	Requirement paragraph	Test method paragraph
Cable aging and compatibility	Specification sheet	4.7.2
Acid gas equivalent	Specification sheet	4.7.15
Halogen content	Specification sheet	4.7.16
Flame propagation	Specification sheet	4.7.7
Immersion	Specification sheet	4.7.18
Smoke index	Specification sheet	4.7.17
Toxicity index	Specification sheet	4.7.19
Durometer	Specification sheet	4.7.6
Weathering	Specification sheet	4.7.20
Fungus resistance	3.3.9	----
Abrasion resistance	Specification sheet	4.7.1
Gas flame (3 hour)	Specification sheet	4.7.8
Finished wire	Specification sheet	Specification sheet
Physicals (aged)	Specification sheet	4.7.12 and 4.7.21
Armor	Specification sheet	4.8.10

4.3.1 Qualification specimens. A manufacturer seeking qualified products listing (QPL) shall manufacture and be responsible for testing a cable type and size required for group qualification in accordance with table XI. When a manufacturer desires qualification of an individual type, size, or group, the selection of test specimens and scope of qualification shall be subject to review. For specification sheets (see 3.1) having more than one type of insulation compound, each insulation type will require qualification. A sufficient length of any test specimen shall be manufactured at one time.

4.3.1.1 Scope of qualification requirements. Authorized testing of qualification samples outlined in table XII or testing of selected samples to incorporate alternate materials in the originally approved Details of Construction Sheets and approval of low smoke electrical cables based on satisfactory test results for the representative samples shall not in any way be construed as meaning that only the type/size/variation of the representative sample(s) has to meet the specification requirements. All types/sizes/variations comprising the group(s) represented by the test sample(s) must meet all specification requirements.

4.3.2 Qualification retention. Retention qualification is required on an annual basis with the initial retention qualification date established by NAVSEA or qualifying activity. NAVSEA or qualifying activity will require annual certification and three years requalification testing (of materials) or both. At a minimum, annual certification is required that equipment and facilities, processes, design and materials have not changed since qualification unless such change has been approved by NAVSEA. The vendor will requalify every three years and perform as required, the following tests, at a minimum, shall be performed in accordance with the applicable test paragraphs, (see table XI), on all materials for which a requirement is specified:

- Halogen content
- Toxicity index
- Acid gas
- Smoke index
- Immersion
- Flame propagation (see 6.2.5)

TABLE XII. Qualification and qualification retention test samples and groups.

Qualification test samples			
Group no.	**Additional cable types and sizes for flame propagation test only**	**All tests specified in the applicable specification sheet type and size**	**Types comprising the group** 1/
1	None	DX-3	DX, TX, and FX
2	DXW-3	MXCOW-10	DXW, TXW, FXW, DXOW, TXOW, FXOW, MXCOW, 7XW, and MXCW
3	None	2XSAOW-10	1XSOW, 2XSAW, 2XSOW, 3XSOW, 2XSAOW, 2XSAWA, 2XSW, 3XSW, and MXSOW
4	None	2XOW-6 or 2XOW-42	2XOW
5	TTX-15	MXO-10	MXO, MXSO, TTX, TTXS, TTXSO, 2XAO, 1XMSO, 2XS, 3XS, 9XS, 2XO, 5XO, 2XSO, and 2XSXO
6	TTXW-15 or TTXW-20	TTXOW-15 or TTXOW-20	TTXW and TTXOW

NOTE:
1/ Includes all sizes and variations of the cable type.

4.4 Conformance inspection. Conformance inspection shall be performed on all completed cable in accordance with the procedure specified herein. This inspection shall consist of basic electrical tests plus Groups A, B, C, and D examination and tests specified in table XIII and in accordance with the specification sheets.

TABLE XIII. Conformance inspection.

Examination or test	Requirement paragraph	Test method paragraph
Basic electrical:		
Conductor resistance	Specification sheet	4.8.4
Voltage withstand	Specification sheet	4.8.6
Insulation resistance	Specification sheet	4.8.5
Conductor and shield continuity	Specification sheet	4.8.8
Jacket flaws	Specification sheet	4.8.7
Group A:		
Visual and dimensional	3.1, 3.2, 3.3, 3.4, 3.5, 3.6, and 3.7	4.6
Capacitance	Specification sheet	4.8.2
Characteristic impedance	Specification sheet	4.8.3
Watertightness	Specification sheet	4.7.14
Weight	Specification sheet	4.7.23

TABLE XIII. Conformance inspection - Continued.

Examination or test	Requirement paragraph	Test method paragraph
Group B:		
Cold bending	Specification sheet	4.7.4
Cross link proof	Specification sheet	4.7.24
Drip	Specification sheet	4.7.5
Tear strength	Specification sheet	4.7.13
Physicals (unaged)	Specification sheet	4.7.12 and 4.7.21
Attenuation	Specification sheet	4.8.1
Gas flame (1 hour)	Specification sheet	4.7.8
Group C:		
Physicals (aged)	Specification sheet	4.7.12 and 4.7.21
Permanence of printing (conductor insulation)	Specification sheet	4.7.10
Permanence of printing (jacket)	Specification sheet	4.7.11
Heat distortion	Specification sheet	4.7.9
Cable sealant removability	Specification sheet	4.7.3
Shrinkage	Specification sheet	4.7.22
Surface transfer impedance	Specification sheet	4.8.9
Group D:		
Flame propagation	Specification sheet	4.7.7

4.4.1 Inspection lot. An inspection lot shall consist of the total number of units of product of any one type, size, and construction manufactured under essentially the same conditions.

4.4.2 Basic electrical tests. Basic electrical tests shall be in accordance with the applicable specification sheet and shall be performed on each length of completed cable. For electrical test purposes, length of completed cable shall be as defined in 6.7.4.1.

4.4.3 Sampling procedure. The required number of samples (see 4.4.3.1 through 4.4.3.4) for Groups A, B, C, and D examination and tests shall be selected at random from the inspection lot. Nonconforming starting and finishing ends of cable shall be removed by the manufacturer prior to selecting samples.

4.4.3.1 Sampling for group A examination and tests. Samples for Group A examination and tests shall be selected from each lot as specified in table XIV.

TABLE XIV. Sampling for group A examination and tests.

Units of product in lot	Number of samples
1	1
2 thru 10	2
11 thru 30	3
31 thru 90	7
91 thru 210	15
211 and over	25

4.4.3.2 Sampling for group B tests. Samples for Group B tests shall be selected from each lot as specified in table XV.

TABLE XV. Sampling for group B tests.

Units of product in lot	Number of samples
8 and under	1
9 thru 30	2
31 thru 90	3
91 thru 210	4
211 and over	5

4.4.3.3 Sampling for group C tests. Samples for Group C tests shall be selected as specified in table XVI.

TABLE XVI. Sampling for group C tests.

Two month's production (units of product)	Number of samples
8 and under	1
9 thru 30	2
31 thru 90	3
91 thru 210	4
211 and over	5

4.4.3.4 Sampling for group D tests. Samples for Group D test shall be selected by testing the first production run of each type and size of cable each calendar year (20xx) (see 6.2.5).

4.4.3.5 Sampling, accept/reject criteria. Material found unacceptable shall be resubmitted for reinspection only after all materials are re-examined or re-tested or both (re-examined and re-tested) and all defective materials are removed or defects corrected. Material resubmitted shall be verified 100 percent for the failing characteristic. Material found acceptable during rescreening inspection/testing can be re-identified and released as a separate lot.

4.4.4 Group A examination and tests. Group A examination and tests as required by the specification sheet shall be performed on samples selected in accordance with 4.4.3.1.

4.4.5 Group B examination and tests. Group B examination and tests as required by the specification sheet shall be performed on specimens taken from samples selected in accordance with 4.4.3.2.

4.4.6 Group C examination and tests. Group C examination and tests as required by the specification sheet shall be performed on specimens taken from samples selected in accordance with 4.4.3.3.

4.4.7 Group D examination and tests. Group D examination and tests as required by the specification sheet, shall be performed on specimens taken from samples selected in accordance with 4.4.3.4.

4.5 Test conditions. Unless otherwise specified (see 3.1), the examination and tests specified in tables XI and XIII shall be made at standard ambient conditions as follows:

a. Temperature: 23±2.0 °C

b. Humidity: 50±40 percent RH

4.6 Visual and dimensional examination. Cables shall be visually examined to verify that the materials, design, construction, physical dimensions, marking, and workmanship are as specified in 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, and 3.7. Concentricity, wall thickness and dimensional examinations shall be made as follows:

4.6.1 Concentricity and wall thickness. The concentricity of the finished wire and the finished cable jacket shall be determined in accordance with 4.6.1.1, as applicable. Wall thickness measurements shall be made on cross sections of the finished wire or cable jacket under suitable magnification. The wall thickness shall be the shortest distance between the outer rim of the finished wire insulation or cable jacket and the outer rim of the underlying conductor or shield strand.

4.6.1.1 Component wire and cable jacket. The concentricity of the finished wire and cable jacket shall be determined by first locating and recording the minimum wall thickness measured on a cross section of the finished wire and cable jacket. From this point on the outer rim of the finished wire and cable jacket (at which the minimum wall thickness was measured), three more reference points (90 degrees apart) on the outside rim of the finished wire and cable jacket shall be established. At each of these three reference points, the nearest member of the conductor shall be selected, and the minimum wall thickness be measured. The average of the four readings shall be the average wall thickness. The percent concentricity shall be defined 100 times the ratio of the minimum wall thickness to the average wall thickness.

4.6.2 Dimensions. Measurements shall be made on not less than a 12-inch length of cable taken from the end of the sample unit. Inner components shall be made accessible by stripping and removing the outer components so as not to nick, cut, cold work, or otherwise damage the component to be measured. Four points for measurement shall be located 3 to 4 inches apart along the finished wire specimen or finished cable specimen lengths, as applicable. Measurements shall be made at each point at two perpendicular planes or as required to assure the minimum and maximum reading is attained at each point. A total of eight measurements shall be performed on each specimen. The minimum, maximum, and average value shall be recorded, as applicable. Measurements shall be made with a micrometer, caliper, or equal. A PI-tape may be used for measurements of diameters greater than 0.250 inch.

4.7 Test methods (physical).

4.7.1 Abrasion resistance. Abrasion resistance of cable jacket material shall be determined as specified in 4.7.1.1 through 4.7.1.4.

4.7.1.1 Specimens. One cable jacket test specimen shall be prepared by extruding material onto a 16 AWG (19/29) conductor. The material shall be manufactured using process conditions as close as possible to those used to produce the overall cable jacket and shall have an overall cable diameter of 0.119+0.001, -0.000 inch.

4.7.1.2 Special apparatus. Apparatus shall include the following:

a. Abrading machine – A cylinder, which incorporates 2 abrading elements on its surface, which is motor driven to rotate about a horizontal axis at 17+3, -2 revolutions per minute (rpm) and over which the specimen is draped, as shown in figures 2 and 3 and as described below.

(1) Each abrading element shall consist of a 5⁄16 inch square, (in^2) high speed tool bit (Cleveland Twist Drill Company number 855 or equivalent) which has been ground on two adjacent, longitudinal sides to produce a single, sharp 90 degree longitudinal edge free of nicks. A medium grade grinding wheel (Norton Company number 39C6018VK or equivalent) shall be used for this grinding. Abrading elements shall be reground as required; in no case shall an abrading element be used in excess of 5 hours without regrinding. Whenever the perpendicular distance between either pair of opposite longitudinal sides of an abrading element become less than 0.3085 inch (as by repeated regrinding) then that abrading element shall be discarded and replaced.

(2) The cylinder shall be 8±⅛ inch in diameter and shall be rigidly fabricated from metal.

(3) Each of the 2 abrading elements shall be maintained in electrical contact with the metal cylinder by securing each in a notch cut into the cylinder, parallel to the cylinder axis; the 2 notches required shall be spaced 180±2 degrees apart around the circumference of the cylinder. These notches shall be cut such that the sharpened 90-degree longitudinal edge of each element shall be facing outward from the cylinder surface and such that the midpoint of a straight line drawn between the midpoints of the 2 longitudinal edges adjacent to the sharpened edge is tangential ±0.003 inch to the cylinder surface.

(4) An automatic counter shall be provided to total the number of times the test specimen is scraped by the abrading elements during the test.

(5) A 1-pound ±0.5-ounce weight shall be provided for applying tension to the specimen.

b. Short circuit monitor – A voltage source of not less than 12 V [either direct current (DC) or root mean square (RMS) alternating current (AC)] which can be applied between the specimen conductor and both abrading elements of the abrading machine as shown in figures 2 and 3. (The connection to the abrasion elements may be provided by a wiping contact on the cylinder.) A means (such as an electrical relay) shall be provided whereby an electrical connection between either abrading element and the specimen conductor shall automatically stop the rotation of the cylinder on the abrading machine (as by removing motor power).

4.7.1.3 Procedure. Specimens shall be wiped with a clean dry cloth to remove any lubricant or dirt. Each specimen shall then be tested (either simultaneously or at one time) as follows. Each specimen shall be hung circumferentially over the cylinder of the abrading machine such that each specimen shall form an arc of not less than 170 degrees around the cylinder for the remainder of the test. One end of each specimen shall then be secured to a fixed surface. The abrading machine weight shall be attached to the opposite specimen end such that both this specimen end and the weight be freely suspended. The automatic counter shall be set initially to zero, the short circuit monitor shall be applied between both abrading elements on the abrading machine and the conductor of each specimen. The cylinder motor shall then be turned on, allowing the cylinder to rotate beneath each specimen, from secured end to weighted end.

4.7.1.4 Observation. Specimen failure shall be construed if electrical contact occurs between either abrading element and any specimen conductor (as evidenced by cessation of cylinder rotation) prior to completing 150 abrasive scrapes (75 cycles).

4.7.2 Cable aging and compatibility (125 °C). This test shall be to detect any significant degradation due to component incompatibility or prolonged overheating of completed cable containing thermosetting or tape insulation. This test permits either of two methods (the current overload method or the hot air oven method) to be used for heat aging.

4.7.2.1 Specimen. Specimens for cable aging and compatibility tests shall be as follows:

a. For the current overload method, the specimen shall consist of a 40±4 foot length of completed cable.

b. For the hot air method, 2 specimens of completed cable shall be required. Specimen number 1 shall have a length of 30±3 feet. Specimen number 2 shall have a length of not less than the sum of 12 inches +20 times the maximum specified overall diameter of the cable (see 3.1). Both specimens shall be removed from the same length of cable.

4.7.2.2 Special apparatus. Apparatus shall include the following:

a. The oven (required for either heat aging method) shall support the requirements as specified in 4.7.2.3, as applicable. The oven air temperature shall be measured in the immediate vicinity of the specimen.

b. The mandrel (required for either heat aging method) shall be rigid, smooth cylinder or partial cylinder, with a continuous curved surface of not less than 180 degrees, of suitable length and construction for the specimen bending as specified in 4.7.2.5. The mandrel diameter shall be approximately 12 times the specified maximum overall cable diameter (see 3.1).

c. Voltage withstand test apparatus (required for either heat aging method) shall be as specified in 4.8.6.2

d. Insulation resistance test apparatus (required for either heat aging method) shall be as specified in 4.8.5.3.

e. Thermocouple device (required for the current overload if submethod 4.7.2.3.a.(1) is used) and an associated temperature indicating device shall be provided for the use and temperatures specified in 4.7.2.3.a. Temperatures shall be measured with an error of not more than ±1 °C.

f. Current source (required for current overload method only) shall be an adjustable source of either DC or 60 Hertz single-phase AC, for maintaining specimen conductors at an elevated temperature as specified in 4.7.2.3.a. A means shall be provided for measuring the current produced by this source with an error of not more than ±5 percent.

g. Resistance meter (required for the current overload method if submethod 4.7.2.3.a is used) shall be provided for measuring the resistance of a single specimen conductor at room temperature and at elevated temperatures, as specified in 4.7.2.3.a. The meter shall exhibit a measurement error of not more than ±1 percent.

4.7.2.3 Procedure. Select and perform either of the two heat aging methods, the current overload method or the hot air method, specified in (a) or (b) herein, respectively. The oven air temperature (in both methods), conductor temperature, and current (in the current overload method only) shall be recorded at intervals of not more than 15 minutes during the first hour after attaining the heat aging temperature, at intervals of not more than 1 hour for the following 5 hours and not less than twice daily thereafter for the duration of the heat aging. The interval between the consecutive temperature recordings shall not exceed 17 hours at any time during heat aging.

a. Prior to heat aging, the current overload method specimen shall be subjected to the insulation resistance and voltage withstand test in accordance with 4.8.5 and 4.8.6, respectively. The voltage withstand test shall use the specified voltages (see 3.1). Following these, specimen conductor ends shall be electrically interconnected such that a single series electrical circuit is formed in the conductors. Provision shall then be made to measure specimen conductor temperature, using either of the following submethods.

(1) The smallest practicable “V” shaped cut shall be made along the specimen at a point approximately midway between the specimen ends, the thermocouple shall be placed beneath the resulting triangular tab. The thermocouple shall be positioned such that it is in firm contact with any single specimen conductor layer. (For specimens with only a single layer of conductors, any specimen conductor may be used.) The thermocouple shall be used with its associated temperature indicating device to measure specimen conductor temperature during heat aging.

(2) The resistance meter shall be connected to measure the resistance between the ends of any single specimen conductor in the innermost conductor layer. (For specimens with only a single layer of conductors, any specimen conductor may be used.) The meter leads shall be positioned on the conductor extremities such that all conductor interconnections are excluded from resistance measurements. The conductor temperature shall then be determined by using the following formula:

Conductor temperature, in °C = $(234.5 + t)(R/r) - 234.5$

Where:

R = Measured conductor resistance, in ohms, during heat aging.

T = Measured room temperature, in °C, to which the specimen is exposed prior to heat aging. Temperature t shall be measured in the immediate vicinity of the specimen; measurement accuracy shall be within ±0.5 °C.

r = Measured conductor resistance, in ohms, when the specimen is exposed to room temperature t. t shall be held constant, within ±0.5 °C for a period of not less than 2 hours prior to this measurement.

The specimen shall next be placed into the oven such that a length of not less than the sum of 12 inches +20 times the maximum specified overall cable diameter (see 3.1) remains straight and horizontal and such that the remainder of the specimen is formed into the largest practicable horizontal coil (to permit free circulation of convection air currents). The current source shall be connected between the two end conductors of the single series circuit within the specimen. The specimen shall then be subjected to heat aging; the air temperature within the oven shall be raised to 50±3 °C and the current source adjusted to produce a conductor temperature of 125±5 °C. These temperatures shall be maintained for a continuous period of not less than 400 hours. The current source shall not be shut off during heat aging, except for momentary shut off for taking resistance measurements when submethod a(2) herein is used. Following heat aging, the specimen shall be allowed to cool throughout to room temperature. The conductor temperature shall then be recorded. A recording which differs from room temperature by more than 5 °C shall be considered to indicate failure of the conductor measurement means. If any such failure should occur, the heat aging test shall be considered to be invalid and shall be repeated using a different specimen removed from the same cable. (A possible advance indication of such a failure and the need to retest, may be the need to make prominent adjustments of conductor current in order to maintain indicated conductor temperature during heat aging.) Following heat aging, the specimen shall be subjected a second time to the insulation resistance and voltage withstand tests as specified in 4.8.5 and 4.8.6, respectively. A sample, of length not less than 12 inches +20 times the maximum specified overall cable diameter (see 3.1), shall the be removed from that portion of the specimen which had been kept straight during the heat aging. This sample shall be subjected to the bending procedure as specified in 4.7.2.5. A portion of the remainder of the specimen shall be subjected to the cable sealant removability test as specified in 4.7.3.

b. Prior to heat aging, hot air oven method specimen 1 shall be subjected to the insulation resistance and voltage withstand as specified in 4.8.5 and 4.8.6, respectively. The voltage withstand test shall use the voltages specified (see 3.1). Both specimens shall then be placed within the oven, specimen number 1 shall be formed into the largest practicable horizontal coil within the oven and specimen number 2 shall be positioned such that it is both straight and horizontal. Both specimens shall be simultaneously subjected to heat aging. The air temperature within the oven shall be raised to 125±3 °C. This temperature shall be maintained for a continuous period of not less than 400 hours. Following heat aging both specimens shall be allowed to cool to room temperature. Specimen 1 shall then be subjected a second time to the insulation resistance and voltage withstand tests as specified in 4.8.5 and 4.8.6, respectively. A portion of specimen 1 shall next be subjected to the cable sealant removability test as specified in 4.7.3. Specimen 2 shall be subjected to the bending procedure as specified in 4.7.2.5.

4.7.2.4 Observation. Any of the following shall constitute specimen failure:

a. Falling away of any material from either end of any specimen during heat aging.

b. Jacket sagging on any specimen.

c. Specimen (specimen 1 if the hot air oven method is used) fails either of the insulation resistance tests (see 4.8.5).

d. Specimen (specimen 1 if the hot air oven method is used) fails either of the voltage withstand tests (see 4.8.6).

e. Specimen (specimen 1 if the hot air oven method is used) fails the cable sealant removability tests (see 4.7.3).

4.7.2.5 Further procedure. The mandrel shall be secured to a fixed surface, one end of the specimen shall be secured such that it is both in contact with the curved surface of the mandrel and perpendicular to the mandrel center of the curvature axis. The opposite end of the specimen shall be bent circumferentially around the curved mandrel surface through an arc of not less than 170 degrees. Bending shall be accomplished at the rate of approximately 20 degrees per second. The specimen shall then be secured to maintain its bent shape (as with a piece of twine, stretched taut and tied between each end of the specimen) and shall be removed from the mandrel. Not less than two thirds of the bent portion of the specimen shall then be dissected; each of its constituent components shall be visually inspected for deterioration.

4.7.2.6 Further observation. Specimen failure shall be construed if the specimen, upon dissection and inspection, exhibits visible deterioration of such a nature or extent as to impair the performance of the cable in service. Deterioration sufficient to constitute specimen failure shall include, but not limited to, distortion or cracking of any constituent component, hardening of sealant material, or any discoloration indicating material incompatibility.

4.7.3 Cable sealant removability. This test shall determine whether or not sealant materials can be readily removed from the constituent components of cable. This test shall not apply to sealant material used to fill voids between either conductor strands or braid strands.

4.7.3.1 Specimen. The specimen shall be a 2-foot length of completed cable.

4.7.3.2 Procedure. Overall specimen components (such as jackets, overall binders, or shields) shall be removed from one end of the specimen for a distance of not less than 10 inches, thereby exposing the cable core. Using fingers only, sealant material shall then be removed from all exposed insulated conductors or from all groupings of insulated conductors which have a common covering (such as insulated conductor pairs or triads, which have an overall shield or binder) for a distance of not less than 8 inches. Tools, cloths, or solvents shall not be used to assist with sealant removal. The common covering and sealant material shall then be removed from not less than one grouping of insulated conductors, on specimens incorporating such groupings, for distance of not less than 5 inches. Fingers only shall then be used for sealant removal. If occasional particles of sealant material remain on any constituent component of the cable core, then the removal of these particles shall be attempted by means of light brushing with fingers or with a dry cloth.

4.7.3.3 Observation. Any of the following shall constitute specimen failure:

a. Sealant material is nonflexible.

b. Sealant material which adheres to the finger or to any component of the cable core. The adherence of occasional small particles of sealant material to the cable core is acceptable unless there are small particles which cannot be removed from the core components by light brushing with fingers or a dry cloth.

c. Sealant material which leaves a residue on cable core components.

d. Sealant material cannot be removed in less than 5 minutes.

4.7.4 Cold bending cable. This test shall determine the ability of completed cable, which is not intended to be flexed during use, to withstand bending at reduced temperature, such as might be encountered during shipboard construction or repair.

4.7.4.1 Specimen. The specimen shall consist of a piece of completed cable which shall have a length of not less than the sum of 12 inches +1.6 times the specified mandrel diameter (see 3.1).

4.7.4.2 Special apparatus. Apparatus shall include the following:

a. Refrigeration chamber shall support the requirements as specified in 4.7.4.3. The chamber air temperature shall be measured in the immediate vicinity of the specimen.

b. Mandrel shall be rigid, smooth cylinder or partial cylinder, with a continuous, curved surface of not less than 180 degrees, of suitable length and construction for the specimen bending of 4.7.4.3. Unless otherwise specified (see 3.1), the mandrel diameter shall be 12 times the diameter of the cable. The mandrel shall be provided with a clip for affixing one specimen end (see 4.7.4.3).

4.7.4.3 Procedure. The specimen shall be straightened. If it does not remain straight of itself, it shall be held straight by securing it (as with twine to a straight wooden bar). The straightened specimen (including wooden bar if applicable) shall be placed within the refrigeration chamber and subjected to an air temperature of -20±2 °C (unless otherwise specified, see 3.1) for a continuous period of not less than 6 hours. Prior to any change of chamber temperature, the specimen shall be removed from the chamber (following detachment from the wooden bar, if applicable) and one specimen end shall be inserted into a clip which has been affixed to (or adjacent to) the mandrel, such that the specimen is both in contact with the curved surface of the mandrel and also perpendicular to the mandrel center of curvature axis. The opposite end of the specimen shall then be bent circumferentially around the curved mandrel surface through an arc of not less than 170 degrees. This bending shall be accomplished at a rate of not less than 20 degrees per second. The period of time between the removal from the refrigeration chamber and the completion of specimen bending shall be not greater than 40 seconds. Care shall be taken to avoid heating the specimen, as by excessive handling, during removal from the refrigeration chamber and during bending. Following bending, the specimen shall be secured to maintain its bent shape (as with a piece of twine stretch taut and tied between each end of the specimen) and shall then be removed from the mandrel. Not less than two thirds of the bent portion of the specimen shall then be dissected and each of its constituent components visually inspected for deterioration.

4.7.4.4 Observation. Specimen failure shall be construed if the specimen either during bending or upon dissection and inspection, exhibits distortion or cracking of any specimen component, or exhibits any other visible deterioration of such a nature or extent as to impair the performance of the cable in service.

4.7.5 Drip. This test shall determine whether or not sealant will exude and drip from the cable ends when cables containing sealant are subjected to high temperatures. Such sealant dripping may produce deleterious effects, such as the coating or bridging of underlying electrical contacts.

4.7.5.1 Specimen. The specimen shall consist of an 18±½ inch length of completed cable.

4.7.5.2 Special apparatus. Apparatus shall include a heating chamber for supporting the requirements as specified in 4.7.5.3. The chamber air temperature shall be measured in the immediate vicinity of the specimen.

4.7.5.3 Procedure. The specimen shall be straightened and shall be suspended from one end within the heating chamber, such that the specimen hangs freely downward. The temperature within the chamber shall then be raised to 95±1 °C. This chamber temperature shall be maintained for a continuous period of not less than 18 hours. Provision shall be made to catch any material which may fall away from the lower specimen end during this test.

4.7.5.4 Observation. Specimen failure shall be construed if any material falls away from the lower specimen end during the test.

4.7.6 Durometer hardness. This test shall be to determine whether or not jacketing material exhibits sufficient hardness (see 4.7.6.4) for use in cable construction.

4.7.6.1 Specimen. The specimen shall consist of a block of material of the dimensions specified in ASTM D2240, which shall have been cured in effectively the same manner as when used in cable manufacture.

4.7.6.2 Special apparatus. Apparatus shall include a Type A durometer, which shall be in accordance with ASTM D2240.

4.7.6.3 Procedure. The specimen shall be tested in accordance with ASTM D2240.

4.7.6.4 Observation. Specimen failure shall be construed if the specimen exhibits a durometer hardness other than that specified (see 3.1).

4.7.7 Flame propagation. This test shall be to determine the relative ability of grouped cable to resist the propagation of fire along its length. The test shall be performed according to UL Flame Exposure of UL Standard 1685, without the smoke requirements.

4.7.8 Gas flame. This test shall determine the ability of completed cable to maintain electrical circuit integrity in the presence of flame.

4.7.8.1 Specimen. The specimen shall consist of a 48±6 inch length of completed cable. The jacket and blocking materials shall be removed for a distance of 3 inches on each end of the sample. Sufficient insulation shall be removed from one end of each conductor for making electrical connections as follows:

a. Specimens with one conductor shall be tested with single-phase voltage between the conductor and a copper braid installed around the specimen's jacket and providing no greater than 50 percent coverage. The braid shall be attached to ground.

b. Specimens with two conductors shall be tested using two phases of the three-phase source.

c. Specimens with three conductors shall be tested with each conductor connected to a separate phase.

d. Specimens with four conductors shall have physically opposite conductors and be connected together in pairs to form two effective electrical circuits.

e. Specimens with six conductors shall have physically opposite conductors and be connected together in pairs to form three effective electrical circuits.

f. Specimens with seven or more conductors shall have conductors connected together to form three effective electrical conductors. Connections shall be made such that physically adjacent conductors shall be members of different effective electrical conductors to the maximum practicable extent and such that the number of conductors constituting each effective electrical conductor does not differ by more than one.

4.7.8.2 Special apparatus. Apparatus shall include the following:

a. A metered and adjustable source of natural gas or other flammable gas and an adjustable source of air (see figures 4, 5, and 6), able to support the requirements as specified in 4.7.8.3. The gas and air support shall be made available as a mixture through a single conduit.

b. A ribbon burner, which accepts gas and air from the gas and air supply via a single, ½-inch nominal pipe set vertically into its underside, which thoroughly blends the gas and air within an internal mixing chamber, which allows the blended gas and air mixture to exit for burning via a multiplicity of holes in its top which shall be fabricated in accordance with figures 4 and 5. The mixing chamber, fabricated from number 16 United States Standard Gauge (USSG) steel, shall be horizontally centered within the burner and shall be airtight except for the specified holes on its two sides and through the inside of the ½-inch nominal pipe. The burner exterior shall be fabricated from number 14 USSG steel and shall be airtight except for the specified holes on its top and the specified holes in the mixing chamber.

c. A three-phase, 60 Hertz voltage source, as shown in figure 6, shall provide a separate, single-phase test voltage through a normal blow fuse or overload relay to each specimen conductor. This voltage source shall be in accordance with the following:

(1) Specimens rated for 1 kV which incorporate conductors with cross sections of less than 14,000 circular mils and all specimens rated for less than 1 kV. The test voltage shall be 120±5 V rms between conductors. Fuses or overload relays shall each have a maximum rating of 1 A.

(2) The secondary winding voltage rating of any constituent voltage step up transformer shall be not less than the required test voltage. Each phase of the voltage source shall have the capacity to supply the specimen with a current which shall be not less than twice the fuse and overload relay rating.

d. A chamber enclosing the horizontally mounted burner and the suspended specimen (see 4.7.8.3). This enclosure shall incorporate an exhaust fan at its top and shall incorporate apertures for admitting air along its sides adjacent to its base. The exhaust fan shall be operated to produce no more suction than is necessary to carry off smoke and gases. The enclosure shall be designed to both minimize horizontal air drafts to the greatest practicable extent and to allow free circulation of convection air currents generated during the gas flame test.

4.7.8.3 Procedure. The burner shall be mounted within the chamber, such that the holes in its top are in a common horizontal plane. The specimen shall be suspended within the enclosure, such that it is parallel to the burner, horizontally centered directly above the burner, and spaced 1⅞±⅛ inches vertically above the top of the burner surface. Specimen suspension shall be accomplished in a manner (such as by wire loops) which shall not significantly shield the specimen from flame and which shall prevent any portion of the specimen from dropping closer than ¾ inch to the top surface of the burner during specimen burning. The gas air supply shall then be attached to the burner and the gas adjusted to provide a flow rate of not less than that calculated by the following formula:

Gas flow rate, in cubic feet per hour = 1387 (T+273)/PN

Where:	T	=	Measured ambient temperature in the vicinity of the burner, in °C. Measurement accuracy shall be within ±0.5 °C.
	P	=	Local atmospheric pressure, in lb/in^2 absolute. Measurement accuracy shall be within ±2 percent.
	N	=	Gross heating value, in $BTUs/ft^3$, of the gas at an atmospheric pressure of 14.69 lb/in^2 absolute and a temperature of 23 °C, this value shall be accurate in ±2 percent.

The gas exiting the burner shall then be ignited and the air flow to the burner adjusted to produce the smallest blue flame possible. The short circuit monitor test voltages shall then be applied to the specimen, as shown in figure 6. The flame and test voltages shall remain continuously applied to the specimen for a period of not less than that specified (see 3.1), unless specimen failure (see 4.7.8.4) occurs prior to the end of this period, in which case the test may be terminated.

4.7.8.4 Observation. Specimen failure shall be construed if any fuse blows or if any overload relay trips prior to completion of the specified test period (see 3.1).

4.7.9 Heat distortion. This test shall determine the ability of insulation and jacket material to resist physical deformation when subjected to an elevated temperature.

4.7.9.1 Specimen. Each specimen shall be removed from the completed cable in accordance with (a) and (b), whichever is indicated. The number of specimens which shall be required shall be in accordance with b(1), b(2), or b(3), as appropriate.

a. Cable jacket. Each specimen shall consist of a piece of jacketing that has been removed from a finished cable and a cut to form a rectangular strip. This strip shall be not less than ⅞ inch long nor less than 9/16±1/16 inch wide, and shall be ground and buffed to a thickness of 0.050+0.010, -0.020 inch with a grinding apparatus (see 4.7.9.2.c). The thickness of the specimen shall be made as uniform as practicable.

b. Insulation. Each specimen shall consist of a single insulated conductor of length not less than ⅞ inch.

(1) Cables containing four or fewer conductors, one specimen shall be prepared from each insulated conductor.

(2) Cables containing more than four but fewer than 21 conductors, one specimen shall be prepared from each of four different insulated conductors (a total of four specimens).

(3) Cables containing 21 or more conductors, the number of specimens prepared shall be equal to the square root (rounded if necessary, to the nearest whole number) of the total number of conductors. Each specimen shall be prepared from a different insulated conductor.

4.7.9.2 Special apparatus. Apparatus shall include the following:

a. A self-standing thickness gauge, for supporting the requirements as specified in 4.7.9.3, which shall exhibit a measurement error of not more than ±0.001 inch. This gauge shall incorporate a flat horizontal platen upon which the entire specimen shall be laid flat during measurement and shall incorporate a foot which rests upon the top of the specimen during measurement. This foot shall be attached to a plunger which moves freely in the vertical direction and which is attached to a dial or other indicating device from which the specimen thickness may be read. The foot shall present a horizontal disk of ⅜+0, -1/64-inch diameter to the specimen, which shall bear down on the specimen with a force of 85+0, -4 grams and shall be loaded with weights (see 4.7.9.3) to present additional force to the specimen.

b. A micrometer (required for insulated conductor specimens only) with flat, parallel measurement surfaces on both spindle and anvil, for the specimen thickness measurement as specified in 4.7.9.3(b)(1), which shall exhibit a measurement error of not more than ±0.0001 inch.

c. A motor driven grinding wheel and a motor driven buffing wheel, or their equal, for the specimen preparation as specified in 4.7.9.1.a and b(1). Guides shall be provided to assure that the specimen is pulled tangentially to the surface of each wheel during grinding and buffing.

d. An oven, for accommodating the gauge with the specimen inserted and for supporting the requirements as specified in 4.7.9.3. The oven air temperature shall be measured in the immediate vicinity of the specimen.

4.7.9.3 Procedure. The initial insulation thickness of each specimen (T in the formula below) shall be determined (see a(1) and (b) below) and the oven shall be preheated to 121±1 °C. This oven temperature shall be maintained for the remainder of the test. The gauge foot shall then be loaded with weights (see a(2) and b(2) below) and the gauge placed within the oven. Not less than one hour later, one specimen shall be selected and also placed within the oven. Not less than one hour after placing the specimen within the oven, the specimen shall be placed beneath the gauge foot such that the gauge indicates the specimen thickness. Not less than 1 hour after placing the specimen beneath the gauge foot, the final specimen thickness or diameter (as appropriate) shall be read from the gauge and the final insulation thickness (t in formula below) determined (see a(3) and b(3) below). In an identical manner, the remaining specimens shall also be tested. The percentage heat distortion of the insulation shall then be calculated by using the following formula:

Percentage heat distortion = Median value of 100(T-t)/T for all tested specimens.

Where: T = Initial insulation thickness of the specimen, in thousandths of an inch (see (a) and (b) below).

T = Final insulation thickness of the specimen, in thousandths of an inch (see (a) and (b) below).

The following additional details apply:

a. Rectangular strip specimens:

(1) The initial insulation thickness (T) shall be the initial specimen thickness, as measured with the gauge, prior to loading the gauge with weights and prior to inserting either the gauge or the specimen into the oven.

(2) The gauge foot shall be loaded with 2000±100 grams.

(3) The final insulation thickness (t) shall be the final thickness, measured as specified.

b. Insulated conductor specimen:

(1) The initial insulation thickness (T) shall be defined as ½ of the difference between the measured overall specimen diameter and the measured specimen conductor diameter. Measurements shall be made using the micrometer. The overall specimen diameter shall be measured in the same radial direction as will be measured when the final insulation thickness (t) (see b(3) below) is determined.

(2) The gauge foot shall be loaded as follows:

(a) Specimens with a conductor cross section of not more than 3999 circular mils nor less than 2300 circular mils: 400±20 grams.

(b) Specimens with a conductor cross section of not more than 21,999 circular mils nor less than 4000 circular mils: 500±25 grams.

(c) Specimens with a conductor cross section of not more than 94,999 circular mils nor less than 22,000 circular mils: 750±35 grams.

(3) The final insulation thickness (t) shall be defined as ½ of the difference between the final specimen diameter, measured as specified and the previously measured specimen conductor diameter.

4.7.9.4 Observation. The specimen shall be considered to have failed the test if the percentage heat distortion is greater than that specified in the applicable specification sheet.

4.7.10 Permanence of printing (conductor insulation). This test shall determine the ability of printed information on insulated conductors to remain legible in the presence of repeated abrasion.

4.7.10.1 Specimen. Each specimen shall consist of a single insulated conductor which shall have sufficient length for use in the test as specified in 4.7.10.3. Specimens shall be removed from completed cable as follows:

a. Cables containing four or fewer conductors: one specimen shall be removed from each insulated conductor.

b. Cables containing more than four but fewer than 21 conductors: one specimen shall be removed from each of four different insulated conductors (a total of four specimens).

c. Cables containing 21 or more conductors: The number of specimens removed shall be equal to the square root (rounded, if necessary, to the nearest whole number) or the total number of conductors. Each specimen shall be removed from a different insulated conductor.

4.7.10.2 Special apparatus. Apparatus shall include an abrading machine, which shall secure a specimen horizontally between two fixed supports, and which shall abrade the specimen printed identification by means of a motor-driven, reciprocating tape consisting of number 50-2/20 unbleached cotton braid. One possible arrangement for the abrading machine is shown on figure 7. The braided cotton tape shall lie flat on the specimen surface, shall remain perpendicular to the specimen axis, and shall abrade an unchanging area of the specimen periphery, over an arc of not less than 135 degrees, at all times during the test. One end of the tape shall be reciprocated at a rate of 28+3 cycles per minute, such that the tape is drawn across the specimen for a distance of 10+1, -0 inches in each direction (20 inches minimum total excursion during cycle). The opposite end of the tape shall be maintained under tension by a freely suspended ½+1⁄64, -0 pound weight. Each side of the tape shall be used to perform not more than 500 cycles; the tape shall then be discarded and replaced. The abrading machine shall incorporate an automatic counter to total the number of abrasion cycles to which the specimen is subjected during the test.

4.7.10.3 Procedure. Each specimen shall be wiped with a clean, dry cloth to remove any lubricant or dirt. One specimen shall then be selected and mounted between the two fixed supports of the abrading machine. Mounting shall be accomplished such that the specimen shall be as taut as practicable, and such that the braided cotton tape shall repeatedly abrade the same portion of the specimen printed identification at all times during the test. The automatic counter shall be set initially to zero. The abrading machine motor shall then be turned on. Allowing the braided cotton tape to reciprocate and abrade the specimen printed identification either until the printed identification is no longer legible in its abraded region, or until not fewer than the specified number of abrasive cycles (see 3.1) have been completed, whichever occurs first. The number of abrasive cycles completed shall then be noted, and the remaining specimens then tested in an identical manner.

4.7.10.4 Observation. Specimen failure shall be construed if the median value of the number of abrasive cycles completed on each specimen is less than that specified (see 3.1).

4.7.11 Permanence of printing (jacket). This test shall determine the ability of printed information of jacketing material to remain legible in the presence of repeated abrasion.

4.7.11.1 Specimen. The specimen shall consist of a piece of completed cable which shall have sufficient length for use in the test as specified in 4.7.11.3.

4.7.11.2 Special apparatus. Apparatus shall include an abrading machine which shall support and secure the specimen such that it is straight and horizontal, and which shall abrade the specimen printed identification by means of a motor driven, transversely reciprocating steel pin. This steel pin shall have a diameter of 0.025+0.001 inch where it abrades the specimen, and shall have a surface roughness of not less than 2 micro inches, as specified in ANSI B46.1. (A selected sewing needle may satisfy these requirements.) One possible arrangement for the abrading machine is shown on figure 8. The steel pin shall be horizontal and perpendicular to the specimen axis, shall ride along the top of the specimen, and shall be weighted to bear down on the specimen with a force of 1+1⁄16, -0 pound at all times during the test. This pin shall be reciprocated at a rate of 60+2 cycles per minute, such that the pin is drawn along the specimen for a distance of 3⁄8+1⁄16, -0 inch in each direction (3⁄4 inch minimum total excursion) during each cycle. The abrading machine shall incorporate an automatic counter to total the number of times that the specimen is abraded by the steel pin during the test.

4.7.11.3 Procedure. The specimen shall be wiped with a clean, dry cloth to remove any lubricant or dirt, and shall be secured in the abrading machine with the specimen printed identification facing upwards, where it is to be abraded by the steel pin. The automatic counter shall be set initially to zero. The abrading machine motor shall then be turned on, allowing the steel pin to reciprocate and abrade the specimen printed identification either until the printed identification is no longer legible in the abraded region, or until not fewer than 250 abrasive cycles have been completed, whichever occurs first. The number of abrasive cycles completed shall then be noted. This test shall be repeated four more times (five times total), subjecting a fresh portion of the specimen printed identification to abrasion each time.

4.7.11.4 Observation. Specimen failure shall be construed if the median value of the number of abrasive cycles completed during each of the five tests is less than that specified (see 3.1).

4.7.12 Physical tests on jacket. This test shall determine whether or not various jacketing materials have been properly processed, by means of tension measurements. This test makes provision for making tension measurements both before and after these materials have been artificially aged.

4.7.12.1 Specimens. Each specimen shall consist of a single piece of jacketing, which shall have sufficient length for use in the test as specified in 4.7.21.

4.7.12.2 Special apparatus. Apparatus shall include a forced fresh air circulating oven for supporting the requirements as specified in 4.7.12.3.a. The oven air temperature shall be measured in the immediate vicinity of specimens.

4.7.12.3 Procedure. Specimens shall be maintained at ambient temperature for a period of not less than 30 minutes immediately prior to any accelerated aging or testing. Each of the specified physicals (aged) accelerated aging procedures shall be performed as follows, using one specimen for each procedure. The same specimen shall not be used for more than one physicals (aged) procedure. Each of the specified physicals (unaged) test shall be performed as specified in 4.7.21.

a. Air oven accelerated aging: each specimen shall be freely suspended vertically, secured by one end, within the oven. The air temperature within the oven shall then be raised to 136±2 °C and shall be maintained at this value for a continuous period of not less than 168 hours. Each specimen shall then be removed from the oven and tested as specified in 4.7.21.

4.7.12.4 Observation. Any of the following shall constitute specimen failure:

a. A specimen tensile strength which is less than that specified (see 3.1).

b. A specimen elongation which is less than that specified (see 3.1).

4.7.13 Tear strength. This test shall determine the ability of elastomeric jacketing material to withstand the propagation of a cut passing through a portion of its length.

4.7.13.1 Specimen. Each specimen shall consist of a piece of jacketing material, which shall have been cut to the dimensions specified in ASTM D470. Specimens shall be removed from completed cables. Not fewer than five specimens shall be required.

4.7.13.2 Special apparatus. Apparatus shall include the following:

a. A micrometer with flat, parallel measurement surfaces on both spindle and anvil, which shall be for the specimen measurements as specified in 4.7.13.3 and which shall exhibit a measurement error of not more than ±0.0001 inch.

b. A motor driven tensile machine which shall be for applying increasing tension to the specimen, and which shall automatically indicate within ±1 percent the maximum tension experienced by the specimen prior to tearing. This tensile machine shall incorporate two parallel and opposing jaws, between which the specimen can be secured, as specified in 4.7.13.3. The two jaws shall increase their separation at the uniform rate of 20±2 inches per minute by means of the tensile machine motor.

4.7.13.3 Procedure. The specimen shall be tested in accordance with ASTM D470.

4.7.13.4 Observation. Specimen failure shall be construed if the median value of the measured tear strengths of all specimens is less than that specified (see 3.1).

4.7.14 Watertightness. This test shall determine the ability of completed cable, which is intended to pass through watertight bulkheads, to prevent the longitudinal flow of low-pressure water (see figure 9).

4.7.14.1 Specimen. The specimen shall consist of a 60+2-inch length of completed cable. The specimen shall be cut to length using a scissors-action cable cutter. (Saws shall not be used.)

4.7.14.2 Special apparatus. Apparatus shall include the following:

a. A source of pressurized water, which shall be provided at a regulated pressure of 27.5±½ lb/in^2 and which shall be for use with the terminal fitting (see (b)) as specified in 4.7.14.3.

b. A metal terminal fitting which applies the source of pressurized water to one end of the specimen, which supports the requirements as specified in 4.7.14.3, and which shall be fabricated as specified in the following. Figure 9 shows one possible arrangement for the terminal fitting. The fitting shall admit the specimen end for the distance specified in 4.7.14.3, and shall have an inside diameter (i.d.), where it fits over the specimen, of not greater than the measured overall specimen diameter +½ inch. The fitting shall have a means for introducing the source of pressurized water to the specimen end, and means for bleeding off any air which might be trapped between the specimen end and the source of pressurized water. The fitting shall also have an aperture for introducing a hardening sealant (see (c) below), to produce a pressure-tight bond between the fitting and the specimen jacket. A plug (such as a thick wrapping of rubber tape around the specimen) shall be provided at the place where the specimen enters the fitting, to prevent sealant loss and to approximately center the specimen within the fitting.

c. A liquid hardening sealant which shall be for producing a pressure tight bond between the fitting and the specimen jacket, when applied as specified (see 4.7.14.3) and allowed to harden. The sealant shall be at a temperature of not more than 100 °C when poured into the terminal fitting, and shall not expand in volume while hardening. An appropriate metal alloy is recommended as a sealant since it can be remelted and reused. Any metal alloy used shall have a melting point of not greater than 88 °C.

4.7.14.3 Procedure. The specimen shall be secured in a vertical position, the terminal fitting (including the plug) shall be fitted over its upper end, and the hardening sealant shall be poured through the appropriate terminal fitting aperture to bond the fitting to the specimen. These shall be done such that the specimen is approximately centered within the terminal fitting, such that not more than a 6-inch length of specimen jacket is exposed to the sealant, such that the end face of the specimen is located a distance of not more than 1 inch above the sealant surface and itself contains no sealant, and such that the aperture through which the sealant was introduced is itself made pressure tight. The sealant shall be allowed to harden, following which the terminal fitting plug shall be removed or cut away to the extent that it exerts no radial compression on the specimen. The specimen shall then be positioned such that it is straight, and such that no portion of the specimen is at a greater elevation than the specimen end within the terminal fitting. The fitting shall then be connected to the source of pressurized water, and excess air within the fitting shall be bled off until it can be certain that the entire enclosed specimen end face is exposed to the pressurized water for the remainder of the test. The source of pressurized water shall remain connected to the fitting for a continuous period of 6+¼, -0 hours. During this test period, water (if any) leaking from the specimen end opposite the terminal fitting shall be collected into an initially dry container. Following the test period, the volume of this collected water shall be measured.

4.7.14.4 Observation. Specimen failure shall be construed if the collected water volume exceeds that shown in table XVII.

TABLE XVII. Limits for water leakage.

Sum of specified cross-sections of all specimen conductors (see 3.1) (circular mills)	Collected water volume (cubic inches, maximum)
Less than 9,001	4
9,001 to 15,000	5
15,001 to 25,000	6
25,001 to 50,000	7
50,001 to 100,000	8
100,001 to 200,000	10
200,001 to 500,000	11
500,001 to 800,000	12
800,001 or greater	13

4.7.15 Acid gas generation. The method given below is to determine the total emission of any strong soluble acids (pH less than 3). The required apparatus is shown on figure 10. A weighed sample of the jacket, fillers, and insulation materials (for component wire, use insulation removed from a 22 AWG wire), normally ¼ to ½ gram, shall be placed in a silica boat which is put into the center of a silica tube, length 50/60 centimeters and internal diameter 20/22 millimeters. The materials shall be tested individually. The silica tube shall be placed in the tube furnace. An air supply, derived from a blower or compressed air cylinder, at the rate of 1 liter per minute ±5 percent shall be passed through the silica tube and then through four absorber flasks each containing 30 milliliters of deionized water. The furnace heating shall be commenced and the temperature of the tube and sample shall be raised to 800+10 °C over a period of approximately 40 minutes and then held at temperature for a further 20 minutes. During the heating period, any acid gases produced will be carried over into the absorber flasks. On completion of the heating cycle, the acid content of the fluids in the absorber flasks shall be titrated against 0.1 N sodium hydroxide solution using Congo red as an indicator. The total titrate indicates the total soluble acids. 1.0 ml of 0.1 N sodium hydroxide solution is equivalent to 3.65 mg of acid expressed as “acid equivalent relative to hydrochloric acid.”

4.7.15.1 Observation. Specimen failure shall be construed if the acid equivalent exceeds the percentage, by weight of the sample, specified (see 3.1).

4.7.16 Halogen content. The halogen content of the cable jacket and fillers shall be determined by X-ray fluorescence or analytically following an examination and analyses of the chemical composition of all ingredients used.

4.7.16.1 Observation. Specimen failure shall be construed if the halogen content is greater than that specified (see 3.1).

4.7.17 Smoke index. The smoke index shall be measured as specified in Defence Standard 02-711 with exceptions and modifications as listed in 4.7.17.1 and 4.7.17.2.

4.7.17.1 Specimen.

a. Jacket. Each specimen shall consist of a sufficient number of 75-millimeter long strips cut from the cable jacket to completely cover the face area of the sample holder. To prevent excessive buckling and distortion of the specimen during test, a wire mesh, manufactured from either a 1.0-millimeter diameter stainless steel wire with a spacing of 12.5 millimeters and a square mesh configuration or a 40 mil stainless steel wire 2 mesh screen (2 openings per inch), shall be placed inside and across the face of the sample holder. The specimen shall be fabricated by placing the specimen holder (with wire mesh) test face down onto a flat surface and positioning each 75-millimeter length in the holder in a parallel arrangement so that when the holder is in the test position the strips will be vertical. An insulating block 10 millimeters thick completely wrapped in aluminum foil shall be placed on top of the strips followed by a tension spring and locking pin.

b. Insulation. The test specimen shall be a 1-meter length of 22 AWG finished wire.

c. Fillers and sealants.

(1) Non-fibrous. The test specimen shall be 3 by 3 inches of 0.070±0.010 inch thick block of the same material used in the cable.

(2) Fibrous. The test specimen shall consist of as many 75-millimeter lengths of 0.070±0.010 inch diameter strands necessary to fill the 3 by 3 inch test specimen holder one layer deep and as closely spaced as possible. The test specimens shall be prepared as described in 4.7.17.1(a).

4.7.17.2 Special procedures. Special procedures shall include the following:

a. Only the use of propane gas shall be allowed.

b. The Radiometer shall be used to calibrate the heat flux at the initial start of each test period.

c. The test chamber shall be calibrated using a NIST CELLULOSE standard at the initial start of each test period.

d. The chamber shall be inspected to assure air tightness. Seals and gaskets shall be replaced as needed.

e. The test shall be run using a minimum of 3 specimens. If test values are below the limits specified (see 3.1), test is complete. If one test value deviates from the median value by more than 20 percent, two additional tests shall be performed. The high and low test values shall be discarded and the remaining 3 averaged.

4.7.17.3 Observation. Specimen failure shall be construed if any smoke index is greater than that specified (see 3.1).

4.7.18 Immersion tests. Specimens of the cable jacket material (see 4.7.12.1) shall be immersed in the fluids shown in table XVIII for 24 hours at the temperatures specified. The specimens shall then be removed, blotted to remove excess fluid, then suspended in air at room temperature for not less than 3½ nor more than 4½ hours. Each specimen shall be tested as specified in 4.7.21.

TABLE XVIII. Immersion test temperatures.

Fluid	Test temperature
Fuel oil, MIL-DTL-16884	98 to 100 °C
Turbine fuel, JP-5, MIL-DTL-5624	48 to 50 °C
Cleaner, isopropyl alcohol, ASTM D770	20 to 25 °C
Hydraulic fluid, MIL-PRF-83282 or MIL-PRF-87257	48 to 50 °C
Hydraulic fluid, MIL-PRF-17672	48 to 50 °C
Lubricating oil, MIL-PRF-23699	98 to 100 °C
Coolant, Monsanto Coolanol 25, or equivalent	20 to 25 °C
Lubrication oil, MIL-PRF-17331	120 to 122 °C

4.7.18.1 Observation. Any of the following shall construe specimen failure:

a. A specimen tensile strength which is less than that specified (see 3.1).

b. A specimen elongation which is less than that specified (see 3.1).

4.7.19 Toxicity index. The toxicity index shall be determined as specified in Defence Standard 02-713. For insulation materials, the toxicity index shall be calculated on the mass of insulation on 1 meter length of finished wire size 22 AWG. For jacket and filler materials, the toxicity index shall be calculated on 100 grams of material. (The toxicity index is derived from the chemical analysis of the products of combustion of the materials.)

4.7.19.1 Observation. Specimen failure shall be construed if any toxicity index is greater than that specified (see 3.1).

4.7.20 Weathering. Jacket material shall be subjected to 720 hours of the xenon arc lamp weathering resistance test in accordance with Section 1200 of UL Standard 1581.

4.7.20.1 Observation. Specimen failure shall be construed if the tensile strength and elongation retention is less than 75 percent or if the specimen surface exhibits signs of cracking when examined using 3X magnification.

4.7.21 Tensile strength and elongation. Both aged and unaged specimens of the jacket material shall be tested in accordance with Methods 3021 and 3031 of FED-STD-228. Unless otherwise specified in the applicable specification sheet, there shall be 1 inch bench marks, 1 inch jaw separation, and a rate of jaw travel of 10 inches per minute. The thickness of the specimen shall be measured using any suitable micrometer.

4.7.21.1 Observation. Specimen failure shall be construed if the tensile strength and elongation retention is less than that specified herein or in the applicable specification sheet.

4.7.22 Shrinkage. A 12-inch specimen of cable shall be cut so that all components are flush at both ends. Unless otherwise specified in the applicable specification sheet, the specimen shall then be aged at 136+3 °C for 6 hours in an air circulating oven. At the end of this period, the specimen shall be removed from the oven and allowed to cool to room temperature. Shrinkage of the jacket shall then be measured to determine the total distance the jacket has receded from both ends of the conductor.

4.7.22.1 Observation. Specimen failure shall be construed if the total shrinkage of the jacket is greater than 0.25 inch.

4.7.23 Weight. The weight of each lot of finished cable shall be determined from the length and weight of a specimen not less than 10 feet long. The specimen shall be accurately measured and the resultant measurements converted to pounds per 1000 feet. Lots failing to conform to the weight requirement specified in the applicable specification sheet shall be rejected.

4.7.24 Cross linking proof. Cable jacket cross link verification shall utilize the hot creep test in accordance with ICEA T-28-562. The procedure for jacket testing shall be modified to run at least 200 °C. Jacket percent of elongation shall be as specified in the individual specification sheets (see 3.1).

4.8 Test methods (electrical).

4.8.1 Attenuation. This test shall determine the ability of completed cable, which is intended for the transmission of data, voice, or control information, to propagate a signal at a frequency of 3 megahertz (MHz) without causing an unacceptable reduction of signal amplitude.

4.8.1.1 Specimen. The specimen shall consist of a piece of completed cable, which shall have sufficient length to exhibit an electrical attenuation of not less than 3 decibels (dB) at the specified test frequency (see 3.1). Individual transmission lines within this specimen (where each single insulated conductor plus surrounding shield or each insulated conductor pair plus surrounding shield is considered to be a transmission line) shall be selected for testing as follows.

a. Specimens containing four or fewer transmission lines: Every transmission line shall be tested.

b. Specimens containing more than four but fewer than 21 transmission lines: Four different transmission lines shall be tested. Not less than one of these transmission lines shall be selected from each concentric cabling layer within the specimen.

c. Specimens containing 21 or more transmission lines: The number of transmission lines tested shall be equal to the square root (rounded, if necessary, to the nearest whole number) of the total number of transmission lines. Not less than one of these transmission lines shall be selected from each concentric cabling layer within the specimen.

An electrical connector, which shall be designed for use at the specified test frequency (see 3.1), and which shall be appropriate for use with the specimen, shall be attached to each end of each transmission line selected for testing.

4.8.1.2 Special apparatus. Apparatus shall include the following, and shall be used at the specified test frequency (see 3.1), and shall be chosen such that all electrical interconnections (see 4.8.1.3) shall be of the same nominal characteristic impedance throughout (except that connectors and specimens in which a single conductor plus surrounding shield is tested may be of a different impedance than this apparatus, if necessary).

a. A sinusoidal signal generator, which shall produce an unchanging signal of the specified test frequency (see 3.1) within a frequency accuracy of 0.25 percent. The signal generator may be amplitude modulated in a constant and unchanging manner if the detector (see (b) below), requires an amplitude modulated signal for proper operation. The signal generator shall generate power to produce a reasonable indication on the detector when used as specified in 4.8.1.3; however, the signal generator shall not generate so much power that the specimen or any piece of test apparatus will consequently experience a significant temperature rise.

b. A crystal diode, bolometer, or other detector, with its associated indicating device, which shall be used as specified in 4.8.1.3.

c. A calibrated variable attenuator, which shall produce a maximum attenuation greater than that exhibited by the specimen, and which shall resolve attenuation within an accuracy of ±0.25 dB.

d. Two fixed attenuators, each of which shall exhibit an attenuation of not less than 10 dB.

e. Impedance matching transformers (required only when testing a conductor pair plus surrounding shield): Two, two winding transformers; one winding of each transformer shall have an impedance equal to the nominal impedance of the fixed attenuators; the second winding of each transformer shall be center tapped, and shall have an impedance equal to the specified impedance of the specimen (see 3.1). When testing a single conductor plus surrounding shield, impedance matching transformers may be used, if necessary, to match the nominal unbalanced impedance of each fixed attenuator (see (d) above), to the specified unbalanced impedance of the specimen (see 3.1), as shown on figure 11.

f. An adapter connector (may not be required, see 4.8.1.3) for joining the two fixed attenuators directly together. This adapter connector shall exhibit an attenuation which shall be not greater than 2 percent of the specimen attenuation. If desired, the adapter connector may be fabricated in the same manner and of the same components as the specimen, except that the shortest practicable length of completed cable shall be used to join the two connectors.

4.8.1.3 Procedure. The test apparatus shall be electrically interconnected as shown on figure 11 (when the transmission line to be tested is a single insulated conductor plus surrounding shield) or as shown on figure 12 (when the transmission line to be tested is an insulated conductor pair plus surrounding shield), as applicable; one of the selected transmission lines shall then be connected where shown. Following this, the calibrated variable attenuator shall be adjusted to a low value, and the signal generator adjusted to produce a test signal of sufficient amplitude to produce a reasonable indication on the detector. The setting on the calibrated variable attenuator and the indication on the detector shall then be noted. Next, the transmission line shall be disconnected from the test apparatus, and the two fixed attenuators shall be connected together either directly, or, if necessary, by means of an adapter connector. The signal generator shall not be readjusted. The calibrated variable attenuator shall then be readjusted until the detector produces the same indication as was noted when the transmission line was connected to the test apparatus. The new setting on the calibrated variable attenuator shall then be noted, and the transmission line attenuation shall be calculated by using the following formula:

Attenuation, in dB per 100 feet = $100 (A_2 - A_1)/L$

Where: A_1 = Initial setting of the calibrated variable attenuator (when the transmission line is connected to the test apparatus), in dB.

A_2 = Final setting of the calibrated variable attenuator (following transmission line removal from the test apparatus), in dB.

L = Measured specimen length, in feet; measurement accuracy shall be within ±1 percent.

In an identical manner, the remaining selected transmission lines shall also be tested.

4.8.1.4 Observation. Specimen failure shall be construed if any transmission line exhibits an attenuation which is greater than that specified (see 3.1).

4.8.2 Capacitance. This test shall determine the capacitive characteristics of completed cable.

4.8.2.1 Specimen. The specimen shall consist of a 122+½-inch length of completed cable, which shall have overall components (such as jackets or overall binders) removed from each end for a distance of 2+½, -0 inches, thereby exposing the insulated conductors (and shields, if applicable) at each end of the cable core. Each exposed shield (if any) at each cable end shall be unwrapped from the end of its enclosed insulated conductor(s) for a distance of 1+⅛ inch; the unwrapped portion of each shield shall then be tightly twisted to form a pigtail for electrical connection. The insulation shall next be stripped from each end of each insulated conductor for a distance of ½+⅛ inch. If the characteristic impedance test is not required (see 3.1), then the insulation may be stripped, for the specified distance from all of the insulated conductors at one specimen end only.

4.8.2.2 Special apparatus. Apparatus shall include an instrument for measuring capacitance (such as a capacitance bridge, Q-meter, or other instrument) which shall be for supporting the requirements as specified in 4.8.2.3. This apparatus shall have a two terminal measurement port, which shall use a sinusoidal wave of the specified frequency (see 3.1) for making measurements, and shall make measurements within an accuracy of ±1 percent.

4.8.2.3 Procedure. The appropriate capacitance test method shall be selected and performed from the following:

a. Specimens incorporating any number of individually shielded, insulated conductor transmission lines: one line shall be selected for measurement, and each end shall be positioned such that its conductor and shield shall not come into mutual electrical contact, nor into electrical contact with any other conductor or shield which may be within the specimen. One end of this selected transmission line shall then be appropriately connected electrically to the capacitance-measuring instrument, and its capacitance shall be measured. In an identical manner, the capacitance of every other transmission line within the specimen shall also be measured. The capacitance per foot of each transmission line shall then be calculated by using the following formula:

Capacitance in picofarads per foot = C/10

Where: C = Measured capacitance of the transmission line, in picofarads.

b. Specimens incorporating any number of individually shielded, insulated conductor pair transmission lines: one transmission line shall be selected for measurement, and each end shall be positioned such that neither its conductors nor its shield come into mutual electrical contact, or into electrical contact with any other conductor or shield which may be within the specimen. Three capacitances shall then be measured at one end of this transmission line as follows, where one conductor of this line has been designated as conductor number 1 and the other conductor of this line has been designated as conductor number 2 as follows:

(1) Conductor number 1 and the shield shall both be electrically connected to one terminal of the capacitance measuring instrument, and conductor number 2 shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated as Ca.

(2) Conductor number 2 and the shield shall next be electrically connected to one terminal of the capacitance measuring instrument, and conductor 1 shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated by Cb.

(3) Both conductor number 1 and conductor number 2 shall then be electrically connected to one terminal of the capacitance measuring instrument, and the shield shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated as Cc.

The mutual capacitance per foot and, if specified (see 3.1), the capacitance unbalance (sometimes called the coefficient of asymmetry) shall then be calculated by using the following approximate formulas:

Mutual capacitance, in picofarads per foot = (Ca + Cb)/20 – Cc/40

Capacitance unbalance, in percent = 10|Ca – Cb|/Cm

Where: Ca, Cb and Cc are as defined in (1), (2) and (3), respectively, in picofarads.

Cm = Calculated mutual capacitance, in picofarads per foot.

The mutual capacitance and, if specified (see 3.1), the capacitance unbalance of every other transmission line shall also be measured and calculated in an identical manner.

c. Specimens incorporating multiple, unshielded, insulated conductor pair transmission lines: the mutual capacitance and, if specified (see 3.1), the capacitance unbalance of every transmission line shall be determined, using the same method as used for specimens incorporating individually shielded, insulated conductor pair transmission lines, with the following change: the overall specimen braid (if any) and all specimen conductors except the conductor pair under test shall be connected together electrically and considered to be the shield of the transmission line under test.

d. Specimens incorporating any number of individually shielded, insulated conductor triad transmission lines: one transmission line shall be selected for measurement, and each end shall be positioned such that none of its conductors, nor its shield, come into mutual electrical contact, nor into electrical contact with any other conductor or shield which may be within the specimen. Four capacitances shall then be measured at one end of this transmission line as follows, where one conductor of this line has been designated as conductor number 1, another conductor of this line has been designated as conductor number 2, and the remaining conductor of this line has been designated as conductor number 3 as follows:

(1) Conductors number 2 and 3 and the shield shall be electrically connected to one terminal of the capacitance measuring instrument, and conductor number 1 shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated as Ca.

(2) Conductors number 1 and 3 and the shield shall next be electrically connected to one terminal of the capacitance measuring instrument, and conductor number 2 shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated as Cb.

(3) Conductors number 1 and 2 and the shield shall next be electrically connected to one terminal of the capacitance measuring instrument, and conductor number 3 shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated as Cc.

(4) Conductors number 1, 2, and 3 shall then be electrically connected to one terminal of the capacitance measuring instrument, and the shield shall be electrically connected to the other instrument terminal. The capacitance shall then be measured and designated as Cd.

The mutual capacitance per foot and, if specified (see 3.1), the capacitance unbalance (sometimes called the coefficient of asymmetry) shall then be calculated by using the following approximate formulas:

$$Cm = [(Ca + Cb + Cc)/40] - [Cd/120]$$

The capacitance unbalance or coefficient of asymmetry (K) of a shielded triad, expressed in percent, shall be determined by the formula:

$$K_1 = 10\ [Ca - Cb]/Cm$$

$$K_2 = 10\ [Ca - Cc]/Cm$$

$$K_3 = 10\ [Cb - Cc]/Cm$$

Where: K_1 = The percent of capacitance unbalance of conductor No. 1 in relation to conductor No. 2.

K_2 = The percent of capacitance unbalance of conductor No. 2 in relation to conductor No. 3.

K_3 = The percent of capacitance unbalance of conductor No. 3 in relation to conductor No. 1.

The mutual capacitance and, if specified (see 3.1), the capacitance unbalance of every other transmission line shall also be measured and calculated in an identical manner.

e. The mutual capacitance and, if specified (see 3.1), the capacitance unbalance of every transmission line shall be determined, using the same method as used in (d) above, for specimens incorporating individually shielded, insulated conductor triad transmission lines with the following change: the overall specimen braid (if any) and all specimen conductors except the conductor triad under test shall be connected together electrically and considered to be the shield of the transmission line under test.

4.8.2.4 Observation. Specimen failure shall be construed if the specimen exhibits a mutual capacitance or unbalance capacitance which is greater than that specified (see 3.1).

4.8.2.5 Additional testing of specimen. If the characteristic impedance and/or mutual inductance tests are specified (see 3.1), then the specimen shall be retained for use in those tests.

4.8.3 Characteristic impedance. This test shall determine the characteristic impedance encountered by signals propagating along completed cable. The mutual capacitance (see 4.8.2) shall be calculated for each transmission line within the completed cable prior to performing the characteristic impedance test. This is necessary since values of mutual capacitance are used to calculate values of characteristic impedance.

4.8.3.1 Specimen. The specimen shall be that which was previously used to determine capacitance characteristics (see 4.8.2.1).

4.8.3.2 Special apparatus. Apparatus shall include an instrument for measuring inductance (such as an inductance bridge, Q meter, or other instrument) which shall support the requirements as specified in 4.8.3.3. This apparatus shall have a two terminal measurement port, which shall use sinusoidal wave of the specified frequency (see 3.1) for making measurements. Measurements shall be made within an accuracy of ±1 percent.

4.8.3.3 Procedure. Select and perform the appropriate characteristic impedance test method from the following:

a. Specimens incorporating any number of individual shielded, insulated conductor transmission lines shall be laid straight. At one specimen end the exposed conductor of each transmission line shall be electrically connected to the pigtail of its associated shield by tightly twisting both together. At the opposite specimen end, one transmission line shall be selected for measurement, which shall then be connected to the inductance measuring instrument. The inductance of this transmission line shall be measured. In an identical manner, the inductance of every other transmission line within the specimen shall also be measured. The characteristic impedance of each transmission line shall then be calculated by using the following formula:

Characteristic impedance, in ohms = $(105L/C_m)1/2$

Where:

C_m = Mutual capacitance, in picofarads per foot, as calculated in 4.8.2.3

L = Measured inductance, in micro henries/10 feet.

b. Specimens incorporating any number of individually shielded or unshielded insulated conductor pair transmission lines shall be laid straight. At one specimen end the two exposed insulated conductors of each transmission line shall be laid adjacent to each other (to minimize superfluous inductance) and electrically connected by tightly twisting both together. At the opposite specimen end, one transmission line shall be selected for measurement, and its two conductors connected electrically to the inductance measuring instrument. Its shield (if any) shall remain disconnected. The inductance of this transmission line shall be measured. In an identical manner, the inductance of every other transmission line within the specimen shall also be measured. The characteristic impedance of each insulated conductor pair shall then be calculated by using the formula shown in (a) above.

4.8.3.4 Observation. Specimen failure shall be construed if the specimen exhibits a characteristic impedance other than that specified (see 3.1).

4.8.4 Conductor resistance. This test shall determine whether or not conductors within the completed cable are fabricated from the specified material.

4.8.4.1 Procedure. Conductor resistance shall be tested in accordance with ASTM B193 and shall be corrected to 25 °C.

4.8.4.2 Observation. Specimen failure shall be construed if any specimen conductor exhibits a conductor resistance greater than that specified (see 3.1).

4.8.5 Insulation resistance. This test shall determine the ability of completed cable to transmit DC without exhibiting unacceptable current flow through insulation or jacketing material, either between conductors, or between single conductor cable and any conducting substance which may be in contact with the surface of the cable during in service use. The voltage withstand test (see 4.8.6) shall be performed prior to the insulation resistance test.

4.8.5.1 Specimen. The conductor insulation resistance test shall be performed on all conductors which have a nominal circular mil area of less than 18 AWG; for conductors which have a nominal circular mil area of 18 AWG or greater, the conductor insulation resistance test shall be performed on conductors selected in accordance with table XIX.

TABLE XIX. Number of conductors tested for insulation resistance.

No. of insulated conductors in cable	No. of insulated conductors selected for test
1 through 4	All
5 through 20	4
21 through 30	5
31 through 42	6
43 through 56	7

4.8.5.2 Specimen. The specimen shall be that which was previously used to perform the voltage withstand test (see 4.8.6.1).

4.8.5.3 Special apparatus. Apparatus shall include the following:

a. A megohmmeter, megohm bridge, or other suitable instrument which shall use a DC test voltage of not less than 200 V nor greater than 500 V, which shall support the requirements as specified in 4.8.5.4, and which shall make measurements within an accuracy of ±10 percent.

b. Water tank (may not be required, see 4.8.5.4.d which shall be of a size to contain the specimen, and which shall be suitable for the use as specified in 4.8.5.4.d.

4.8.5.4 Procedure. The specimen shall be maintained at a constant temperature, within ±3 °C, for a period of not less than 5 hours immediately prior to testing. This temperature shall be noted and shall be used to calculate F (see formula below) when measurements are made in accordance with (a), (b) or (c) below. The megohmmeter shall then be electrically connected to the specimen as specified [see (a), (b), (c), and (d) below]. For each connection, the test voltage from the megohmmeter shall be continuously applied to the specimen for a period of 3 minutes, or until a steady reading is obtained immediately following which the resistance reading of the megohmmeter shall be noted. Care shall be taken during each such measurement to assure that any electrical jumper leads connecting the specimen to the megohmmeter shall be spaced sufficiently far from each other and from any common conducting surface that measurement accuracy shall not be impaired.

a. Conductor to ground (cable, one conductor, unshielded, jacketed). Specimens incorporating a single insulated, jacketed conductor without shield or armor shall be tested to water. The specimen shall be submerged, except for its extreme ends (which shall remain exposed to the air), in the water tank for a period of not less than 1 hour. Following this, and while the specimen is still submerged, the specimen shall be tested as follows. The single conductor shall be electrically connected to one terminal of the megohmmeter. The other megohmmeter terminal shall be electrically connected to the water surrounding the specimen (as by means of a bare metal wire which is both connected to the megohmmeter terminal and suspended within the water surrounding the specimen). The insulation resistance test shall then be performed as specified.

b. Conductor to conductor (cable, unshielded, jacketed). Use for cable types incorporating two or more insulated conductors (such as, singles, pairs, or triples) with no individual or overall shield: one insulated conductor shall be selected and electrically connected to one terminal of the megohmmeter. All other conductors within that transmission line shall be electrically connected to the other megohmmeter terminal. The insulation resistance test shall then be performed as specified. In a similar manner, the insulation resistance test shall be performed between each remaining conductor within the selected transmission line and the short circuited combination of all other conductors within that transmission line. Following this, and in an identical manner, the insulation resistance test shall be performed on all remaining transmission lines within the specimen.

c. Conductor to conductor with overall shield (cable, overall shielded, and jacketed). Used for cable types incorporating two or more insulated conductors (such as singles, pairs, or triples) with no individual shields and with an overall shield: one insulated conductor shall be selected and electrically connected to one terminal of the megohmmeter. All other unshielded insulated conductors and the overall shield, shall be electrically connected to the other megohmmeter terminal. The insulation resistance test shall then be performed as specified. In a similar manner, the insulation resistance test shall be performed between each remaining insulated conductor within the specimen and the short circuited combination of all other insulated conductors and overall shield.

d. Conductor to conductor with component shield (cable, shielded components, overall unshielded, jacketed). Used for cable types incorporating one or more individually shielded, insulated conductors: one insulated conductor shall be selected for measurement, and shall be electrically connected to one terminal of the megohmmeter. All other insulated conductors within the component and the shield shall be electrically connected to the other megohmmeter terminal. The insulation resistance test shall then be performed as specified. Following this, and in an identical manner, the insulation resistance test shall be performed on all remaining insulated conductors within the component. After the completion of this component, this procedure shall be repeated for all other shielded components within the specimen. The cable shall then be tested for component shield insulation resistance [see (g)].

e. Conductor to conductor with component shield and one overall shield (or two or more overall shields not electrically isolated from each other)(cable, shielded components, overall shielded, jacketed). Used for cable types incorporating one or more individually shielded, insulated conductors. One insulated conductor shall be selected for measurement, and shall be electrically connected to one terminal of the megohmmeter. All other insulated conductors within the component and the shield shall be electrically connected to the other megohmmeter terminal. The insulation resistance test shall then be performed as specified. Following this, and in an identical manner, the insulation resistance test shall be performed on all remaining insulated conductors within the component. After the completion of this component, this procedure shall be repeated for all other shielded components within the specimen. The cable shall then be tested for component shield insulation resistance [see (h)].

f. Conductor to conductor with component shield and two electrically isolated overall shields (cable, shielded components, overall dual shielded, jacketed). Used for cable types incorporating one or more individually shielded, insulated conductors. One insulated conductor shall be selected for measurement, and shall be electrically connected to one terminal of the megohmmeter. All other insulated conductors within the component and the shield shall be electrically connected to the other megohmmeter terminal. The insulation resistance test shall then be performed as specified. Following this, and in an identical manner, the insulation resistance test shall be performed on all remaining insulated conductors within the component. After the completion of this component, this procedure shall be repeated for all other shielded components within the specimen. The cable shall then be tested for component shield insulation resistance, see h and overall shield insulation resistance [see (i)].

g. Component shield to shield. Used for cable types incorporating two or more individually shielded components (these measurements shall be required only when component shield to shield measurements are specified, see 3.1): one component shield shall be selected and electrically connected to one terminal of the megohmmeter. All other specimen component shields shall be electrically connected to the other megohmmeter terminal, and the insulation resistance test shall then be performed as specified. In a similar manner, the insulation resistance test shall be performed between each remaining component shields within the specimen and the short circuited combination of all other component shields.

h. Component shield to shield and overall shield. Used for cable types incorporating two or more individually shielded components and an overall shield (these measurements shall be required only when component shield to shield measurements are specified; see 3.1): one component shield shall be selected and electrically connected to one terminal of the megohmmeter. All other specimen component shields and the overall shield shall be electrically connected to the other megohmmeter terminal, and the insulation resistance test shall then be performed as specified. In a similar manner, the insulation resistance test shall be performed between each remaining component shields within the specimen and the short circuited combination of all other component shields.

i. Overall shield to shield. Used for cable types incorporating two or more overall shields (electrically separate) (these measurements shall be required only when overall shield to overall shield measurements are specified; see 3.1): the inner overall shield shall be selected and electrically connected to one terminal of the megohmmeter. The other overall shield shall be electrically connected to the other megohmmeter terminal, and the insulation resistance test shall then be performed as specified.

The lowest value of resistance measured in accordance with each of (a), (b), (c), (d), (e), (f), (g), (h), and (i), as applicable, shall be modified to include the effects of specimen length and temperature by using the following formula:

Insulation resistance, in megohms 1000 feet = RLF/1000

Where: R = Lowest value of resistance measured in accordance with (a), (b), (c), (d), (e), (f), (g), (h), and (i), as applicable, in megohms.

L = Measured specimen length, in feet; measurement accuracy shall be within ±2 percent.

F = An ad hoc number, which shall accurately modify the measured resistance R to that value of resistance which would be measured if the specimen were at a uniform temperature of 15.5 °C. This number shall be determined by the specimen manufacturer via ad hoc testing for the specific insulation or jacketing material separating the conductors between which the resistance measurement was made, and shall be normalized to unity for a material temperature of 15.5 °C.

4.8.5.5 Observation. Specimen failure shall be construed if any calculated value of insulation resistance is less than that specified (see 3.1).

4.8.6 Voltage withstand. This test shall determine the ability of completed cable to withstand overvoltages without exhibiting electrical discharge through insulation or jacketing material, either between conductors, or between these conductors and any conducting material which may be in contact with the surface of the cable during in service use.

4.8.6.1 Specimen. The specimen shall consist of a unit of product as specified in 6.7.4.1.

4.8.6.2 Special apparatus. Apparatus shall include the following:

a. An adjustable voltage source, which shall be in accordance with either of the following, as appropriate (see 3.1):

(1) An AC voltage source which shall produce a single phase, approximately sinusoidal voltage under all test conditions, which shall have a frequency of not more than 100 Hertz, and which can be adjusted to the specified rms magnitude (see 3.1). This source shall have the capacity to provide an effective power of not less than 5 kVA, and shall incorporate an overload relay which shall reduce the source voltage to zero whenever an applied load (that is, the specimen, see 4.8.6.3) attempts to draw electrical current to exceed this effective power capacity.

(2) A source of DC voltage which can be adjusted to the specified magnitude (see 3.1), and which shall have the capacity to provide an electrical current of not less than ¼ A. This source shall incorporate an overload relay which shall reduce the source voltage to zero whenever an applied load (that is, the specimen, see 4.8.6.3) attempts to draw electrical current to exceed this current capacity.

b. When required, a water tank, which shall be filled with water and shall be of sufficient size to contain the specimen, shall be used as specified in 4.8.6.3(d) [may not be required, see 4.8.6.3(d)].

4.8.6.3 Procedure. The voltage source shall be electrically connected to the specimen as specified [see (a), (b), (c), (d), (e), (f), (g), (h), and (i)]. For each connection, the test voltage from the voltage source shall be increased, in a uniform manner, from 0 V to the specified voltage (see 3.1) during a period of not more than 60 seconds or less than 10 seconds, except that specified voltages of less than 600 V may be applied instantaneously. (This gradual voltage application is generally necessary to prevent a current in rush, and the consequent tripping of the voltage source overload relay caused by specimen capacitance.) This specified voltage shall then be maintained for a period of 1+½, -0 minute (unless the voltage source overload relay trips, see 4.8.6.4); following which the test voltage shall be reduced to zero at approximately the same rate at which it was applied.

a. Conductor to ground (cable, one conductor, unshielded, jacketed). Specimens incorporating a single insulated, jacketed conductor without shield or armor shall be tested to water. The specimen shall be submerged, except for its extreme ends (which shall remain exposed to the air), in the water tank for a period of not less than 1 hour. Following this, and while the specimen is still submerged, the specimen shall be tested as follows. The single conductor shall be electrically connected to one terminal of the voltage source. The other voltage source terminal shall be electrically connected to the water surrounding the specimen (as by means of a bare metal wire which is both connected to the voltage source terminal and suspended within the water surrounding the specimen). The voltage withstand test shall then be performed as specified.

b. Conductor to conductor (cable, unshielded, jacketed). Used for cable types incorporating two or more insulated conductors (such as singles, pairs, or triples) with no individual or overall shield: one insulated conductor shall be selected and electrically connected to one terminal of the voltage source. All other conductors within that transmission line shall be electrically connected to the other voltage source terminal. The voltage withstand test shall then be performed as specified. In a similar manner, the voltage withstand test shall be performed between each remaining conductor within the selected transmission line and the short circuited combination of all other conductors within that transmission line. Following this, and in an identical manner, the voltage withstand test shall be performed on all remaining transmission lines within the specimen.

c. Conductor to conductor with overall shield (cable, overall shielded, jacketed). Used for cable types incorporating two or more insulated conductors (such as singles, pairs, or triples) with no individual shields and with an overall shield: one insulated conductor shall be selected and electrically connected to one terminal of the voltage source. All other unshielded insulated conductors and the overall shield shall be electrically connected to the other voltage source terminal. The voltage withstand test shall then be performed as specified. In a similar manner, the voltage withstand test shall be performed between each remaining insulated conductor within the specimen and the short circuited combination of all other insulated conductors and overall shield.

d. Conductor to conductor with component shield (cable, shielded components, overall unshielded, jacketed). Used for cable types incorporating one or more individually shielded, insulated conductors: one insulated conductor shall be selected for measurement, and shall be electrically connected to one terminal of the voltage source. All other insulated conductors within the component and the shield shall be electrically connected to the other voltage source terminal. The voltage withstand test shall then be performed as specified. Following this, and in an identical manner, the voltage withstand test shall be performed on all remaining insulated conductors within the component. After the completion of this component, this procedure shall be repeated for all other shielded components within the specimen. The cable shall then be tested for component shield voltage withstand [see (g)].

e. Conductor to conductor with component shield and one overall shield (or two or more overall shields not electrically isolated from each other) (cable, shielded components, overall shielded, jacketed). Used for cable types incorporating one or more individually shielded, insulated conductors: one insulated conductor shall be selected for measurement, and shall be electrically connected to one terminal of the voltage source. All other insulated conductors within the component and the shield shall be electrically connected to the other voltage source terminal. The voltage withstand test shall then be performed as specified. Following this, and in an identical manner, the voltage withstand test shall be performed on all remaining insulated conductors within the component. After the completion of this component, this procedure shall be repeated for all other shielded components within the specimen. The cable shall then be tested for component shield voltage withstand [see (h)].

f. Conductor to conductor with component shield and two electrically isolated overall shields (cable, shielded components, overall dual shielded, jacketed). Used for cable types incorporating one or more individually shielded, insulated conductors: one insulated conductor shall be selected for measurement, and shall be electrically connected to one terminal of the voltage source. All other insulated conductors within the component and the shield shall be electrically connected to the other voltage source terminal. The voltage withstand test shall then be performed as specified. Following this, and in an identical manner, the voltage withstand test shall be performed on all remaining insulated conductors within the component. After the completion of this component, this procedure shall be repeated for all other shielded components within the specimen. The cable shall then be tested for component shield voltage withstand, see h and overall shield voltage withstand [see (i)].

g. Component shield to shield. Used for cable types incorporating two or more individually shielded components (these measurements shall be required only when component shield to shield measurements are specified; see 3.1): one component shield shall be selected and electrically connected to one terminal of the voltage source. All other specimen component shields shall be electrically connected to the other voltage source terminal, and the voltage withstand test shall then be performed as specified. In a similar manner, the voltage withstand test shall be performed between each remaining component shields within the specimen and the short circuited combination of all other component shields.

h. Component shield to shield and overall shield. Used for cable types incorporating two or more individually shielded components and an overall shield (these measurements shall be required only when component shield to shield measurements are specified; see 3.1): one component shield shall be selected and electrically connected to one terminal of the voltage source. All other specimen component shields and the overall shield shall be electrically connected to the other voltage withstand terminal, and the voltage withstand test shall then be performed as specified. In a similar manner, the voltage withstand test shall be performed between each remaining component shields within the specimen and the short circuited combination of all other component shields.

i. Overall shield to shield. Used for cable types incorporating two or more overall shields (electrically separate) (these measurements shall be required only when overall shield to overall shield measurements are specified; see 3.1): the inner overall shield shall be selected and electrically connected to one terminal of the voltage source. The other overall shield shall be electrically connected to the other voltage source terminal, and the voltage withstand test shall then be performed as specified.

4.8.6.4 Observation. Specimen failure shall be construed if the voltage source overload relay trips prior to removal of the test voltage from any specimen connection. If the insulation resistance test is specified (see 3.1), then the specimen shall be retained for use in that test.

4.8.7 Jacket flaws. One hundred percent of all finished cables with overall shields shall be subjected to a 3.0 kV (rms) spark test in accordance with Clause 900 of UL Standard 1581.

4.8.8 Conductor and shield continuity. One hundred percent of all finished cable shall be tested for continuity prior to shipment. To establish continuity, not more than 25 V DC shall be applied across each conductor and shield of the cable through an appropriate indicator, such as an ohmmeter, light, or buzzer. The test voltage may be applied to conductors and shields individually or in series.

4.8.8.1 Observation. Specimen failure shall be construed if the specimen exhibits an open electrical circuit.

4.8.9 Surface transfer impedance. The surface transfer impedance characteristics of the overall cable shield of finished cable shall be tested in accordance with NEMA WC 61, and as specified in 4.8.9.1. The electromagnetic pulse (EMP) response of the cable shield shall be determined in accordance with 4.8.9.2.

4.8.9.1 Cable sample preparation. The individual shields of shielded components, when present, shall be connected to the conductors and the connected conductors and shields shall be the conductor as specified in NEMA WC 61.

4.8.9.2 Determination of EMP response. The surface transfer impedance determined as specified shall be known over the frequency range DC to 100 MHz. It shall be assumed constant in the frequency range DC to 0.1 MHz. The EMP response in dB shall be determined as follows:

$$\text{EMP response} = (-185) - 10 \cdot \log\left[\int_{0}^{1\cdot 10^{8}} \frac{\left[\left[Z_t \cdot (f)\right]^2\right]}{\left(\alpha^2 + f^2\right)\cdot\left(\beta^2 + f^2\right)}\, df\right]$$

The integral expression may be approximated by a summation if at least 100 points per decade of frequency are used.

4.8.9.3 Observation. Specimen failure shall be construed if the surface transfer impedance is greater than specified (see 3.1) or if the calculated EMP response of the overall cable shield is less than specified (see 3.1).

4.8.10 Armor. Cable armor performance shall be determined as specified in 4.8.10.1 through 4.8.10.4.

4.8.10.1 Specimen. Each specimen shall consist of a single piece of armor wire, of not less than 6 inches in length, which has been removed from a spool of armor wire prior to cable armoring. Each specimen shall be removed from a different spool. Ten specimens shall be required.

4.8.10.2 Special apparatus. Apparatus shall include the following:

a. Mandrel. A ¼±1⁄64 inch diameter steel cylinder, of length and construction for the springiness test as specified in 4.8.10.3.

b. Scale. A spring or other type scale, the measurement error of which shall not exceed ±5 percent for use in the springiness and toughness tests specified in 4.8.10.3.

c. Special vise. A special vise, with 2 parallel edges of 0.030±0.001 inch radius between which a specimen may be clamped to perform the toughness test as specified in 4.8.10.3.

4.8.10.3 Procedure. The two following tests shall be performed using not fewer than five specimens. The specimen shall be tested one at a time for each test. The same specimen shall not be used for more than one test.

a. Springiness. One specimen shall be selected and secured by one end to the mandrel such that it is both in contact with the curved surface of the mandrel and perpendicular to the mandrel axis. The opposite end of the specimen shall be attached to the scale. The specimen shall be wrapped circumferentially around the mandrel, by handling the scale only, for not fewer than four complete turns, while maintaining a specimen tension of not less than 100 nor more than 125 grams. Care should be taken to pull the scale in such a direction that it accurately indicates the specimen tension. The specimen shall then be released from the scale and allowed to uncoil. Any specimen which is kinked at any place other than the attachment points at either end shall be considered an invalid specimen. The test shall be repeated using a different specimen. This test shall be successfully repeated four more times (five times total) using a different specimen each time.

b. Toughness. One specimen shall be selected and secured by one end between the rounded, horizontal, and parallel vise edges, such that not less than 2 inches of the specimen extends vertically above the vise. The scale shall then be attached to the free end of the specimen and a specimen tension of 100±10 grams shall be established by handling the scale only. The specimen shall be bent 90+15, -0 degrees alternately in both directions perpendicular to the vise edges, while maintaining the specified vise tension. Not fewer than ten 90 degree bends shall be made unless the specimen breaks sooner. The bending rate shall not exceed fifty 90 degree bends per minute. This test shall be repeated four more times (five times total), using different specimens each time.

4.8.10.4 Observation. Either of the following shall constitute specimen failure:

a. Springiness. The outside diameter (O.D.) of the coil formed by any of the specimens around the mandrel, as measured at a middle portion of the specimen, exceeds ⅜ inch.

b. Toughness. Any specimen withstands fewer than ten 90-degree bends without breaking.

4.9 Certified test reports. The contractor shall prepare test reports as specified (see 6.2.1 and 6.2.5).

5. PACKAGING

5.1 Packaging. For acquisition purposes, the packaging requirements shall be as specified in the contract or order (see 6.2). When packaging of materiel is to be performed by DoD or in-house contractor personnel, these personnel need to contact the responsible packaging activity to ascertain packaging requirements. Packaging requirements are maintained by the Inventory Control Point's packaging activities within the Military Service or Defense Agency, or within the military service's system commands. Packaging data retrieval is available from the managing Military Department's or Defense Agency's automated packaging files, CD-ROM products, or by contacting the responsible packaging activity.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. Cables specified herein are intended for use in various applications involving Naval ships and shore stations.

6.2 Acquisition requirements. Acquisition documents should specify the following:

a. Title, number, and date of this specification.

b. Military part number (see 1.3).

c. Type and size of cable or cord required with reference to applicable specification sheet (see 3.1).

d. Jacket color required (see 3.3.3).

e. Identification codes required if other than the standard identification code and where applicable, twisted pair and triad identification codes (see 3.7.1).

f. Identification method required if other than identification Method 1 or Method 3 (see 3.7.2).

g. Placement of completed cables if other than on reels (see 3.7.5).

h. Inspection conditions (see 4.2).

i. Packaging requirements (see 5.1).

j. Requirements for certified test reports and conductor strand inspection (see 6.2.2 and 6.2.3).

k. Quantity required (see 6.2.3).

6.2.1 Certified test reports. The contractor will prepare test reports in accordance with the data-ordering document (see 6.2). The test report will contain the following information:

a. Manufacturer's QPL number and date or serial number and date of NAVSEA letter of approval.

b. A statement to the effect that the product was constructed from materials listed on the manufacturer's approved details of construction sheet.

c. A statement that the product meets all of the requirements of this specification.

d. Results of all conformance tests showing actual values obtained.

e. Year and month cable or cord was manufactured.

f. Serial numbers of the marker tape taken from each end of each length of cable or cord.

g. Customer's name and contract or order number.

h. A statement that the product contains no metallic mercury or mercury compounds and is free from mercury contamination.

i. The serial number of all NAVSEA letters approving deviations from the approved specification sheets.

6.2.2 Conductor strand inspection. Records of tests and/or certifications should be kept on file and be made available upon request.

6.2.3 Quantity. The quantity of each type and size on a contract or order should be specified as an integral multiple of the unit ordering length shown by the specification sheet.

6.2.4 Lengths. The range of standard, random, remnant, and scrap lengths for each nominal length is shown in table X. In order to compensate for handling and probable loss on issue, remnant lengths are subject to the price reductions specified in table X. Scrap lengths are not acceptable. It is not intended that items being acquired in exact lengths for a specific job or ship should necessarily be shipped in lengths which are integral multiples of the unit ordering length or that price reductions should apply in the event that exact footages or fractional lengths are required and so indicated in acquisition of cable other than stock purposes.

6.2.5 Flame propagation testing. Flame propagation testing will be selected by testing the first production run of each type and size of cable each calendar year (20xx) and emailed to NAVSEA 05S at commandstandards@navy.mil. The test results should also be maintained in a log (at the factory), and should contain as a minimum the following information.

Part #	Lot #	Date of test	Test lab	Footage in tray	Flame travel height	Flame extinction time	Pass/fail	Tested by

6.3 Special clause. Except when small quantities are to be purchased, invitations for bid and contracts or orders should specify the following:

"In order to compensate for handling and probable loss in issue, remnant lengths should be subject to the price reductions specified in table II. In order that the number of lengths be kept to a minimum consistent with good manufacturing practices, for each type and size of cable on the contract or order, not less than 70 percent of the total footage to be shipped should be in standard lengths, and not more than 30 percent may be in any combination of random and remnant lengths. When the total quantity of any one item is six nominal lengths or less, a footage approximately two nominal lengths (in lieu of 30 percent) may be in any combination of random and remnant lengths. When the total quantity of any one item is two nominal lengths or less, the total footage may be in any combination of random lengths."

6.4 Time delay. Comparison inspection will normally require 40 calendar days from the date the sample is sent to the Government designated laboratory to the date the inspection results are received by the manufacturer. This time delay should be taken into consideration by a contractor when estimating delivery time.

6.5 Qualification. With respect to products requiring qualification, awards will be made only for products which are, at the time of award of contract, qualified for inclusion in Qualified Products List QPL No. 24640 whether or not such products have actually been so listed by that date. The attention of the contractors is called to these requirements, and manufacturers are urged to arrange to have the products that they propose to offer to the Federal Government tested for qualification in order that they may be eligible to be awarded contracts or orders for the products covered by this specification. Information pertaining to qualification of products may be obtained from Commander, Naval Sea Systems Command, ATTN: SEA 05S, 1333 Isaac Hull Avenue, SE, Stop 5160, Washington Navy Yard DC 20376-5160 or emailed to CommandStandards@navy.mil. An online listing of products qualified to this specification may be found in the Qualified Products Database (QPD) at https://assist.daps.dla.mil.

6.6 Sub-contracted material and parts. The preparation for delivery requirements of referenced documents listed in Section 2 do not apply when material and parts are acquired by the contractor for incorporation into the equipment and lose their separate identity when the equipment is shipped.

6.7 Definitions. For the purpose of the conformance inspection, the sampling terms specified in 6.7.1 through 6.7.4 should apply.

6.7.1 Defective unit. A defective unit is a unit of product from which a specimen that failed to meet one or more requirements was taken.

6.7.2 Sample. A sample is one unit of product selected from an inspection lot.

6.7.3 Specimen. A specimen is an individual length of cable or an individual length of a part of cable which has been taken from a sample.

6.7.4 Unit of product. A unit of product is the unit ordering length as specified on the specification sheet, except that when the unit ordering length is 500 feet, two such lengths should constitute a unit of product. Random and remnant lengths or special order lengths may be added together to equal a unit ordering length. Length tolerances as given for standard lengths should apply (see 6.2.4).

6.7.4.1 Unit for electrical testing. For electrical test purposes, a unit of product should be defined as an electrically continuous splice free length. This will allow for longer production lengths to be tested electrically prior to preparation for shipment. Lengths longer than the unit ordering lengths may be supplied when the end user and manufacturer agree.

6.8 Subject term (key word) listing.

Circuit integrity

Flame propagation

Gas flame

Smoke index

Toxicity index

Waterblock

6.9 Changes from previous issue. Marginal notations are not used in this revision to identify changes with respect to the previous issue due to the extent of the changes.

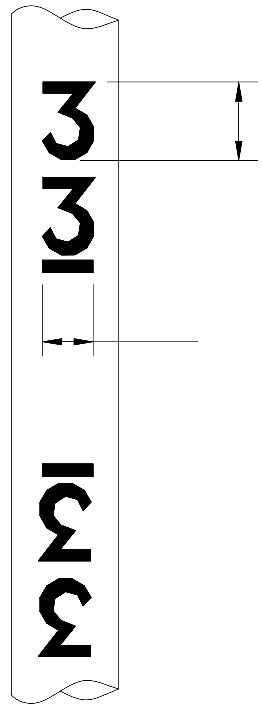

FIGURE 1. Conductor of pair number 33.

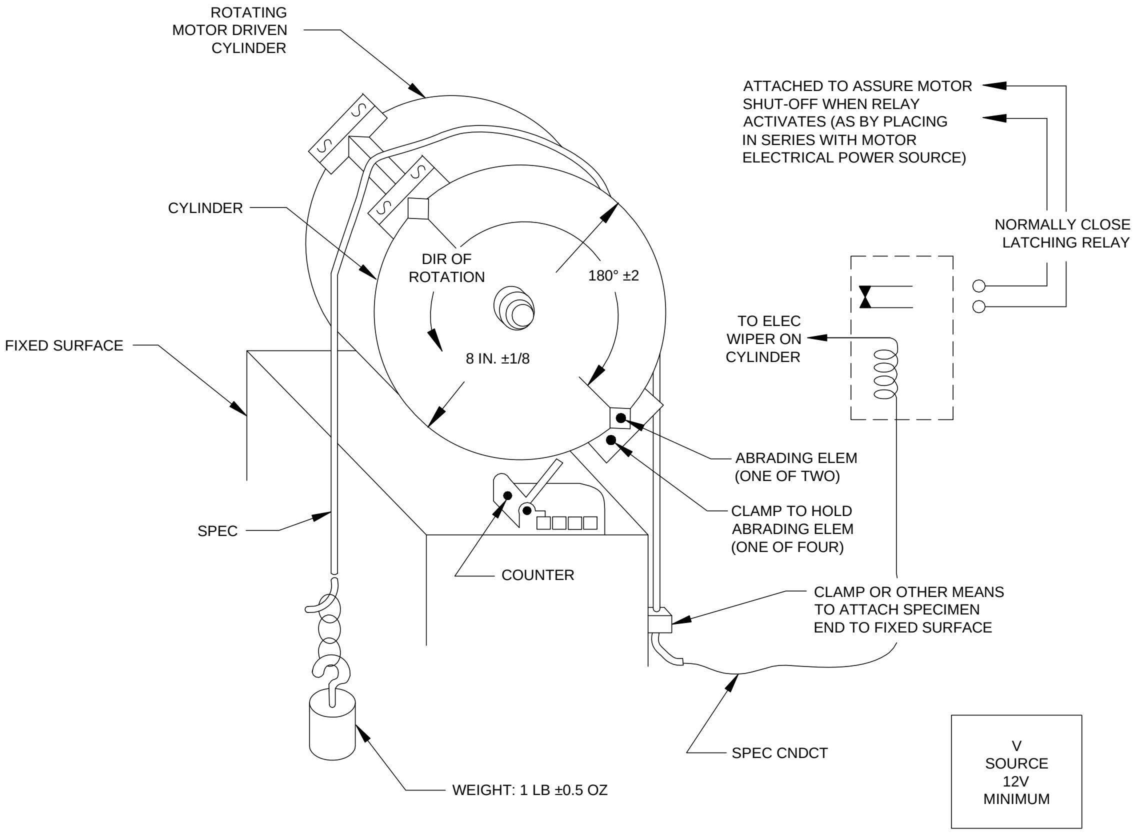

FIGURE 2. Diagram of abrading machine for the abrasion resistance test.

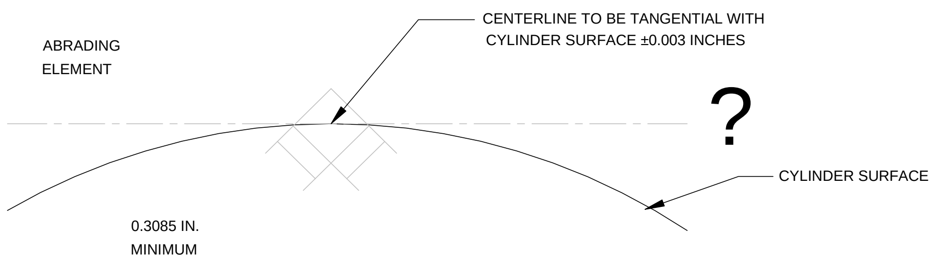

FIGURE 3. Detail diagram of abrading element fit on cylinder surface.

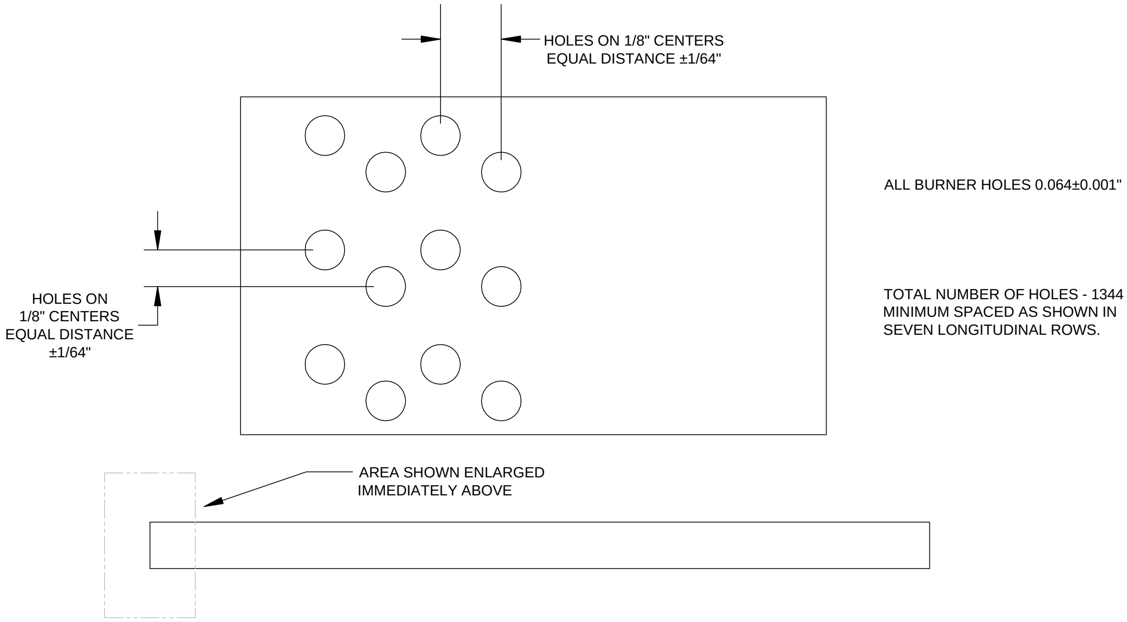

FIGURE 4. Top view of burner for gas flame test.

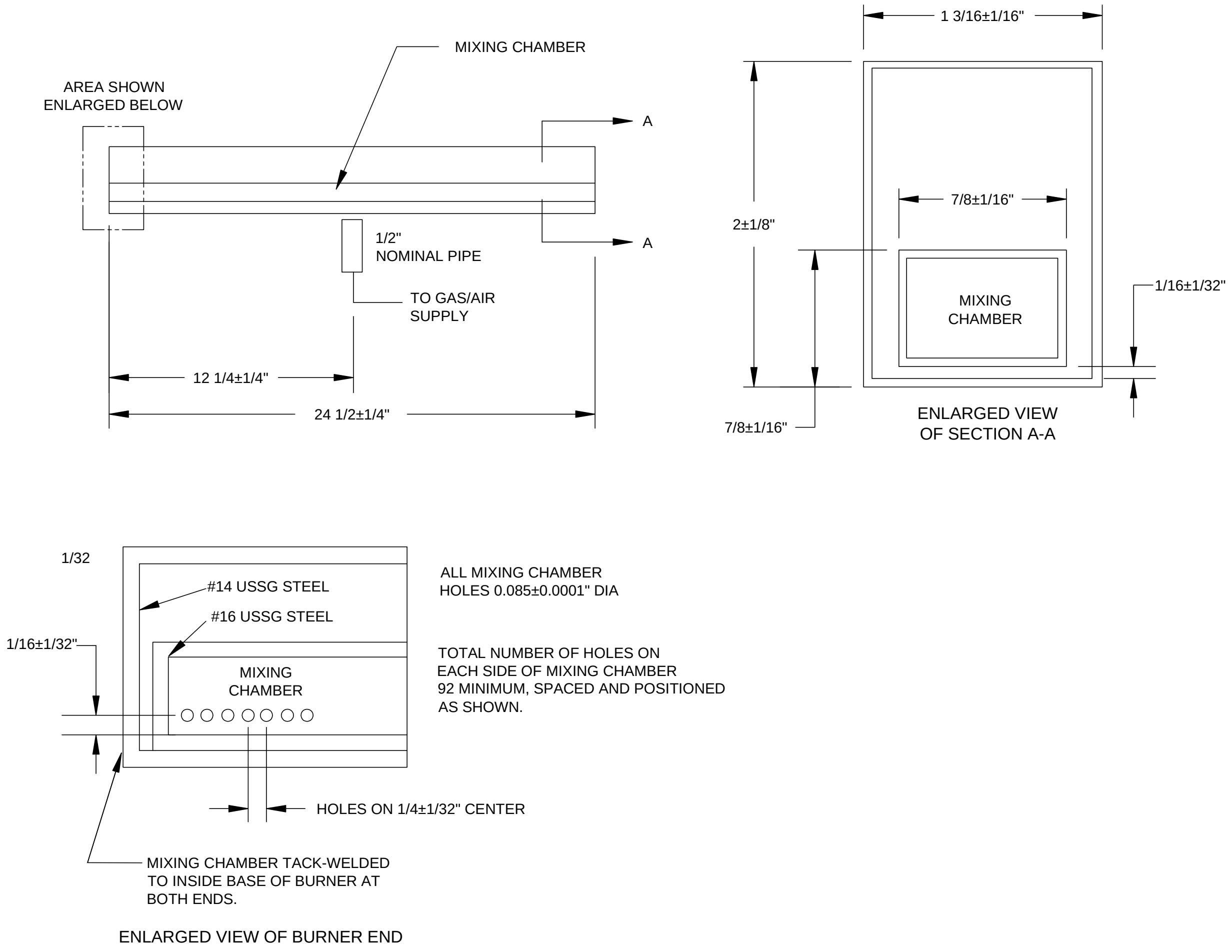

FIGURE 5. Side view of burner showing internal mixing chamber for the gas flame test.

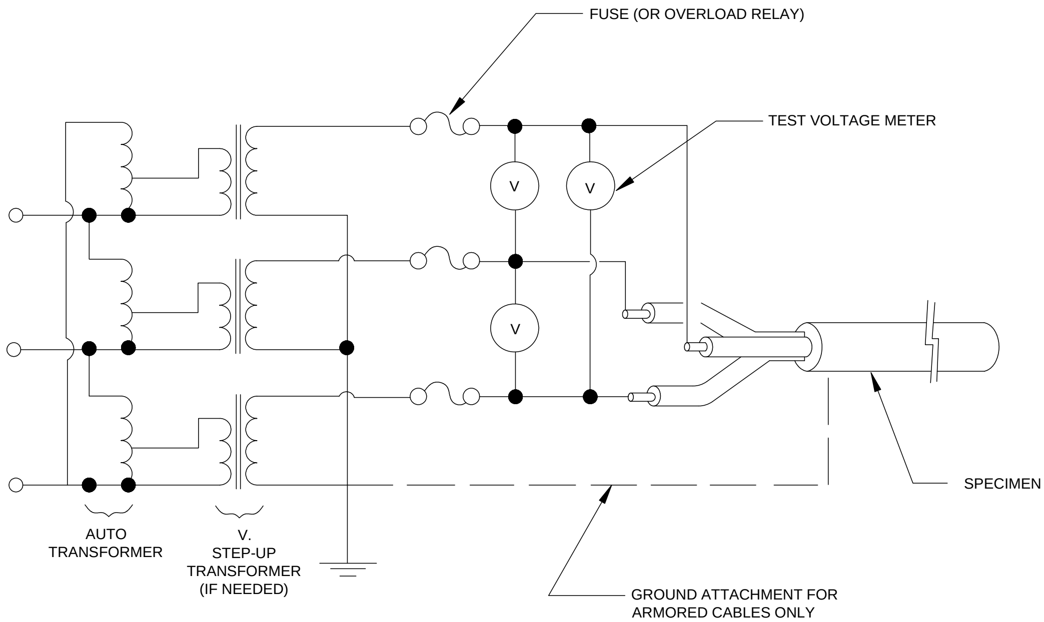

FIGURE 6. Application of test voltages for the gas flame test.

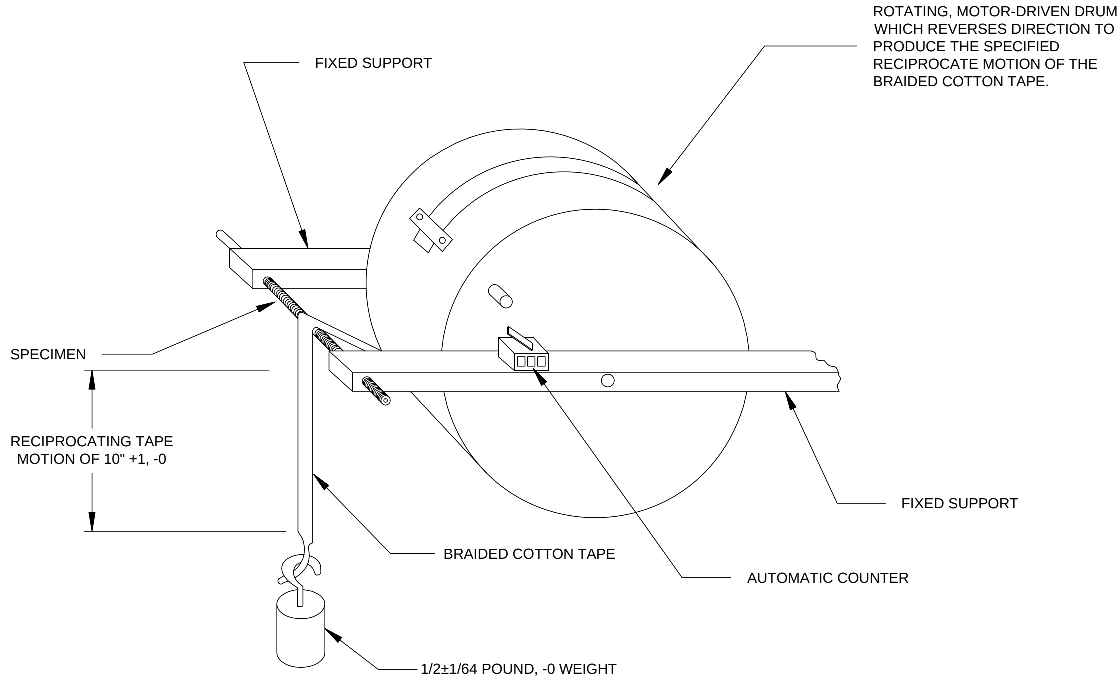

FIGURE 7. Diagram of typical abrading machine for the permanence of printing (conductor insulation) test.

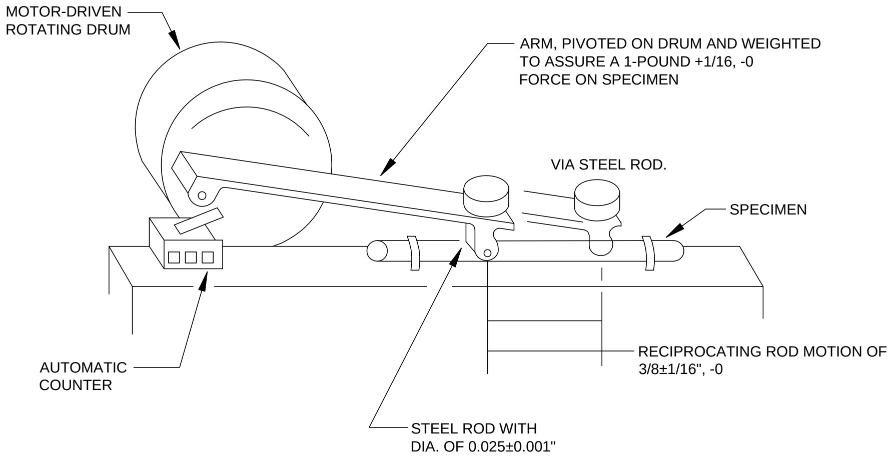

FIGURE 8. Diagram of abrading machine for the permanence of printing (jacket) test.

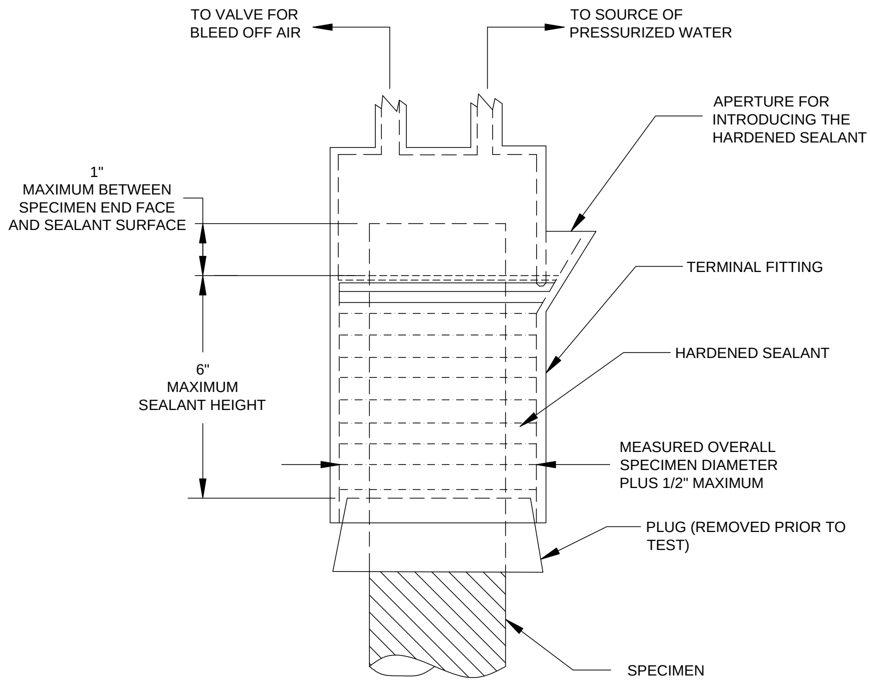

FIGURE 9. Diagram of terminal fitting, showing internal details, for the watertightness test.

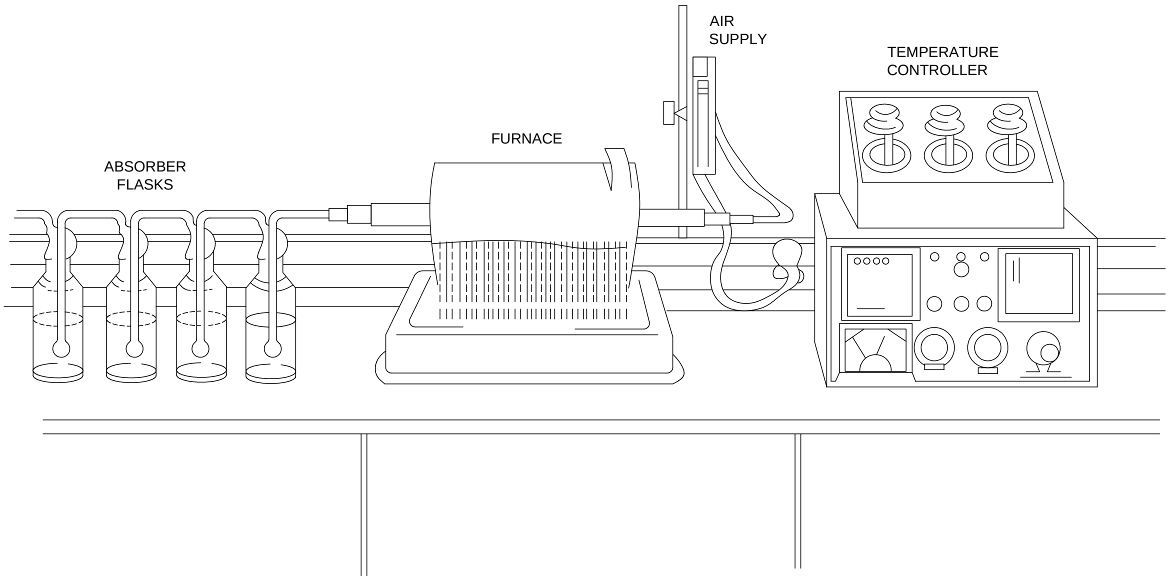

FIGURE 10. Acid gas test apparatus.

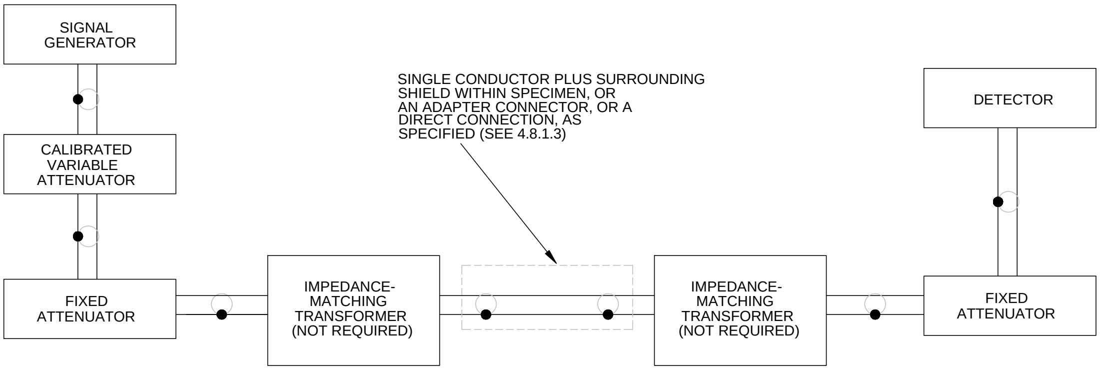

FIGURE 11. Block diagram of electrical connections for the attenuation test when testing a single conductor plus surrounding shield.

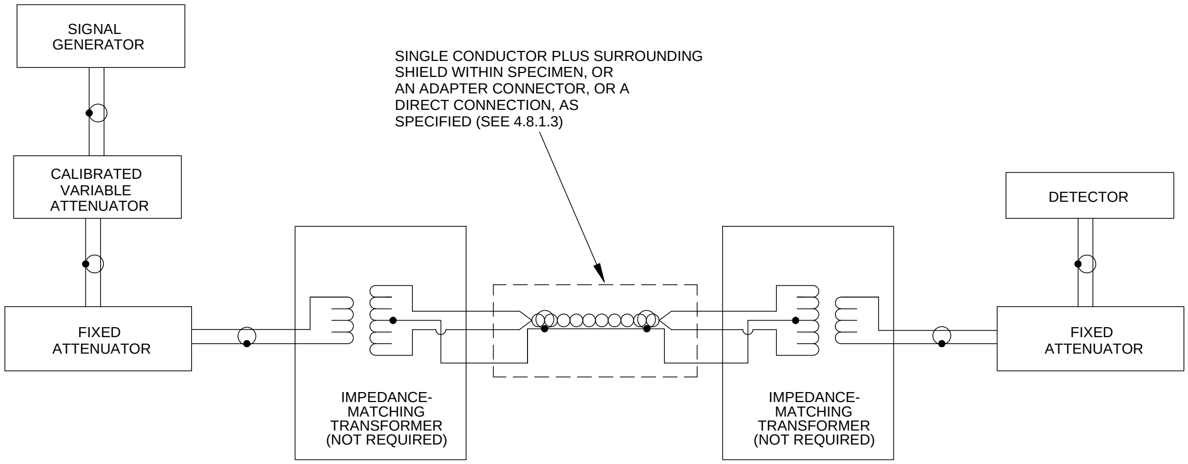

FIGURE 12. Block diagram of electrical connections for the attenuation test when testing a conductor pair plus surrounding shield.

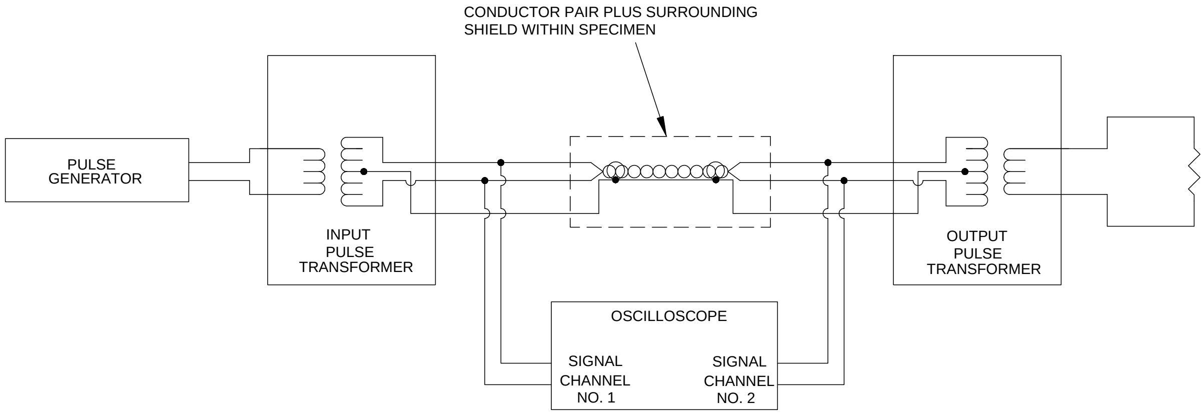

FIGURE 13. Block diagram of electrical connections for the pulse response test.

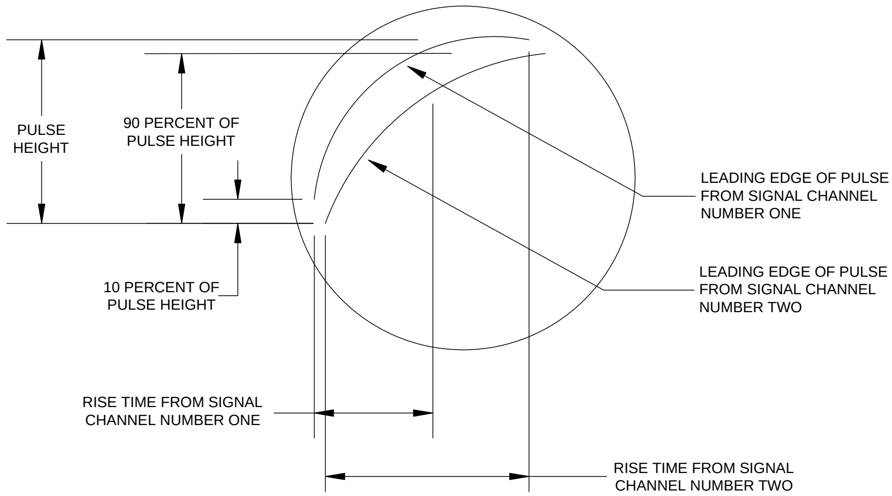

FIGURE 14. Oscilloscope display showing rise time measurements for the pulse response time test.

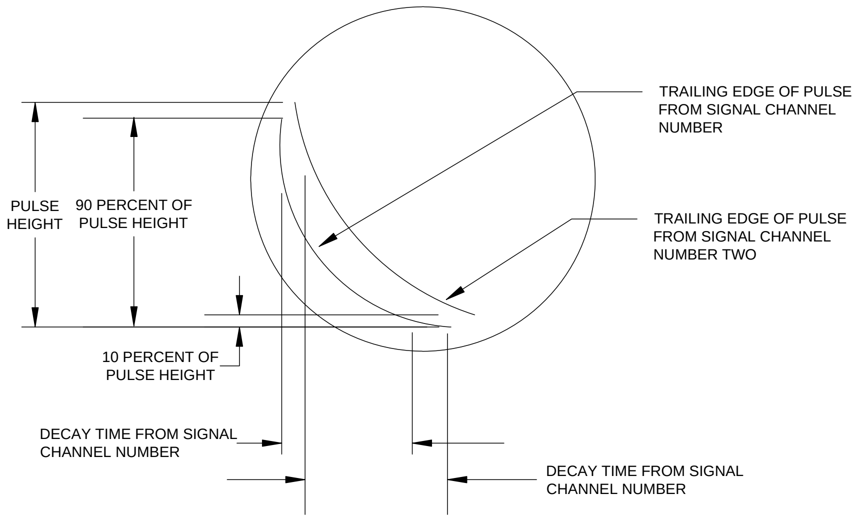

FIGURE 15. Oscilloscope display showing decay time measurements for the pulse response time test.

Custodians:
Army – MI
Navy – SH

Preparing Activity:
Navy – SH
(Project 6145-2009-068)

Review Activities:
Army – AR, AV, CR, CR4
Navy – CG, EC
DLA – CC

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