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RDT Standard

FOIL-SHIELDED
INSTRUMENTATION CABLE

JUNE 1974

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RDT STANDARD

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DIVISION OF REACTOR RESEARCH AND DEVELOPMENT

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FOIL-SHIELDED INSTRUMENTATION CABLE

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FOIL-SHIELDED INSTRUMENTATION CABLE

1. SCOPE

This standard defines requirements for armored and unarmored foil-shielded instrumentation cable for use in nuclear reactor facilities outside the reactor vessel. The cable is intended for use in the transmission of instrumentation and control signals in an environment where the signal-to-noise ratio is degraded by the coupling of electric fields associated with electromagnetic noise sources.

1.1 Classification. The foil-shielded cables described in this standard are of two types.

Type I Cables containing one or more twisted foil-shielded pairs or multiplets of insulated identical conductors having an operating temperature rating within the range from minus 26°C to 105°C and an operating voltage rating within the range from 200V to 3000V rms.

Type II Cables containing one or more twisted, foil-shielded pairs of insulated non-identical conductors (thermocouple extension wire) having an operating temperature rating from minus 26°C to 285°C.

1.2 Definitions.

1.2.1 Batch (or Lot). All cables of the same construction offered for delivery at one time.

1.2.2 Design Basis Event (DBE). Postulated abnormal event used in the design to establish the performance requirements of the cable.

1.2.3 Multiplet. A foil-shielded group of three or more twisted conductors.

1.2.4 Ohm - Ft. The unit of insulation resistance between 1-ft lengths of insulated conductors. The resistance for a section greater than 1 ft in length is calculated by dividing the resistance in ohm-ft (Ω -ft) by the cable length in feet.

1.2.5 Unit of Product. Cables having the same construction and length or lengths that have a total length not less than 500 ft nor more than 1000 ft.

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2. APPLICABLE DOCUMENTS

The following documents are a part of this standard to the extent specified herein. The issue of the document in effect on the date of the invitation to bid, including any amendments also in effect on that date, shall apply unless otherwise specified. Where this standard appears to conflict with the requirements of a referenced document, such conflict shall be brought to the attention of the purchaser for resolution.

2.1 RDT Standards.

RDT F 2-4T	Quality Verification Program Requirements
RDT F 3-2T	Calibration Program Requirements
RDT F 7-2T	Preparations for Sealing, Packaging, Packing, and Marking of Components for Shipment and Storage

2.2 Military Specifications.

MIL-C-23553A	Cable, Audio, Signal, Shore Use
MIL-W-16878D with Supplement 1A	Wire, Electrical, Insulated, High Temperature
MIL-STD-104B	Limits for Electrical Insulation Color
MIL-STD-105D	Sampling Procedures and Tables for Inspection by Attributes
MIL-W-81381	Wire, Electric, Polyimide-Insulated, Copper and Copper Alloy

2.3 Federal Standards and Specifications.

Fed. Test Method Standard No. 228	Cable and Wire, Insulated, Methods of Testing
Method 6111	Voltage Withstand, Insulation, Wire and Cable
QQ-W-343D	Wire, Electrical (Uninsulated)

2.4 American Society for Testing and Materials (ASTM) Specifications.

ASTM B 33	Tinned Soft or Annealed Copper Wire for Electrical Purposes
ASTM E 220	Calibration of Thermocouples by Comparison Techniques

2.5 Underwriters Laboratory (UL) Standards.

UL-83	Thermoplastic-Insulated Wires
UL-94	Test for Flammability of Plastic Materials for Parts in Devices and Appliances

2.6 Insulated Power Cable Engineers Association (IPCEA) Standards.

IPCEA S-61-402	Thermoplastic-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy
IPCEA S-19-81	Rubber-Insulated Wire and Cable for the Transmission and Distribution of Electrical Energy

2.7 American National Standards (ANSI).

ANSI C96.1	Temperature Measurement Thermocouples
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3. TECHNICAL REQUIREMENTS

3.1 Conductors.

3.1.1 Materials.

3.1.1.1 Type I Cable. The conductors shall conform to the requirements of either MIL-W-16878D, ASTM B-33, or QQ-W-343D and shall be as specified in the Ordering Data.

3.1.1.2 Type II Cable. The ISA thermocouple extension wire type (as defined in ANSI C96.1), calibration temperature, and limits of error shall be as specified in the Ordering Data. The temperature-emf relationship shall be in accordance with ANSI C96.1. All wire shall be free of cracks, scratches, kinks, slivers or abrasions and shall be fully annealed before assembly. The wire shall not be enameled or otherwise coated.

3.1.2 Wire Gage. The American Wire Gage (AWG) number or nominal diameter of conductor shall be as specified in the Ordering Data.

3.1.3 Stranded Conductors. Stranded conductors shall be as specified in the Ordering Data. The minimum number of strands, strand diameter, nominal diameter, and length of lay and stranding shall be in accordance with the detail specifications of MIL-W-16878D or QQ-W-343D for the wire gage specified in 3.1.2.

3.1.4 Joining Conductors. If joints are made in the conductor of a Type I Cable they shall be made by brazing with a silver alloy solder and a non-acid flux or by welding. For Type II Cable the joints shall be welded. Joints shall be cleaned and butted and shall be free from sharp projections. Bunch brazes or welds shall not be made. The tensile strength of any section of a conductor joint, that was brazed or welded, shall not be less than 85 percent of the tensile strength of an adjacent section without a joint.

3.1.5 Conductor Resistance.

3.1.5.1 Type I Cable. The maximum resistance for solid copper conductors shall be as specified in ASTM B 33 for the gage specified in 3.1.2. The maximum resistance for stranded conductors shall be as specified in the applicable detail specification MIL-W-16878D, Supplement 1A.

3.1.5.2 Type II Cable. The maximum conductor loop resistance of the loop formed by the thermocouple wires specified in 3.1.1 shall be within $\pm 10\%$ of the value determined from the resistivity length and cross sectional area of the thermocouple wires and shall be as specified in the Ordering Data.

3.2 Conductor Insulation.

3.2.1 Material. The insulation material shall be as specified in the Ordering Data.

3.2.1.1 Type I Cable. The material shall be self extinguishing (as defined by the Burning Rating Code in UL-94) and shall be in accordance with MIL-W-16878D, MIL-W-81381, UL-83, IPCEA S-61-402, or IPCEA S-19-81, as applicable. The minimum tensile strength and minimum elongation shall be as specified for the material in the applicable standard.

3.2.1.2 Type II Cable. The insulation material and thickness requirements shall be in accordance with 3.2.1.1 and ANSI C96.1.

3.2.2 Color Coding and Identification.

3.2.2.1 Type I Cable. Unless otherwise specified in the Ordering Data, the color coding of pairs shall be in accordance with MIL-C-23553A, Table I, so as to identify each pair in the completed cable. Color Coding on multiplet cable shall be as specified in the Ordering Data.

3.2.2.2 Type II Cable. The color coding shall be in accordance with ANSI C96.1, Table IV. Each pair in a cable consisting of two or more pairs shall be numbered. Numbers shall be marked on the insulation material a minimum of every 2 in.

3.2.3 Color Standards. Unless otherwise specified in the Ordering Data, the color standards shall conform to the requirements of MIL-STD-104B.

3.2.4 Striping. All striping shall provide readily discernible stripes on the primary insulation. These stripes may be an integral part of the insulation or an external plastic coating on the insulation over which shall be a transparent jacket. All striping shall be spiral, shall adhere firmly to the insulation, and shall remain intact when subjected to the tests specified in 4.2.5, 4.2.6, 4.2.7, and 4.2.8 as applicable.

3.3 Jacket.

3.3.1 Material. The jacket material shall be as specified in the Ordering Data. The material shall be self extinguishing and shall be in accordance with MIL-W-16878D, MIL-W-81381, UL-83, IPCEA S-61-402, or IPCEA S-19-81, as applicable. The minimum tensile strength and minimum elongation shall be as specified for the material in the applicable standard.

3.3.2 Color Coding.

3.3.2.1 Type I Cable. The jacket shall be colored as specified in the Ordering Data and shall conform to 3.2.3.

3.3.2.2 Type II Cable. The jacket shall be colored as specified in ANSI C96.1.

3.3.3 Jacket Thickness, Construction, and Outside Cable Diameters.

3.3.3.1 Unarmored. The nominal jacket thickness shall be in accordance with IPCEA S-61-402 or IPCEA S-19-81. The nominal outside diameter (D) of the cable as specified in the Ordering Data shall be within $\pm 10\%$ of the diameter calculated from the following formula:

$$D = NKd + 2T \quad (1)$$

Where: N = No. of pairs or conductors
K = Constant (see Table 1)
d = Diameter of individual conductors over insulation
T = Thickness of overall tape plus jacket

3.3.3.2 Armored. The jacket shall consist of an inner jacket overlaid with either an interlocking, galvanized steel armor or multiple strands of served soft annealed steel wire having a thickness in accordance with either IPCEA S-61-402 or IPCEA S-19-81, and an optional outer jacket. Inner jacket, armored jacket, and outer jacket requirements shall be as specified in the Ordering Data. The nominal outside diameter (D) of the cable shall be within $\pm 10\%$ of the diameter calculated from the following formula:

$$D = NKd + 2 (T_i + T_a + T_o) \quad (2)$$

Where: N = No. of pairs or conductors
K = Constant (see Table 1)
d = Diameter of individual conductors over insulation
 T_i = Thickness of inner overall tape plus jacket
 T_a = Thickness of armor
 T_o = Thickness of outer jacket

Table 1

Factor K for Multiple Pair and Multiple Conductor Cable

No. of Conductors** or Pairs	Factor K	
	Round Conductors	Twisted Pairs*
1	1.0	-----
2	2.	2.414
3	2.155	3.50
4	2.414	3.85
5	2.700	4.35
6	3.000	4.60
7	3.000	4.75
8	3.310	5.20
9	3.610	5.50
10	4.000	5.85
11	4.000	6.10
12	4.155	6.25
13	4.240	6.40
14	4.414	6.70
15	4.550	6.90
16	4.700	7.20
17	5.000	7.35
18	5.000	7.50
19	5.000	7.60
20	5.310	7.80
21	5.310	8.10
22	5.610	8.25
23	5.610	8.45
24	6.000	8.80
25	6.000	8.95

*Pairs cabled in the same direction of lay as the twist of the pairs.

**A "n" multiplet is considered to consist of "n" round conductors.

(continued)

Table 1
(continued)

Factor K for Multiple Pair and Multiple Conductor Cable

No. of Conductors** or Pairs	Factor K	
	Round Conductors	Twisted Pairs*
26	6.000	9.15
27	6.155	9.25
28	6.240	9.35
29	6.240	9.50
30	6.414	9.70
31	6.550	9.80
32	6.550	9.95
33	6.700	10.20
34	7.000	10.30
35	7.000	10.35
36	7.000	10.40
37	7.000	10.50
61	9.000	-----
81	10.550	-----
91	11.000	-----

*Pairs cabled in the same direction of lay as the twist of the pairs.

**A "n" multiplet is considered to consist of "n" round conductors.

*** For numbers of conductors or pairs exceeding the values given here, Table 1 may be extrapolated.

3.4 Design.

3.4.1 Number of Pairs or Multiplets. The number of pairs or multiplets shall be as specified in the Ordering Data.

3.4.2 Twisting of Pairs or Multiplets. The insulated conductors together with the associated drain wire shall be twisted into pairs or multiplets. The average length of lay in any pair or multiplet of the finished cable shall not be less than 1-1/4 in. or more than 3 in. when measured on any 10-ft length.

3.4.3 Shielding of Pairs or Multiplets. Each pair or multiplet shall be shielded by a tightly wrapped spiral tape. Depending on the normal operating conditions specified in 3.5.1.1, the tape shall consist of either a polyester* or polyimide** film, having a minimum thickness of 1 mil and commensurate with that thickness necessary to meet the shield-to-shield rated working voltage requirements of 3.5.7. The film shall be cemented to either an aluminum or copper foil as specified in the Ordering Data.*** The foil shall have a thickness necessary to meet the crosstalk requirements of 3.5.2. The tape shall be applied with a lay in the same direction and length as the lay of the twisted pairs described in 3.4.2. The metal foil shall be toward the insulated conductors except in the case of a single pair or multiplet where it may face away from the insulated conductors. The shield of each pair or multiplet in cable consisting of two or more pairs or multiplets shall be insulated from one another. If desired, a polyester or polyimide tape may be spirally wrapped over the shielded pair with a 25% minimum overlap. A single pair or multiplet may have foil shields with design features that inhibit the unwrapping of the shield of individual pairs or multiplets when the ends are handled are preferred to those without such features. Additionally, there shall be no exposed unshielded areas when a shielded pair or multiplet is coiled around a mandrel that has a diameter three times the overall diameter of the shield pair or multiplet.

3.4.4 Shielding Tape Color Code.

3.4.4.1 Type I Cable. Unless otherwise specified in the Ordering Data, the shielding tape shall be color coded consecutively as follows:

1. First 26 pairs or multiplets:	Blue
2. Second 26 pairs or multiplets:	Orange
3. Third 26 pairs or multiplets:	Green
4. Fourth 26 pairs or multiplets:	Brown
5. Subsequent groups of 26 pairs or multiplets:	As specified in the Ordering Data

3.4.4.2 Type II Cable. Unless otherwise specified in the Ordering Data, the color of the shielding tape shall be natural.

*E.I. Dupont **DeNemours** & Co., Summary of Properties, Technical Information Bulletin M-1J.

** Ibid, Technical Information Bulletin H-1C.

*** Nominal thickness of aluminum foils normally range between 0.00035 and 0.001 in. Nominal thickness of copper foils (used by one manufacturer to meet the crosstalk requirements of MIL-C-23437) normally range between 0.0007 and 0.0014 in.

3.4.5 Drain Wire. Each pair or multiplet shall contain a drain wire. Unless otherwise specified in the Ordering Data, the drain wire shall be stranded tinned copper. Tinned copper wire shall conform to the requirements of MIL-W-16878D or ASTM B 33. The drain wire shall be located within the shield except for the case of a single pair or multiplet with the foil facing away from insulated conductors where it shall be located outside the shield. The drain wire shall make conductive contact to the shield. The lay of the drain wire shall be the same as the twisted pair or multiplet. The gage of the drain wire shall be as follows:

<u>Cable Wire Size</u>	<u>Drain Wire Size</u>
1. 22 AWG or smaller	Same as cable wire size
2. Larger than 22 AWG	Two AWG sizes smaller than cable wire size

3.4.6 Cable Construction.

3.4.6.1 Type I Cable. The shielded pairs or multiplets shall be assembled to form a substantially cylindrical core. Adjacent layers may be cabled in the same or in opposite directions. For convenience in the construction of cables consisting of large numbers of pairs or multiplets, the cable may be formed of units each consisting of a smaller number of pairs or multiplets. If fillers are used they shall be nonhygroscopic and self-extinguishing as defined in UL-94.

3.4.6.2 Type II Cable. The construction shall be in accordance with 3.4.6.1. Additionally, a single No. 22 AWG, 7-strand, tinned-copper communications wire, insulated with the material specified in 3.2.1 and colored brown, shall be included in the cable.

3.4.7 Core Covering. The cable core shall be helically wrapped with a single wrap of either polyester or polyimide tape having a thickness ranging from 0.001 in. minimum to 0.005 in. maximum depending upon the operating conditions specified in 3.5.1. The core covering shall be applied with an overlay of at least 10%. This requirement is not applicable to single pair or multiplet cable.

3.4.8 Cable Marking. Unless otherwise specified in the Ordering Data, a permanently marked tape shall be inserted between the core covering and the jacket. Single pair or multiple marked tape shall be inserted between the jacket and the shield. The tape shall be marked with the footage in sequence every 12 in., but need not start at 0 ft. The cable shall be marked a minimum of every 24 in. with the following:

1. Manufacturer's name (or symbol designation).
2. Year of manufacture (+ 1 month).
3. Procurement specification number.

3.4.9 Cable Length. The length of cable shall be as specified in the Ordering Data.

3.5 Performance.

3.5.1 Operating Conditions. Each cable shall be capable of performing as specified herein when subjected to the following environmental conditions. Proof of capability is demonstrated by successful completion of the tests described in 4.2 as modified by 4.3.2.

3.5.1.1 Normal Conditions. The cable shall be capable of performing continuously when subjected to the temperature, pressure, radiation, and other environmental conditions expected during normal operation as specified in the Ordering Data.

3.5.1.2 DBE Conditions. The cable shall be capable of performing continuously when subjected to the postulated abnormal environmental conditions specified in the Ordering Data provided that these conditions do not exceed the physical limitations of the materials specified in 3.1 to 3.4.

3.5.2 Crosstalk. The crosstalk between two adjacent individual pairs or multiplets with the same direction of cable lay or between two single-pair or two single-multiplet cables shall be greater than that shown in the attenuation frequency curve shown in Figure 1 unless otherwise specified in the Ordering Data. The test procedure shall be in accordance with 4.2.1 unless otherwise specified in the Ordering Data.*

3.5.3 Continuity. In each length of cable, the conductors shall be free from contacts between conductor and shield, short circuits, and open circuits. The shielding and drain wire of each pair shall be continuous and free of short circuits to any other conductor or shield.

3.5.4 Insulation Resistance.

3.5.4.1 Type I Cable. The insulation resistance measured between the drain wires of adjacent shields of the same lay shall be a minimum of 10^5 M Ω -ft or as specified in the Ordering Data. The conductor-to-conductor insulation resistance shall be a minimum of twice the value of the applicable detailed specification of MIL-W-16878D, Supplement 1A, Table II, or as specified in the Ordering Data. The test procedure shall be in accordance with 4.2.3.

3.5.4.2 Type II Cable. The insulation resistance measured between the drain wires of adjacent shields of the same lay shall be a minimum of 10^5 M Ω -ft or as specified in the Ordering Data. The resistance constant, as determined by measurement from conductor-to-shield and conductor-to-conductor, shall be in accordance with the values specified in the

*Improved techniques for the measurement of crosstalk are being evolved by the industry. The manufacturer may use such techniques in lieu of those specified in 4.2.1 if approval is obtained from the purchaser.

Fig. 1. CABLE CROSSTALK TEST, MINIMUM ATTENUATION LIMITS

applicable parts of IPCEA S-61-402 or IPCEA S-19-81 for the material specified in 3.2.1 or as specified in the Ordering Data. The test procedure shall be in accordance with 4.2.3.

3.5.5 Dielectric Strength. The conductor-to-conductor, conductor-to-shield, and shield-to-shield dielectric strength of each pair or multiplet shall be as specified in the Ordering Data. The test procedure shall be as specified in 4.2.2.

3.5.5.1 Reeling Effects. The cable shall meet the shield-to-shield dielectric strength test requirements of 3.5.5 after repeated unreeling as specified in MIL-C-23553A.

3.5.6 Limits of Error and Calibration Temperature. For Type II Cable, the temperature-emf relationship of the particular thermocouple type, calibration temperature, and limits of error shall be as specified in 3.1.1.2. The test procedure shall be in accordance with 4.4.3.4.

3.5.7 Rated Working Voltage. The conductor-to-conductor, conductor-to-shield, and shield-to-shield rated working voltage shall be as specified in the Ordering Data.

3.5.8 Flame Resistance. The cable, individual shielded pairs or multiplets and insulated conductors shall be capable of passing the flame resisting test as specified in 4.2.4.

3.5.9 Cold Bend. The cable shall be capable of passing a cold bend test as specified in 4.2.5. After the cable is tested there shall be no evidence of cracks or flaws in either the insulation or jacket material. The conditioning temperature and time shall be as specified in the Ordering Data.

3.5.10 Aging Stability. The cable shall be capable of passing an aging stability test as specified in paragraph 4.2.6 of this standard. After the test there shall be no evidence of cracks or flaws in the insulation material or jacket. The cable shall then be subjected to the dielectric strength test of 4.2.2 and meet the requirements specified therein. The maximum and minimum conditioning and test temperature shall be as specified in the Ordering Data.

3.5.11 Heat Shock. The primary insulation of the single conductor shall be capable of passing a heat shock test as specified in 4.2.7. After the test there shall be no evidence of cracks or flaws in the primary insulation. The test temperature shall be $121^{\circ}\text{C} \pm 1^{\circ}\text{C}$ or as specified in the Ordering Data.

3.5.12 Tests on Natural or Synthetic Rubber - Insulated Cable. Unless otherwise specified in the Ordering Data, if the wire jacket insulating material specified in 3.2.1 and 3.3.1, or both are classified as natural or synthetic rubber (defined in IPCEA S-19-81), the cable shall be capable of passing the following additional tests:

1. Ozone resistance.
2. Oil immersion.
3. Water absorption.
4. Heat Distortion.

The test procedures shall be as specified in 4.2.8. The cable shall meet the requirements of IPCEA S-19-81 for these tests.

3.5.13 Water Absorption. Unless otherwise specified in the Ordering Data, if the water absorption test of 3.5.12 is not applicable, the cable shall be capable of passing the water absorption test specified in 4.2.9. The cable shall meet the requirements of IPCEA S-61-402.

4. QUALITY ASSURANCE REQUIREMENTS

4.1 Quality Verification Program. A quality verification index shall be prepared and followed in accordance with Section 2 of RDT F 2-4.

4.1.1 Documentation. The following records, procedures, specifications, calculations, and drawings shall be prepared and submitted to the purchaser for approval before the start of production.

1. Quality verification plan.
2. Process control and examination procedures.
3. Test procedures.

4.2 Qualification Tests. Design qualification tests shall be performed on a prototype cable of each type specified in the Ordering Data, unless specifically excluded in 4.3.2. The test equipment used shall be calibrated in accordance with RDT F 3-2. The cable tested shall pass the following tests to qualify the cable:

4.2.1 Crosstalk Test. The crosstalk requirements specified in 3.5.2 shall be determined as follows: A known signal voltage shall be connected to one of the two tested pairs or multiplets and the signal voltage coupled to the second pair or multiplet by crosstalk (or stray) coupling shall be measured. The ratio of these voltages, expressed in dB, is a measure of the crosstalk.

4.2.1.1 Equipment Required.

1. RF signal generator, 160 kHz to 40 MHz, 50 Ω output impedance, 1 volt or greater output.
2. RF receiver, 160 kHz to 40 MHz, 50 Ω input impedance.

3. Calibrated attenuator, continuously adjustable, 50Ω , 0-120dB minimum range. NOTE: This item may be an integral part of item 1, 2 or both.

4. Coaxial connectors and components of the following types:

<u>Type</u>	<u>No. Required</u>
a. Straight plug	6
b. Tee adapter	1
c. Bulkhead adapter	1
d. Bulkhead receptacle with backshell	2
e. Dummy load, 50Ω	1

5. Coaxial cable, as required.

6. Screen room.

4.2.1.2 Equipment Setup. The test equipment shall be setup as shown in Figure 2. Lengths of coaxial cable used to make connections between the signal generator, receiver and test specimen shall be as short as possible. The connector characteristic impedance shall be 50Ω . Typical connectors with modified backshells, to make the transition from the coaxial cable to the shielded pair or multiplet, are also shown in Figure 2. Extreme care shall be exercised in maintaining conductive continuity between the cable shields and the backshells.

4.2.1.3 Test Procedures.

a. Set the signal generator output attenuator or receiver input attenuator to obtain a reference reading on the receiver output meter (this reference level should be a minimum of 3 dB above the receiver noise level). The attenuator reading in dB and receiver output voltage level shall be recorded.

b. Interchange connectors A and B in Figure 2 and readjust the attenuator until the receiver output voltage is identical to that recorded in (1). The attenuator reading in dB shall be recorded. The difference in the attenuator readings in dB is indicative of the crosstalk coupling.

4.2.2 Dielectric Strength. Dielectric strength voltage tests shall be performed in accordance with 3.5.5 and with either IPCEA S-61-402 or Federal Test Method Standard No. 228, Method 6111. The DBE environmental condition as specified in 3.5.1.2 shall be present concurrently during testing.

4.2.2.1 Reeling Effects. Dielectric strength voltage tests shall be performed in accordance with 3.5.6.1 and the procedures specified in 4.2.2, under normal conditions as specified in 3.5.1.1.

Fig. 2. SETUP FOR CROSSTALK TESTS

4.2.3 Insulation Resistance. Insulation resistance measurements shall be performed in the DBE environment on the same cable specimen used for the dielectric strength test of 4.2.2. This test shall be in accordance with IPCEA S-61-402 and shall meet the requirements of 3.5.4.

4.2.4 Flame Resistance. Cable specimens* shall be subjected to the flame resisting test specified in either IPCEA S-61-402 or UL-83 and shall meet the requirements of 3.5.8.

4.2.5 Cold Bend. Cable specimens* shall be subjected to a cold bend test as specified in MIL-C-23553A, except that the conditioning temperatures and time shall be as specified in the Ordering Data. The cable shall meet the requirements of 3.5.9.

4.2.6 Aging Stability. Cable specimens* shall be subjected to an aging stability test as specified in MIL-C-23553A, except that the maximum and minimum conditioning temperatures and time shall be as specified in the Ordering Data. The cable shall meet the requirements of 3.5.10.

4.2.7 Heat Shock. Cable specimens* shall be subjected to the heat shock test specified in the applicable paragraph of UL-83, IPCEA S-61-402 or IPCEA S-19-81 and shall meet the requirements of 3.5.11.

4.2.8 Tests on Natural or Synthetic Rubber - Insulated Cable. Cable specimens* shall be subjected to the tests specified in 3.5.12 in accordance with the procedures specified in the applicable sections of IPCEA S-19-81. The cable shall meet the requirements of 3.5.12.

4.2.9 Water Absorption. Cable specimens* shall be subjected to the water absorption test in accordance with the procedures specified in the applicable sections of IPCEA S-61-402. The cable shall meet the requirements of 3.5.13.

4.3 Prototype Approval. Unless otherwise specified in the Ordering Data, production cables shall not be fabricated until the qualification tests of 4.2 have been approved by the persons specified in the Ordering Data.

4.3.1 Design Changes. Prior to requesting approval of any proposed change in design, material or fabrication technique for any cable subsequent to qualification of the prototype, new qualification tests shall be conducted to verify the acceptability of the proposed change. Change tests may be waived by the purchaser where the design changes do not effect cable performance.

4.3.2 Waiving of Prototypes. The fabrication and qualification testing of prototype cables may be waived by the purchaser if sufficient information on prototypes of similar design is submitted for evaluation with the bid

*The number of specimens to be subjected to the test are specified in the standard or specification invoked by the purchaser in the procurement specification.

proposal. This information shall include complete descriptions of the prototype assemblies, test procedures, results, and copies of certified test reports.

4.4 Production, Inspection and Testing. All cables of the same construction offered for delivery at one time shall be considered to be a lot or batch for purposes of sampling and inspection by attributes in accordance with MIL-STD-105D. Each lot or batch shall pass the production inspections and tests for acceptance as specified in 4.4.2 and 4.4.3. The unit of product shall be considered to be a cable having the same construction and length or lengths that have a total length of from 500 to 1000 feet. The sample shall consist of that number of sample units required by the sampling plan for the lot size.

4.4.1 In-Process Inspections. Each component part of the cable shall be inspected before assembly and during various stages of assembly to ensure the specified technical requirements will be met.

4.4.2 Visual and Mechanical Examinations.

4.4.2.1 The outer diameter of the cable shall be checked for conformance to the requirements of 3.3.3.

4.4.2.2 The required number and size of conductors in each cable shall be checked for conformance to the requirements of 3.1.2 and 3.4.1.

4.4.2.3 The color of the insulation and shielding tape shall be checked for conformance to the requirements of 3.2.2 and 3.4.4.

4.4.2.4 The drain wire size shall be checked for conformance to 3.4.5.

4.4.2.5 A shielded pair or multiplet shall be coiled around a mandrel that has a diameter three times the overall diameter of the shielded pair or multiplet to check for conformance to the requirement of 3.4.3 that no unshielded areas are exposed.

4.4.3 Electrical Tests.

4.4.3.1 Dielectric Strength Test. Unless otherwise specified in the Ordering Data, dielectric strength voltage tests shall be performed on each pair or multiplet under normal conditions in accordance with 3.5.1.1 and 4.2.2. If tested, the cable shall meet the requirements of 3.5.5.

4.4.3.2 Insulation Resistance Test. Insulation resistance tests shall be performed on each pair or multiplet under normal conditions in accordance with 3.5.1.1 and 4.2.3 except that the requirement for a prior dielectric strength test may be waived in 4.4.3.1. The cable shall meet the requirements of 3.5.4.

4.4.3.3 Crosstalk. A crosstalk test shall be performed on samples of the completed cable in accordance with 4.2.1. Unit samples and test samples shall be in accordance with MIL-C-23533A. The cable shall meet the requirements of 3.5.2.

4.4.3.4 Calibration of Type II Cable. A minimum of one sample thermocouple from each batch or lot shall be prepared and calibrated in accordance with the procedures specified in ASTM E 220. The thermocouple shall meet the requirements of 3.5.6.

4.4.3.5 Continuity. Following all other electrical tests, each pair or multiplet and shield shall receive a continuity test. The cable shall meet the requirements of 3.5.3.

4.5 Certificate of Compliance. A certified statement of compliance with the requirements of this standard together with supporting data shall be provided to the purchaser with each lot.

5. PREPARATION FOR DELIVERY

Preparation for delivery shall be in accordance with RDT F 7-2, Section 4, and as specified herein and in the Ordering Data.

5.1 Cable Put-Up. Cable shall be put-up on nonreturnable reels that contain either 500 or 1000 ft continuous lengths $\pm 10\%$ unless otherwise specified in the Ordering Data. The 100-ft cable samples that have satisfactorily passed the crosstalk tests shall be furnished provided that the footage is properly tagged to cable and marked on the reel. The cable lengths shall have both ends brought out so that the cable can be tested without unreeling. The reels shall be constructed with flanges of sufficient thickness to protect the cable from damage during handling, shipment and storage. The diameter of the reel core shall not be less than 20 times the cable diameter.

5.2 Labeling of Prototypes. Prototype cables shall be labeled or tagged as "test prototype" if they are to be shipped to the job site.

5.3 End Seals. The ends of the cable shall be sealed with waterproof pressure sensitive tape applied over the ends and back from the ends approximately 4 in.

5.4 Marking. Each reel of cable shall be identified in accordance with RDT F 7-2, Section 10.

6. ORDERING DATA AND NOTES

6.1 Ordering Data. The following technical and procurement data will be furnished with the purchase document. Any necessary data not furnished with the purchase document shall be requested before submitting a bid.

1. Conductor material Type I (3.1.1.1).

2. ISA thermocouple wire type calibration temperature and limits of error (3.1.1.2).

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3. Conductor wire gage (3.1.2).
 4. Conductor stranding (3.1.3).
 5. Thermocouple wire maximum loop resistance (3.1.5.2).
 6. Insulation material (3.2.1).
 7. Color coding (special requirements) (3.2.2.1).
 8. Color standards (special requirements) (3.2.3).
 9. Jacket material (3.3.1).
 10. Jacket color (3.3.2).
 11. Unarmored jacket thickness, construction and outside cable diameter (3.3.3.1).
 12. Armored jacket thickness, construction and outside cable diameter (3.3.3.2).
 13. Number of pairs or multiplets (3.4.1).
 14. Shielding conductor material (3.4.3).
 15. Shielding tape color code (special requirements) (3.4.4).
 16. Drain wire material and wire gage (special requirements) (3.4.5).
 17. Cable length (3.4.9).
 18. Normal conditions (3.5.1.1).
 19. DBE conditions (3.5.1.2).
 20. Crosstalk (3.5.2).
 21. Insulation resistance (special requirements) (3.5.4).
 22. Dielectric strength (3.5.5).
 23. Rated working voltage (3.5.7).
 24. Cold bend test conditioning temperature (3.5.9).
 25. Aging stability conditioning temperatures (3.5.10).
 26. Heat shock test temperature (3.5.11).
 27. Tests on natural or synthetic rubber - insulated cable (3.5.12).

28. Water absorption (3.5.13).
29. Qualification tests, cable type to be tested (4.2).
30. Prototype approval requirements (4.3).
31. Production dielectric strength test (4.4.3.1).
32. Preparation for delivery (5).
33. Cable put-up (special requirements) (5.1).