NEMA Standards Publication No. TF1-1993 (R2000)

Coated Electrical Sleeving

Published by:

National Electrical Manufacturers Association
1300 North 17th Street, Suite 1847
Rosslyn, VA 22209

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Foreword

The Standards Publication has been prepared by the Electrical Tubing and Sleeving Section of the National Electrical Manufacturers Association and is intended primarily to establish test methods and performance characteristics for flexible coated sleeving used for electrical insulation.

These standards have been developed and revised over a period of years in close coordination with user needs. In addition, this Standards Publication has been closely coordinated with parallel standards writing efforts going on in Subcommittee 15C of the International Electro-Technical Commission, ASTM, NAVSEA and UL.

This Standards Publication which was developed by the Electrical Tubing and Sleeving Section is reviewed periodically for any revisions that may be necessary to keep them up to date with advanced technology. Proposed or recommended revisions should be submitted to:

Vice President, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, DC 20037

Scope

This Standards Publication covers requirements for and the testing of flexible coated sleeving used for electrical insulation.

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Section 1
REFERENCED STANDARDS AND DEFINITIONS

1.1 REFERENCED STANDARDS

The following publications are adopted, in whole or in part, as indicated, by reference in this Standards Publication.

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

ASTM D149-1990	*Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies, Standard Test Method for*
ASTM D471-1979	*Rubber Property—Effect of Liquids, Standard Test Method for*
ASTM D618-1961 (R 1981)	*Conditioning Plastics and Electrical Insulating Materials for Testing, Standard Methods of*
ASTM D1676-1988	*Film-Insulated Magnet Wire, Standard Test Methods*
ASTM D2436-1985	*Forced-Convection Laboratory Ovens for Electrical Insulation, Specification for*

Institute of Electrical and Electronics Engineers
345 East 47th Street
New York, NY 10017

IEEE 1-1986	*General Principles for Temperature Limits in the Rating of Electric Equipment and for the Evaluation of Electrical Insulation, Standard*
IEEE 98-1984	*Preparation of Test Procedures for the Thermal Evaluation of Solid Electrical Insulating Materials, Standard for*
IEEE 101-1987	*Guide for the Statistical Analysis of Thermal Life Test Data*

Underwriters Laboratories, Inc.
333 Pfingsten Road
Northbrook, IL 60062

UL 1441-1981	*Coated Electrical Sleeving*

1.2 DEFINITIONS

1.2.1 Coated Sleeving

A flexible, tubular product woven from cotton, rayon, nylon, glass or other fibers which is impregnated, coated, or impregnated and coated with an electrical insulating material.

1.2.2 Dielectric Breakdown Voltage

The voltage which an insulating material can withstand before breakdown occurs, usually expressed in volts (ac, rms). Also known as puncture voltage.

1.2.3 Elastomer

A material which returns rapidly to approximately its initial state after substantial deformation by a stress and release of that stress.

1.2.4 Temperature Index

A numerical value which indicates the continuous-duty use temperature of an insulating material. This value is determined by long-range heat-aging of test specimens under controlled conditions. In the case of coated sleeving, this corresponds to the temperature in degrees Celsius at which the material will retain 50% of its dielectric breakdown voltage after 20,000 hours exposure at that temperature.

1.2.5 Thermoplastic

A material capable of being repeatedly softened by heating and hardened by cooling through a temperature range characteristic of the material, and in the softened state, capable of being repeatedly shaped by flow.

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1.2.6 Thermoset

A material which changes into a substantially infusible and insoluble product when cured by heat, radiation, catalysis, or other means, possibly in combination.

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Section 2
CLASSIFICATION

2.1 TYPES

Type 1—A flexible treated sleeving made from organic-base fibers such as cotton, rayon, or nylon and impregnated or coated with an insulating material which can be shown by applicable experience or accepted test to have a temperature index of 105.

Type 2—A flexible treated sleeving made from inorganic-base yarns such as fibrous glass and impregnated or coated with an insulating material which can be shown by applicable experience or accepted test to have a temperature index of 130.

Type 3—A flexible treated sleeving made from inorganic-base yarns such as fibrous glass and impregnated or coated with an insulating material, such as polyvinyl chloride, which can be shown by applicable experience or accepted test to have a temperature index of-105.

Type 4—A flexible treated sleeving made from inorganic-base yarns such as fibrous glass and impregnated or coated with an insulating material, such as silicone resin or polytetrafluoroethylene, which can be shown by applicable experience or accepted test to have a temperature index of 200.

Type 5—A flexible treated sleeving made from inorganic-base yarns such as fibrous glass and impregnated or coated with an insulating material, such as silicone elastomer, which can be shown by experience or accepted test to have a temperature index of 200.

Type 6—A flexible treated sleeving made from inorganic-base yarns such as fibrous glass and impregnated or coated with an insulating material, such as epoxies, Polyesters, or acrylics, which can be shown by experience or accepted test to have a temperature index of 155.

Type 7—A flexible treated sleeving made from inorganic-base yarns such as fibrous glass and impregnated or coated with an insulating material which can be shown by experience or accepted test to have a temperature index of 180.

See IEEE Standard 98.

2.2 GRADES

Grades of coated sleeving for each type are identified according to their dielectric breakdown voltage as given in Table 2-1.

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Table 2-1
BREAKDOWN VOLTAGE REQUIREMENTS, kV, MINIMUM

		C48/23/50*		C-96/23/93*		
Type	Grad	Avg	Ind.	Avg.	Ind.	E-96/(TI+50)** Avg.
1	A	7.0	5.0	2.1	1.5	4.0
	B	4.0	2.5	1.2	0.8	...
	C	2.5	1.5	...	...	...
2	A	7.0	5.0	2.1	1.5	4.5
	B	4.0	2.5	1.2	0.8	...
	C	2.5	1.5	...	...	...
3	A	8.0	6.0	4.0	3.0	4.0
	B	4.0	2.5	2.0	1.3	...
	C	2.5	1.5	...	...	...
4	A	8.0	6.0	6.4	4.8	5.0
	B	4.0	2.5	2.8	1.8	...
	C	2.5	1.5	...	...	...
5	A	8.0	6.0	6.4	4.8	5.5
	B	4.0	2.5	3.2	2.0	...
	C	2.5	1.5	...	...	...
6	A	7.0	5.0	2.1	1.5	4.5
	B	4.0	2.5	1.2	0.8	...
	C	2.5	1.5	...	...	...
7	A	7.0	5.0	3.5	2.5	4.0
	B	4.0	2.5	2.0	1.3	...
	C	2.5	1.5	...	...	...

*Conditioning designations per ASTM D 618

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Section 3
DIMENSIONAL REQUIREMENTS

3.1 INSIDE DIAMETER AND WALL THICKNESS

Coated sleeving shall meet the inside diameter and wall thickness requirements as shown in Table 3-1.

Table 3-1
INSIDE DIAMETER AND WALL THICKNESS*

	Inside Diameter, Inch (mm)		Minimum Overall Wall Thickness Inch (mm)		
Trade Size	Maximum	Minimum	Grade A	Grade B	Grade C
30 AWG	0.018 (0.46)	0.010 (0.26)	0.011 (0.279)	0.007 (0.18)	0.006 (0.152)
28 AWG	0.020 (0.51)	0.012 (0.31)	0.011 (0.279)	0.007 (0.18)	0.006 (0.152)
26 AWG	0.022 (0.56)	0.016 (0.41)	0.011 (0.279)	0.007 (0.18)	0.006 (0.152)
24 AWG	0.027 (0.69)	0.020 (0.51)	0.011 (0.279)	0.007 (0.18)	0.006 (0.152)
22 AWG	0.032 (0.81)	0.025 (0.64)	0.013 (0.330)	0.007 (0.18)	0.006 (0.152)
20 AWG	0.039 (0.99)	0.032 (0.81)	0.013 (0.330)	0.007 (0.18)	0.006 (0.152)
19 AWG	0.044 (1.11)	0.036 (0.91)	0.013 (0.330)	0.007 (0.18)	0.006 (0.152)
18 AWG	0.049 (1.25)	0.040 (1.02)	0.015 (0.381)	0.007 (0.18)	0.006 (0.152)
17 AWG	0.054 (1.37)	0.045 (1.14)	0.015 (0.381)	O.007 (0.18)	0.006 (0.152)
16 AWG	0.061 (1.55)	0.051 (1.30)	0.015 (0.381)	0.007 (0.18)	0.006 (0.152)
15 AWG	0.067 (1.70)	0.057 (1.45)	0.015 (0.381)	0.007 (0.18)	0.006 (0.152)
14 AWG	0.074 (1.88)	0.064 (1.63)	0.015 (0.381)	0.007 (0.18)	0.006 (0.152)
13 AWG	0.082 (2.08)	0.072 (1.83)	0.015 (0.381)	0.007 (0.18)	0.006 (0.152)
12 AWG	0.091 (2.31)	0.081 (2.06)	0.015 (0.381)	0.007 (0.18)	0.006 (0.152)
11 AWG	0.101 (2.6)	0.091 (2.31)	0.018 (0.457)	0.009 (0.23)	0.008 (0.203)
10 AWG	0.112 (2.8)	0.102 (2.6)	0.018 (0.457)	0.009 (0.23)	0.008 (0.203)
9 AWG	0.124 (3.2)	0.114 (2.0)	0.018 (0.457)	0.009 (0.23)	0.008 (0.203)
8 AWG	0.141 (3.6)	0.129 (3.3)	0.018 (0.457)	0.009 (0.23)	0.008 (0.203)
7 AWG	0.158 (4.0)	0.144 (3.7)	0.018 (0.457)	0.009 (0.23)	0.008 (0.203)
6 AWG	0.178 (4.5)	0.162 (4.1)	0.020 (0.508)	0.011 (0.28)	0.010 (0.254)
5 AWG	0.198 (5.0)	0.182 (4.6)	0.020 (0.508)	0.011 (0.28)	0.010 (0.254)
4 AWG	0.224 (5.7)	0.204 (5.2)	0.020 (0.508)	0.011 (0.28)	0.010 (0.254)
3 AWG	0.249 (6.3)	0.229 (5.8)	0.020 (0.508)	0.011 (0.28)	0.010 (0.254)
2 AWG	0.278 (7.1)	0.258 (6.6)	0.020 (0.508)	0.011 (0.28)	0.010 (0.254)
1 AWG	0.311 (7.9)	0.289 (7.3)	0.020 (0.508)	0.011 (0.28)	0.010 (0.254)
0 AWG	0.347 (8.8)	0.325 (8.3)	0.025 (0.635)	0.011 (0.28)	0.016 (0.406)
3/8"	0.399 (10.1)	0.375 (9.5)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)
7/16"	0.462 (11.7)	0.438 (11.1)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)
1/2"	0.524 (13.3)	0.500 (12.7)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)
5/8"	0.655 (16.7)	0.625 (15.9)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)
3/4"	0.786 (20.0)	0.750 (19.1)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)
7/8"	0.911 (23.2)	0.875 (22.2)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)
1"	1.036 (26.3)	1.000 (25.4)	0.025 (0.635)	0.017 (0.43)	0.016 (0.406)

Table 3-1continued next page

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Table 3-1 (continued)
INSIDE DIAMETER AND WALL THICKNESS*

Trade Size	Inside Diameter, Inch (mm)		Minimum Overall Wall Thickness Inch (mm)		
	Maximum	Minimum	Grade A	Grade B	Grade C
1-1/8"	1.161 (29.6)	1.125 (28.7)	0.030 (0.765)	0.020 (0.51)	0.019 (0.482)
1-1/4"	1.286 (32.8)	1.250 (31.9)	0.030 (0.765)	0.020 (0.51)	0.019 (0.482)
1-3/8"	1.411 (35-9)	1.375 (35.1)	0.030 (0.765)	0.020 (0.51)	0.019 (0.482)
1-1/2"	1.536 (39.2)	1.500 (38.3)	0.035 (0.893)	0.025 (0.64)	0.024 (0.610)
1-3/4"	1.786 (45.5)	1.750 (44.6)	0.035 (0.893)	0.025 (0.64)	0.024 (0.610)
2"	2.036 (51.9)	2.000 (51.0)	0.040 (1.020)	0.035 (0.893)	0.034 (0.864)
2-1/4"	2.330 (59.4)	2.250 (57.4)	0.040 (1.020)	0.035 (0.893)	0.034 (0.864)
2-1/2"	2.536 (64.7)	2.500 (63.8)	0.040 (1.020)	0.035 (0.893)	0.034 (0.864)
2-3/4"	2.850 (72.7)	2.750 (70.1)	0.040 (1.020)	0.035 (0.893)	0.034 (0.864)
3"	3.036 (77.4)	3.000 (76.5)	0.040 (1.020)	0.035 (0.893)	0.034 (0.864)
3-1/4"	3.330 (84.9)	3.250 (82.9)	0.045 (1.148)	0.040 (1.02)	0.039 (0.991)
3-1/2"	3.538 (90.2)	3.500 (89.3)	0.045 (1.148)	0.040 (1.02)	0.039 (0.991)
3-3/4"	3.850 (98.2)	3.750 (95.6)	0.045 (1.148)	0.040 (1.02)	0.039 (0.991)
4"	4.038 (103.0)	4.000 (102.0)	0.045 (1.148)	0.040 (1.02)	0.039 (0.991)

* Minimum and/or maximum values for wall thickness may be agreed upon between the purchaser and the supplier as long as the electrical and mechanical properties of the coated sleeving are not adversely affected.

3.2 LENGTH

Coated sleeving is normally supplied in coils or spools of continuous length or in 36 in. (0.91 m) lengths, depending on the size, as shown in Table 3-1, and varying according to the manufacturer.

The length of product in any coil or spool shall not be less than declared. The length of cut pieces shall conform to the tolerances shown in Table 3-2.

Table 3-2
TOLERANCE ON CUT LENGTHS

Length of Piece, in. (mm)	±Tolerance, in. (mm)
Up to 3 (76)	1/16 (1.6)
3 (76) up to 6 (152)	3/32 (2.4)
6 (152) up to 12 (305)	1/8 (3.2)
12 (305) to 36 (914)	± 1/2 (12.7)
Over 36 (914)	±1/2 (12.7)

3.3 SPLICES

Spools or coils shall not contain more splices than shown in Table 3-3. The splices shall be minimum in length and shall be conspicuously marked. They shall be of sufficient strength to withstand normal handling during fabrication processes.

Table 3-3
NUMBER OF ALLOWABLE SPLICES*

Ft. Spool**	# of Splices Maximum
50	2
100	3
150	3
250	4
500	7
1000	10
over 1000	†

*Cut pieces in lengths up to 20 ft., in any size, shall contain no splices.

**Splices in spools or coils shall be at least 20 ft. apart.

†For lengths over 1,000 ft. (300 m), or sizes over 1" (25 mm), the number of splices shall be as agreed upon by the purchaser and the supplier.

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Section 4
PERFORMANCE REQUIREMENTS

4.1 ELECTRICAL REQUIREMENTS

Coated sleeving shall meet the dielectric breakdown voltage requirements shown in Table 2-1.

4.2 NON-ELECTRICAL REQUIREMENTS

Coated sleeving shall meet the chemical, thermal, and mechanical requirements shown in Table 4-1.

4.3 COLORS

Colors shall be as agreed upon between the purchaser and the supplier.

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Table 4-1
CHEMICAL, THERMAL, AND MECHANICAL REQUIREMENTS

Property	Section	Types 1	2	3	4	5	6	7
Flammability—Vertical Burning Rate	5.7							
Burn rate, secs./in., min.		45	45	45	45	45	45	45
Flammability—Horizontal Flame Test	5.7							
Burn rate, in./min. (max) sizes 24-12		...	...	3	3	3	3	...
sizes 11 and larger		...	...	1.5	1.5	1.5	1.5	...
Ignition of cotton (all sizes)		...	...	none	none	none	none	...
Low Temperature Flexibility	5.7	no cracking of coating after 180° bend						
Oil Resistance	5.9							
Blistering of coating		none	none	...	none	...	...	...
Percent swelling of wall, max.		20	20	...	20	...	...	...
Compatibility with Insulated Wire	5.10							
softening of coating, liquefaction		...	none	...	none	none	none	none
% retention of dielectric breakdown voltage of twisted pairs, min.		...	50	...	50	50	50	50
Effect of Axial Compression (Push-Back	5.11							
Visual cracking		...	...	...	...	none	...	...
Dielectric breakdown voltage at distended area, kV, min. avg. (Grade A only)		...	...	...	...	5.0	...	...
Thermal Endurance	5.12							
Temperature index, min. (grades A and B only)		105	130	105	200	200	155	180
Flexibility after Heat Aging	5.13	no cracking of coating after 180° bend						

Note: Except where noted, requirements apply to all grades of sleeving

Section 5
METHODS OF TEST

5.1 PROCEDURES

Procedures for determining compliance with the various requirements of this standard shall be as described herein.

5.2 SAMPLING

For purposes of sampling, a lot shall consist of all coated sleeving of the same type, size, grade, and color offered for delivery at one time. A random sample shall be selected from the shipment according to Table 5-1.

Table 5-1
SAMPLING SCHEDULE

Lot size, ft. (m)	No. of samples
up to 200 (61.0)	1
200 (61.0) to 10,000 (3048)	2
over 10,000 (3048)	3

A sample normally consists of 24 ft. (8 m), which will permit complete testing as described herein, with the exception of the thermal endurance test. This latter test, applicable to all types of coated sleeving, is intended to be conducted only once in order to establish type qualification, and will require an additional minimum amount of 55 ft. (17 m) of size 12 coated sleeving.

5.3 CONDITIONING

Unless otherwise specified, all tests shall be conducted at 23°C ±2°C and 50 ±5 percent relative humidity on sleeving maintained at these conditions for at least 48 hours. Humidity tests shall be conducted on specimens conditioned for 96 hours at 23°C ±2°C and 93 ±3 percent relative humidity. Tests on specimens conditioned under humidity shall be conducted within 1 min. after removal from the conditioning atmosphere.

5.4 OVENS

Conditioning and aging requiring ovens operating at elevated temperature shall be conducted in forced ventilation ovens meeting the requirements of ASTM D 2436.

Gravity-convection ovens have not been found suitable for tests in accordance with this Standards publication.

5.5 DIMENSIONAL MEASUREMENTS

5.5.1 Apparatus and Materials

5.5.1.1 GAUGE RODS

A maximum and minimum rod are required for each size of coated sleeving. Rust resistant metal rods with smooth surfaces and rounded ends shall be used. Each rod shall have the diameter shown in Table 3-1 for maximum or minimum value within a tolerance of ±0.0002 in. (±.012 mm).

5.5.1.2 MICROMETER

A dial-type, dead-weight pin micrometer having a flat presser foot of rectangular cross-section 0.043 in. (1.09 mm) wide by 0.312 in. (7.92 mm) long and having a 0.043 in. (1.09 mm) diameter pin 0.437 in. (11.1 mm) long as an anvil shall be used. The presser foot shall be positioned so as to rest on the anvil with its long axis parallel to the long axis of the anvil. The presser foot shall exert a force of 25 ±2 g on the anvil.

5.5.1.3 PROCEDURE

5.5.1.3.1 Inside Diameter Measurement

Insert the minimum-size gauge rod into the coated sleeving for a distance of 5 in. (125 mm). If the rod fits snugly without expanding the coated sleeving, the specimen shall be considered as having an inside diameter equal to the diameter of the rod. If the rod fits loosely, then the maximum-size rod shall be inserted similarly into the coated sleeving. If this rod fits snugly or expands the coated sleeving, then the specimen shall be considered as being within the limits of inside diameter specified in Table 3-1.

5.5.1.3.2 Wall Thickness Measurement

Insert the test specimen on the pin-anvil of the micrometer and bring the presser foot to rest gently on the specimen, reading the indicated thickness immediately. Rotate the specimen on the anvil a sufficient number of times between successive measurements to determine the actual minimum wall thickness.

5.5.1.3.3 Report

The report shall include the following.

a. Identification of the coated sleeving
b. Size of the coated sleeving as determined from Table 3-1
c. Minimum wall thickness in millimeters

5.6 DIELECTRIC BREAKDOWN VOLTAGE

5.6.1 Apparatus and Materials

Dielectric breakdown voltage tests shall be conducted using equipment described in ASTM D 149. Voltage shall be increased from zero to breakdown at a uniform rate of 500 v/s. Outer electrodes shall be soft metal foil, 0.001 in. (0.03 mm) thick and 1 in. (25.4 mm) wide, snugly applied around the outer surface of the coated sleeving. Inner electrodes shall consist of metal rods of nominal diameter for the size tested that do not expand

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the coated sleeving. Outer foil electrodes shall be spaced sufficiently distant from the ends of the specimen so as to avoid flashover.

5.6.2 Test Specimens

Prepare specimens by mounting 4 in. (100 mm) lengths of coated sleeving on a metal rod of nominal size and of such length as to provide a short length of bare metal rod at one end for making electrode connections to ground.

5.6.2.1 PROCEDURE A—STANDARD CONDITIONING

Condition ten specimens for 48 hrs. at 23° ±2°C and 50 ±5 percent relative humidity. Apply foil electrodes centrally on the specimens and measure the dielectric breakdown voltage. Calculate the average breakdown voltage for the ten specimens.

5.6.2.2 PROCEDURE B—HIGH-HUMIDITY CONDITIONING

Condition ten specimens in a suitable chamber providing an atmosphere of 93 ±3 percent relative humidity at 23°C ±2°C. After a period of 96 hr, remove the specimens, mount on a metal rod of nominal size for the coated sleeving tested, apply foil electrodes centrally on the specimens and immediately measure the dielectric breakdown voltage. Calculate the average dielectric breakdown voltage for the ten specimens.

A saturated solution of reagent-grade potassium sulfate in distilled water has been found useful in maintaining an atmosphere of 93 percent relative humidity over the range 20°C to 40°C.

5.6.2.3 PROCEDURE C—ELEVATED TEMPERATURE CONDITIONING

Condition ten specimens in an oven (see 5.4 herein) maintained at a temperature of 50°C ±3°C over the nominal temperature index of the sleeving. After a period of 96 hrs., remove the specimens and allow to cool to room temperature. Mount the specimens on rods of nominal size for the coated sleeving and apply foil electrodes centrally on the specimens and measure the dielectric breakdown voltage. Calculate the average dielectric breakdown voltage for the ten specimens.

5.6.3 Report

The report shall include the following.

a. Identification of the coated sleeving
b. Type of conditioning of the specimens
c. Minimum individual and average dielectric breakdown voltages for the specimens, kV

5.7 FLAMMABILITY

5.7.1 Apparatus and Materials

5.7.1.1 SHEET-METAL TEST CHAMBER

A three-walled sheet-metal enclosure, 24 in. (600 mm) wide by 12 in. (300 mm) deep by 12 in. (300 mm) high, open at the top and front shall be used. It shall be equipped with a solid metal specimen-holder rod 27 in. (690 mm) long mounted horizontally in the center of the enclosure. The rod shall be supported at two points 22 in. (560 mm) apart. Three metal index rods shall be mounted independently of the specimen-holder rod and in such manner that their longitudinal axes are coplanar and at right angles to the axis of the specimen-holder rod, with their free ends not closer than 0.75 in. (19 mm) to the mounted specimen surfaces. The index rods shall be spaced from the left-hand support of the mounted specimen at 2 in. (51 mm), 7 in. (178 mm) and 13 in. (330 mm), respectively. (See Figure 5-1.)

5.7.1.2 SPECIMEN-HOLDER RODS

Bare metal rods having diameters that will provide snug fits within the coated sleeving specimens to be tested shall be used.

5.7.1.3 BURNER

A Tirrel-type gas burner with a 3/4 in. (8.5 mm) barrel diameter and an approximately 4 in. (100 mm) barrel length above the air inlet ports, and mounted so as to apply the flame beneath the specimen in a vertical manner shall be used.

5.7.1.4 GAS SUPPLY

Natural gas or methane shall be used.

5.7.1.5 TIMEPIECE

Graduated to 0.2 seconds shall be used.

5.7.1.6 COTTON

Surgical, untreated, about 0.25 in. to 1.0 in. (6 to 25 mm) thick shall be used.

5.7.2 Procedure A—Vertical Burning Rate (Candle Test)

Prepare three specimens of coated sleeving, each 4 in. (100 mm) long. Mark off a gauge length of 1 in. (25 mm) on each specimen. Close the other end of the specimen to prevent passage of air through the coated sleeving during the test.

Insert the end having the gauge marks inscribed into the flame of a gas burner to a distance of about 0.25 in. (6 mm) above the top of the burner. Rotate a coated sleeving specimen in the flame so as to ignite it uniformly around its circumference.

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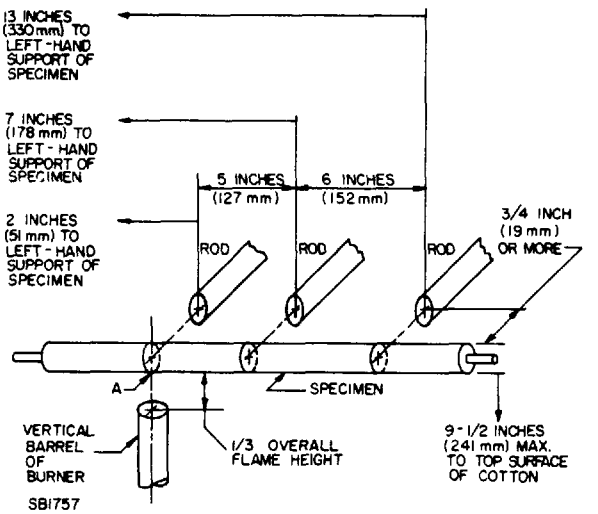

Source: UL 1441-81 Standard

Figure 5-1
SCHEMATIC ARRANGEMENT FOR HORIZONTAL FLAME TEST

Remove the specimen from the flame and position it vertically, flaming end uppermost, in still air. When the leading edge of the flame reaches the upper gauge mark, activate a timepiece. Note the time in seconds for the flame to travel down the specimen to the lower gauge mark.

5.7.2.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Time to burn between gauge marks for each specimen, seconds
c. Evidence of self-extinguishing (flame does not reach upper gauge mark)

5.7.3 Procedure B—Horizontal Flame Test

Prepare three specimens of coated sleeving as described below.

Mount a 24 in. (600 mm) length of coated sleeving on a specimen-holder rod of the same nominal size as the coated sleeving, and position centrally on the rod. Place the mounted specimen centrally on the support rod in the test chamber. Cover the area below the specimen with cotton so that the vertical distance from the cotton to the specimen surface does not exceed 9.5 in. (241 mm).

Ignite the gas burner and adjust the flame so that the overall height of the flame is about 2 in. (51 mm), with an inner blue cone of about one-third the overall flame height. Position the burner vertically below the specimen so that the tip of the inner cone impinges on the surface of the specimen at the first index point (2 in. from the left support).

Apply the flame to the specimen for 30 sec. and remove. Note if the flame progresses along the specimen beyond the second index point (7 in. from the left support). If flaming of the specimen passes this index point, the amount of time that the specimen flame takes to progress to the 13 in. index point is noted and divided by the total length of specimen burned between the 7 in. and 13 in. index points. Record whether any particles, drops, or both, are emitted by the specimen during or after application of the burner flame. Evidence of burning of the cotton is also to be noted. Flameless charring of the cotton is to be ignored.

5.7.3.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Rate of flame travel from 7 in. to 13 in. index points in in./min. (mm/min.) for each specimen
c. Evidence of particles or drops emitted during burning
d. Evidence of ignition of the cotton

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5.8 LOW-TEMPERATURE FLEXIBILITY

5.8.1 Apparatus

5.8.1.1 COLD CHAMBER

An enclosure capable of maintaining a temperature of minus 10.0°C±2.0°C (14.0°F ±3.6°F.) shall be used.

5.8.1.2 MANDRELS

Metal rods of diameter as shown in Table 5-2 shall be used.

5.8.2 Test Specimens

Three specimens of coated sleeving 10 in. (250 mm) long shall be used.

5.8.3 Procedure

Condition the test specimens (without a conductor), together with the corresponding mandrel for the size of the specimens as selected from Table 5-2 in the cold chamber for 1 hr at -10.0°C. At the end of this period, and without removing the specimens or mandrel from the chamber, wind the specimens around the mandrel at a rate of about 3 sec per turn for the number of turns indicated in Table 5-2 for that size. Successive turns of the sleeving shall be in contact with one another.

While the specimens are held tightly in place on the mandrel, remove the specimens and mandrel from the chamber and immediately examine the specimens with the unaided eye for evidence of cracks.

Internal cracks at the coating-braid interface can often be detected by corresponding depressions on the outer surface of the coated sleeving.

5.8.3.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Size of coated sleeving
c. Diameter of the mandrel (for sizes 3/4 in. and larger)
d. Evidence of cracks on the outer or inner coated sleeving surface

5.9 OIL RESISTANCE

5.9.1 Test Specimens

Prepare three specimens of sleeving, each 3 in. (76 mm) long.

5.9.2 Procedure

Determine the average wall thickness of each specimen by inserting the specimen on the pin-anvil of the micrometer (see 5.5) and bringing the presser foot to rest gently on the specimen, reading the indicated thickness immediately. Rotate the specimen through 120 angular degrees and re-measure the wall thickness. Repeat to obtain three readings and compute the average wall thickness.

Table 5-2
MANDRELS FOR LOW-TEMPERATURE FLEXIBILITY TEST

Size	Maximum Acceptable Mandrel Diameter in. (mm)	Number of Complete Turns Around Mandrel
24	0.126 (3.20)	6
22	0.141 (3.58)	6
20	0.172 (4.37)	6
19	0.188 (4.78)	6
18	0.203 (5.16)	6
17	0.219 (5.56)	6
16	0.234 (5.94)	6
15	0.250 (6.35)	6
14	0.313 (7.95)	6
13	0.344 (8.74)	6
12	0.375 (9.53)	6
11	0.469 (11.9)	6
10	0.563 (14.3)	6
9	0.625 (15.9)	6
8	0.688 (17.5)	6
7	0.969 (24.6)	6
6	1.250 (31.8)	6
5	1.313 (33.4)	6
4	1.375 (34.9)	6
3	1.469 (37.3)	6
2	1.563 (39.7)	6
1	2.688 (68.3)	6
0	2.875 (73.0)	6
3/8"	3.375 (85.7)	6
7/16	3.391 (86.1)	6
1/2"	3.438 (87.3)	1/2
5/8"	3.547 (90.1)	1/2
3/4"	6	1/2
7/8"	7	1/2
1-4"	10	1/2

Immerse the specimens for a period of 24 hr in ASTM No. 2 oil (D 471) maintained at 105°C ±2°C. At the end of this period, remove the specimens, wipe off excess oil gently without disturbing the coated sleeving surface, and allow to cool to room temperature.

Examine the specimen for evidence of blistering, splitting or flaking of the coating. Determine the extent of swelling of the coated sleeving by measuring the wall thickness, calculating the average thickness for each

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specimen, and expressing any change as a percentage of the untreated average wall thickness for that specimen.

5.9.2.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Visual examination of the coating for each specimen after exposure to the oil
c. Average percentage change in wall thickness for the three specimens

5.10 COMPATIBILITY WITH INSULATED WIRE

5.10.1 Apparatus and Materials

5.10.1.1 GLASS CONTAINERS

Sealable and capable of withstanding internal pressure at elevated temperatures shall be used. Tubes and bottles shall be thoroughly washed in detergent solution, rinsed, and washed out with distilled water and allowed to dry without wiping.

Type T glass tubes (aerosol) and round-bottom polymerization flasks have been found to be satisfactory for this test.

5.10.1.2 GASKETS

Conformable, non-reactive materials, such as silicone rubber, capable of performing as seals at the temperatures observed in this test shall be used.

5.10.1.3 COPPER WIRE

Film-insulated (heavy enamelled), size AWG 18 shall be used. The type of film insulation shall be selected to meet the design requirements for this test.

5.10.2 Test Specimens

5.10.2.1 COATED SLEEVING

Specimens shall be 6 in. (150 mm) lengths of coated sleeving in full section for sizes up to 5, and in rectangular strips 0.25 in. (6.3 mm) wide and 1.5 in. (38 mm) long for sizes larger that 5. The number of specimens shall be such as to provide a surface ratio of coated sleeving to wire approximately equivalent to that expected to the service application.

5.10.2.2 TWISTED-WIRE PAIRS

Prepare 40 twisted-wire pairs about 6 in. (150 mm) long in accordance with the procedure described in ASTM D 1676-83. Proof test each pair for 5 seconds at a voltage equal to 75 percent of its previously determined average breakdown voltage, discarding all pairs that fail to meet this test.

5.10.3 Procedure

Select a test temperature that is 25°C ±3°C higher than the intended service use of the sleeving (usually corresponding to the nominal temperature index of the coated sleeving).

Place five wire pairs selected at random in each of eight test tubes. Place one specimen of coated sleeving each in four of the tubes. Insert the tubes containing coated sleeving and wire pairs in an oven at the selected test temperature for 2 hr to remove moisture. After this conditioning, remove the tubes from the oven and immediately seal.

Place four tubes containing wire pairs and coated sleeving, and four tubes containing wire pair controls only in an oven at the selected test temperature.

After 72 hours, remove all tubes from the oven, cool to room temperature and carefully remove the wire pairs and measure their dielectric breakdown voltage. Calculate the average dielectric breakdown voltage of both the test pairs and the control pairs.

If the average breakdown voltage for the control pairs is less than 50 percent of the value for the unaged pairs, it is likely that the temperature of test selected was too high for that wire insulation type, and the test should be repeated at a lower temperature.

5.10.3.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Type of insulation on the wire
c. Test temperature, °C
d. Percentage retention of breakdown voltage for the test airs with coated sleeving, based on the value for the wire controls
e. Evidence of condensate on the container walls

5.11 EFFECT OF AXIAL COMPRESSION (PUSH-BACK)

5.11.1 Test Specimens

Prepare three lengths of Type 5 coated sleeving, 4 in. (100 mm) long for sizes up to 0, and 5 in. (125 mm) long for sizes 0 and larger.

5.11.2 Procedure

Condition specimens in an oven maintained at 250°C ±3°C (482°F ±5.4°F) for a period of 168 hrs. Remove the specimens and allow to cool at room temperature for 0.5 hr. At the end of the re-conditioning period, insert a straight metal rod of nominal size into the coated sleeving and slowly push the ends of the coated sleeving together on the rod until the length of the coated sleeving has been reduced by 20 percent.

Examine the coated sleeving in the push-back condition for evidence of cracking at the distended area. Allow the specimen to relax on the rod, apply a 1 in. (25 mm) wide foil electrode snugly over the distended area and measure the dielectric breakdown voltage. Calculate the

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average dielectric breakdown voltage for the three specimens.

5.11.2.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Visual evidence of cracks at the distended area
c. Average dielectric breakdown voltage at the distended area, kV

5.12 THERMAL ENDURANCE

5.12.1 Test Specimens

Specimens shall consist of 4 in. (100 mm) lengths of Size 12 coated sleeving, randomized with respect to position in the larger sample and mounted on clean, bare copper wire that provides a snug fit of the coated sleeving without distortion.

The wire used in mounting the specimens shall be about 5 in. (130 mm) in length and formed into a hook at one end to facilitate hanging the specimen vertically during oven aging, and a means provided at the other end to restrain the coated sleeving during aging.

Prepare at least 50 specimens for each oven exposure temperature anticipated, in addition to 10 specimens for the initial (unaged) dielectric breakdown voltage test.

5.12.2 Proof-Testing Specimens

Condition 10 specimens for 48 hrs. at the lowest aging temperature to be observed. Allow the specimens to cool to room temperature and immediately measure the dielectric breakdown voltage using a foil outer electrode 1 in. (25 mm) wide applied centrally on the coated sleeving. Calculate the average of the 10 readings and record this as the initial (unaged) dielectric breakdown voltage. Subject all specimens to be tested to a 5-second proof voltage equal to 75 percent of the average dielectric breakdown voltage, discarding all specimens that fail to meet this test.

5.12.3 Selection of Exposure Temperatures and Periods

Choose three or more exposure temperatures in accordance with IEEE Standard 98.

5.12.4 Procedure

Insert a group of 50 specimens in each aging oven, making certain that specimens do not touch each other and are freely exposed.

At the end of each prescribed exposure period remove 5 specimens selected at random and allow to cool to room temperature. Carefully wrap a length of 1 in. (25 mm) foil centrally around the specimen and determine the dielectric breakdown voltage using the procedure described under 5.6 herein. Continue this procedure until the computed average dielectric breakdown voltage for the sets falls below a value 50% of the initial (unaged) dielectric breakdown voltage.

If after several exposure periods it is evident that the 50 percent endpoint will not be attainable before completion of the ten exposure period or the exhaustion of the specimens, the duration of the remaining periods may be increased by an amount judged to be necessary to complete the test.

5.12.5 Construction of Thermal Life Curves

Plot the average dielectric breakdown voltage for each set against the exposure time for that set and construct a smooth curve through the points. From these curves thus obtained, determine the life in hours corresponding retention of 50% of initial (unaged) dielectric breakdown voltage.

It is convenient to use semi-logarithmic coordinates for this plot, with the logarithmic of time as the abscissa.

5.12.6 Determination of the Temperature Index

Plot the logarithm of the thermal life for each exposure temperature against the reciprocal of the exposure temperature in kelvins. Determine the best-fitting straight line through the plotted points using the method of linear regression, together with the unilateral 95 percent lower confidence limit of the mean time using the procedure described in IEEE 101. Extrapolate these lines to the 20,000-hours ordinate to give the corresponding temperature indices.

5.12.6.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Average initial dielectric breakdown voltage, kV
c. Thermal life curves for each exposure temperature
d. Thermal endurance plot (Arrhenius chart)
e. Temperature index at 20,000 hr
f. Value of temperature index corresponding to the lower 95 percent confidence limit at the 20,000-hour point

5.13 FLEXIBILITY AFTER HEAT AGING

5.13.1 Apparatus and Materials

5.13.1.1 MANDRELS

Smooth, bare metal rods, about 6 in. (150 mm) long, having diameters as shown in Table 5-3 shall be used.

5.13.2 Procedure

Prepare three specimens of coated sleeving each about 6 in. (150 mm) long. Place specimens in an oven at 20°C over the nominal temperature class of the sleeving (see 2.1). After 96 hr, remove the specimens and allow to

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condition for 1 hr. at 23°C±2°C and 50 ±5 percent relative humidity.

Table 5-3
MANDRELS FOR FLEXIBILITY AFTER HEAT AGING TEST

Size of Sleeving, in.	Mandrel diameter, in. (mm)
24 through 6	1/4 (6.4)
5 through 0	5/16 (8.0)
3/8 through 5/8	3/8 (9.5)
3/4 through 1	7/16 (11.1)
> 1	1-1/2 (38.1)

Bend specimens slowly (taking about 5 sec.) through 180 angular degrees around the mandrel specified for the size of the sleeving (refer to Table 5-3). Note any cracking across the flat portion of the bent specimen, disregarding any edge cracking.

5.13.2.1 REPORT

The report shall include the following.

a. Identification of the coated sleeving
b. Temperature of aging, °C
c. Evidence of cracking after bending

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The purpose of NEMA standards, their classification, and status are set forth in certain clauses of the NEMA *Standardization Policies and Procedures* manual and are referenced below:

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National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for their particular needs. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process, or procedure with reference to one or more of the following: nomenclature, composition, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Standardization Policies and Procedures, p. 1)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the Standards Publication may be capable of otherwise equivalent performance.

(Standardization Policies and Procedures, p. 6)

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3. Adoptive Standard, which is adopted in whole or in part from the standards of another organization, either domestic, regional, or international.

(Standardization Policies and Procedures, pp. 5)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design, which standard has received the affirmative vote of at least two-thirds of the Subdivision votes cast in the affirmative or negative.

(Standardization Policies and Procedures, pp. 5)

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Standards in NEMA Standards Publications are identified as "NEMA Standard," "Suggested Standard for Future Design," or "Adoptive Standard." These indicate the status of the standard. A statement incorporating the auxiliary verb "shall" indicates that compliance with a requirement is mandatory for compliance with the standard. These classes of standards are identified in the foreword or throughout the text.

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