



Designation: D 1051 – 95 (Reapproved 2000)

## Standard Specification for Rubber Insulating Sleeves<sup>1</sup>

This standard is issued under the fixed designation D 1051; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

### 1. Scope

1.1 This specification covers acceptance testing of rubber insulating sleeves for protection of workers from electrical shock.

1.2 Two types of sleeves are provided and are designated as Type I, nonresistant to ozone, and Type II, resistant to ozone.

1.3 Five classes of sleeves, differing in electrical characteristics, are provided and are designated as Class 0, Class 1, Class 2, Class 3, and Class 4.

1.4 Two styles of sleeves, differing in configuration, are provided and are designated as Style A, straight taper, and Style B, curved elbow.

1.5 All type I sleeves may be provided with or without a surface halogenation treatment.

1.6 The following safety hazards caveat pertains only to the test methods portion, Sections 16-19, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.* Specific safety hazards statements are given in 18.2.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

D 149 Test Method for Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies<sup>2</sup>

D 297 Test Methods for Rubber Products—Chemical Analysis<sup>3</sup>

D 412 Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension<sup>3</sup>

D 518 Test Method for Rubber Deterioration—Surface Cracking<sup>3</sup>

D 570 Test Method for Water Absorption of Plastics<sup>4</sup>

D 573 Test Method for Rubber—Deterioration in an Air Oven<sup>3</sup>

D 624 Test Method for Tear Strength of Conventional Vulcanized Rubber and Thermoplastic Elastomers<sup>3</sup>

D 1149 Test Method for Rubber Deterioration—Surface Ozone Cracking in a Chamber<sup>3</sup>

D 1415 Test Method for Rubber Property—International Hardness<sup>3</sup>

D 2240 Test Method for Rubber Property—Durometer Hardness<sup>3</sup>

F 819 Definitions of Terms Relating to Electrical Protective Equipment for Workers<sup>5</sup>

F 1236 Guide for Visual Inspection of Electrical Protection Rubber Products<sup>5</sup>

#### 2.2 ANSI Standard:

C84.1 Voltage Ratings for Electric Power Systems and Equipment<sup>6</sup>

### 3. Terminology

#### 3.1 Definitions of Terms Specific to This Standard:

3.1.1 *color splash*—a splash, smear or streak of contrasting color evident on the inside or outside of the sleeves that was deposited during the dripping operation and is vulcanized into the sleeve as part of the homogeneous compound.

3.1.2 *halogenation treatment*—exposure of the entire sleeve surface area to a halogen for the purpose of reducing surface friction.

3.1.3 *user*—the employer or entity purchasing the equipment to be utilized by workers for their protection; in the absence of such an employer or entity, the individual purchasing and utilizing the protective equipment.

3.1.4 *voltage, maximum use*—the a-c voltage (rms) rating of the protective equipment that designates the maximum nominal design voltage of the energized system that may be safely worked. The nominal design voltage is equal to the phase to phase voltage on multiphase circuits.

3.1.4.1 If there is no multiphase exposure in a system area and the voltage exposure is limited to phase (polarity on d-c systems) to ground potential, the phase (polarity on d-c systems) to ground potential shall be considered to be the nominal design voltage. If electrical equipment and devices are insulated, or isolated or both, such that the multiphase exposure on a grounded wye circuit is removed, then the nominal design

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee F18 on Electrical Protective Equipment for Workers and is the direct responsibility of Subcommittee F18.15 on Worker Personal Equipment. This standard replaces ANSI Standard J6.5, which is no longer available.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 10.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 09.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>5</sup> *Annual Book of ASTM Standards*, Vol 10.03.

<sup>6</sup> Available from American National Standards Institute, Inc., 11 West 42nd Street, 13th Floor, New York, NY 10036.

voltage may be considered as the phase-to-ground voltage on that circuit.

3.1.5 *voltage, nominal design*—a nominal value consistent with the latest revision on ANSI C84.1, assigned to the circuit or system for the purpose of conveniently designating its voltage class.

**4. Significance and Use**

4.1 This specification covers the minimum electrical, chemical, and physical properties guaranteed by the manufacturer and the detailed procedures by which such properties are to be determined. The purchaser at his option may perform or have performed any of these tests in order to verify the guarantee. Claims for failure to meet the specification are subject to verification by the manufacturer.

4.2 Sleeves are used for personal protection; therefore, when authorizing their use, a margin of safety shall be allowed between the maximum voltage on which they are used and the proof-test voltage at which they are tested. The relationship between proof-test voltage and the maximum voltage at which the sleeves shall be used is shown in Table 1.

4.3 Work practices vary from user to user, dependent upon many factors. These may include but are not limited to, operating system voltages, construction design, work procedure techniques, weather conditions, etc. Therefore, except for the restrictions set forth in this specification because of design limitations, the use and maintenance of this equipment is beyond the scope of this specification.

4.4 It is common practice and the responsibility of the user of this type of protective equipment to prepare complete instructions and regulations to govern the correct and safe use of such equipment.

**5. Classification**

5.1 Sleeves covered under this specification shall be designated as Type I or Type II; Class 0, Class 1, Class 2, Class 3, and Class 4; and Style A or Style B.

5.1.1 *Type I*, nonresistant to ozone, made from a high-grade *cis*-1,4-polyisoprene rubber compound of natural or synthetic origin, properly vulcanized.

5.1.2 *Type II*, resistant to ozone, made of any elastomer or combination of elastomeric compounds.

5.1.3 The class designation shall be based on the electrical properties as shown in Table 1.

5.1.4 *Style A*, straight taper design.

5.1.5 *Style B*, curved elbow design.

**TABLE 1 Proof Test/Use Voltage Relationship**

Class of Sleeve	A-C Proof-Test Voltage rms V	D-C Proof-Test Voltage avg, V	Maximum Use Voltage <sup>A</sup> a-c (rms), V
0	5 000	20 000	1 000
1	10 000	40 000	7 500
2	20 000	50 000	17 000
3	30 000	60 000	26 500
4	40 000	70 000	36 000

<sup>A</sup>Except for Class 0 sleeves, the maximum use voltage is based on the following formula:

Maximum use voltage (maximum nominal design voltage) = 0.95 a-c proof-test voltage – 2000 V

**6. Ordering Information**

6.1 Orders for sleeves under this specification should include the following information:

- 6.1.1 Type,
- 6.1.2 Class,
- 6.1.3 Style,
- 6.1.4 Size,
- 6.1.5 Color, and
- 6.1.6 With or without halogenation treatment.

6.2 The listing of types, classes, styles, sizes, and colors is not intended to mean that all shall necessarily be available from manufacturers; it signifies only that, if made, they shall conform to the details of this specification.

**7. Manufacture and Marking**

7.1 The sleeves shall be produced by a seamless process.

7.2 Sleeves shall have a smooth finish and self-reinforced edges.

7.3 The holes provided in sleeves for the purposes of strap or harness attachments shall have non-metallic reinforced edges and shall be nominally 8 mm (5/16 in.) in diameter.

7.4 Each sleeve shall be marked clearly and permanently with the name of the manufacturer or supplier, ASTM D1051, type, class, size, and right or left. All such marking shall be confined to the shoulder flap area and shall be nonconducting and applied in such a manner as to not impair the required properties of the sleeves.

7.4.1 A label shall be used to identify the voltage class: Class 0—red, Class 1—white, Class 2—yellow, Class 3—green, and Class 4—orange. The other required information may be placed on the label or molded directly into the sleeve.

7.4.2 To minimize problems of marking and identification, the following standard abbreviations may be used: Regular (Rg), Large (Lg), Extra Large (XLg), and Class 1 (1), Class 2 (2), etc. Right or left shall not be abbreviated.

7.4.3 At the request of the user, the sleeves may be given a halogenation treatment to reduce surface friction. This treatment shall have no detrimental effect upon the electrical, chemical or physical properties of the sleeves.

**8. Chemical and Physical Requirements**

8.1 The sleeve material shall conform to the physical requirements in Table 2, the accelerated aging in 19.2.5, and, for Type I sleeves, the determination of rubber polymer in accordance with 19.1.1.

**9. Electrical Requirements**

9.1 Each sleeve shall be given a proof test and shall

**TABLE 2 Physical Requirements**

Property	Type I	Type II
Tensile strength, min, Die C, MPa (psi)	17.2 (2500)	10.3 (1500)
Tensile stress at 200 %, max, MPa (psi)	2.1 (300)	2.1 (300)
Ultimate elongation, min, %	600	500
Tension set, max at 400 %, %	25	25
Tear resistance, min, kN/m (lbf/in.)	21 (120)	14 (80)
Puncture resistance, min, kN/m (lbf/in.)	18 (100)	18 (100)
Hardness, Shore A, max	47	47
Moisture absorption, max, %	1.5	1.5

withstand the 60-Hz a-c proof-test voltage (rms value) or the d-c proof-test voltage (average value) specified in Table 1. The proof test shall be performed in accordance with Section 18. The voltage shall be applied continuously for 3 min.

9.2 The sleeve material, when tested between 50-mm (2-in.) disk electrodes with edges rounded to a radius of 6 mm (0.25 in.), shall show a 60-Hz dielectric strength of not less than 14.8 MV/m (375 V rms/mil) of specimen thickness for each individual test.

9.3 The Type II sleeve material shall show no visible effects from ozone when tested in accordance with 18.7. Any visible signs of ozone deterioration of the sleeve material such as checking, cracking, breaks, pitting, etc., shall be considered as evidence of failure to meet the requirements of Type II sleeves. In case of dispute, Method A of the ozone resistance test shall be the referee test.

**10. Dimensions and Permissible Variations**

10.1 The thicknesses shall fall within the limits specified in Table 3 when measured in accordance with 17.1.

10.2 The dimensions for each style and size shall fall within the limits specified in Table 4 when measured in accordance with 17.2 in conjunction with Fig. 1 and Fig. 2. Variations in sleeve length and wrist dimensions are acceptable when required to meet special physical requirements.

10.2.1 The taper of sleeves should be uniform as this is significant because of the advent of dry-form electrical testing.

**11. Workmanship and Finish**

11.1 Sleeves shall be free on both inner and outer surface of harmful physical irregularities that can be detected by thorough test and inspection.

11.1.1 Harmful physical irregularities may be defined as any feature that disrupts the uniform, smooth surface contour and represents a potential hazard to the user, such as pinholes, cracks, blisters, cuts, conductive imbedded foreign matter, creases, pinch marks, voids (entrapped air), prominent ripples, and prominent mold marks.

11.2 Nonharmful physical irregularities may be defined as surface irregularities present on the inner and outer surfaces of the rubber sleeve due to imperfections on forms or molds and inherent difficulties in the manufacturing process. These irregularities may appear as mold marks that look like cuts even though they are actually a raised ridge of rubber, indentations, protuberances, or imbedded foreign material that are acceptable provided that:

11.2.1 The indentations, protuberance or mold marks tend to blend into a smooth slope upon stretching of the material.

11.2.2 The rubber thickness at any irregularity conforms to the thickness requirements.

11.2.3 Foreign material remains in place when the sleeve is folded and stretched with the material surrounding it.

11.2.4 Color splashes are no longer than 3 mm in any direction on a surface of the sleeve.

**12. Guarantee**

12.1 The manufacturer or supplier shall replace, without charge to the purchaser, unused sleeves which, at any time within a period of 9 months from date of initial delivery of shipment to the purchaser or designee, fail to pass the tests in this specification. This guarantee will be binding on the manufacturer or supplier only if the sleeves have been properly stored and have not been subjected to more than an original acceptance test and one retest.

12.2 Any acceptance test made by the purchaser’s designee, shall be performed within the first 2 months of the guarantee period unless otherwise specified.

NOTE 1—Proper storage means that sleeves are stored right side out, not distorted and not stored directly above or in proximity to steam pipes, radiators, or other sources of artificial heat, or exposed to direct sunlight or other sources of ozone. It is desirable that the ambient storage temperature shall not exceed 35°C (95°F).

**13. Sampling**

13.1 Each sleeve in a lot or shipment shall be subject to inspection and test to meet the requirements of Sections 7, 10, 11, 15, and 9.1.

13.2 An original sample of 1 % of the lot or shipment or not less than two sleeves, whichever is greater, shall be selected at random from the lot or shipment for the test requirements of Sections 8, 9.2 and 9.3. Where a failure occurs in the first sample, a second sample of the same quantity shall be selected and tested.

**14. Rejection**

14.1 Individual sleeves shall be rejected if they fail to meet requirements of Sections 7 and 11, 9.1 and the minimum requirement of 10.1.

14.2 Individual sleeves may be rejected at the option of the purchaser if they fail to meet the requirements of Sections 15 and 10.2.

14.3 The entire lot or shipment of sleeves shall be rejected under any of the following conditions:

14.3.1 If 5 % or more, but not less than two sleeves, in a lot or shipment fail to meet the requirements of 9.1.

14.3.2 If two dielectric breakdowns that do not meet the requirements of 9.2 occur in the sample.

14.3.3 If one dielectric breakdown in the original sample and one or more dielectric breakdowns in the second sample fail to meet the requirements of 9.2.

14.3.4 If the sample of Type II sleeves using the sampling methods of 13.2 fails to meet the requirements of 9.3.

14.4 The testing shall be terminated and the manufacturer or supplier notified if, during the course of testing, the sleeves in a lot or shipment fail to meet the requirements of 9.1, 9.2, or 9.3, as determined by the rejection criteria of 14.3.1, 14.3.2, 14.3.3, or 14.3.4. The manufacturer or supplier may in such a case require the purchaser to submit proof that the test procedure and equipment conform to the appropriate paragraphs of Section 18. When such proof has been furnished, the

**TABLE 3 Thickness**

Class of Sleeve	Minimum		Maximum	
	mm	in.	mm	in.
0	0.51	0.020	1.02	0.040
1	0.76	0.030	1.52	0.060
2	1.27	0.050	2.54	0.100
3	1.90	0.075	2.92	0.115
4	2.54	0.100	3.56	0.140

TABLE 4 Dimensions and Tolerances

Style	Size	Dimensions <sup>A</sup>							
		A		B		C		D	
		mm	in.	mm	in.	mm	in.	mm	in.
Straight taper (Fig. 1)	regular	667	26¼	394	15½	286	11¼	140	5½
	large	724	28½	432	17	327	12⅞	175	6⅞
	extra large	762	30	483	19	337	13¼	175	6⅞
Curved elbow (Fig. 2)	regular	673	26½	394	15½	311	12¼	146	5¼
	large	705	27¾	406	16	327	12⅞	175	6⅞
	extra large	749	29½	445	17½	327	12⅞	178	7

<sup>A</sup>Tolerances shall be as follows:  
 A—±13 mm (±½ in.)  
 B—Minimum allowable length  
 C—±13 mm (±½ in.)  
 D—±6 mm (±¼ in.)

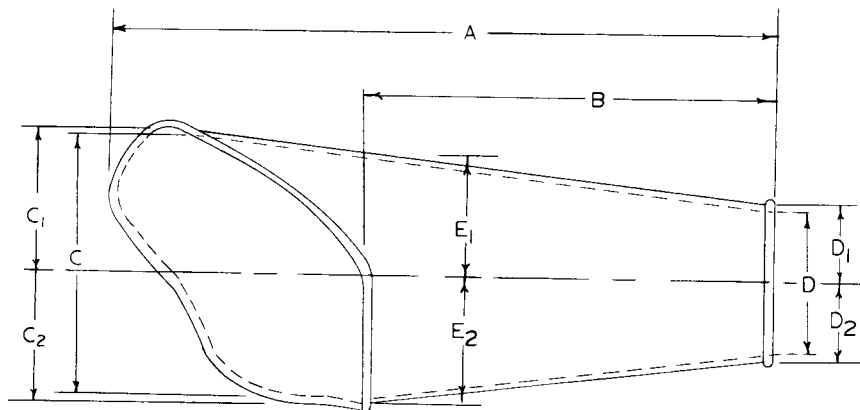


FIG. 1 Style A, Straight Taper Sleeve

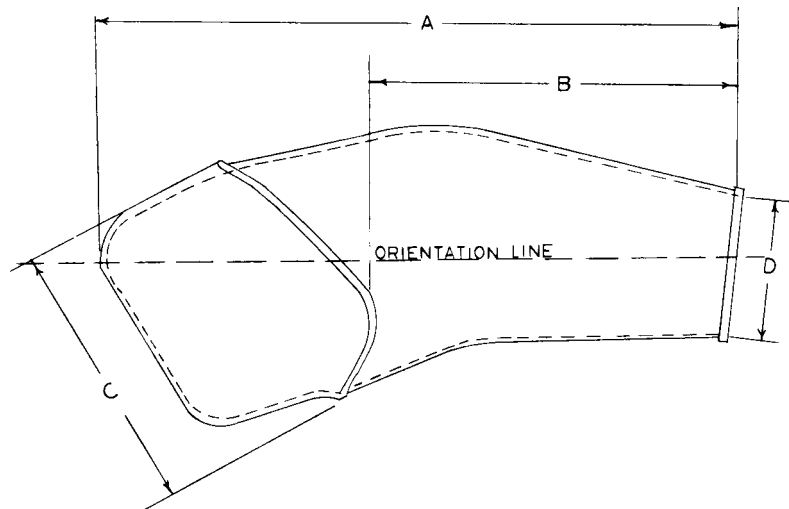


FIG. 2 Style B, Curved Elbow Sleeve

manufacturer or supplier may request that his representative witness the testing of additional sleeves from the shipment.

14.5 The entire lot or shipment may be rejected at the option of the purchaser, if two specimens of the first sample and one of the second sample, selected in accordance with 13.2, fail any of the separate requirements outlined in Section 8.

14.6 The entire lot or shipment of sleeves may be rejected at the option of the purchaser if 25 % of the sleeves in the lot or shipment fail to meet the requirements of Section 10 or 11.

14.7 All rejected material shall be returned as directed by the manufacturer, at his or the supplier's request, without being

defaced by rubber stamp or other permanent marking. However, those sleeves punctured when tested under 9.1 and 9.2 shall be stamped, punched, or cut prior to being returned to the supplier to indicate that they are unfit for electrical use.

### 15. Packaging

15.1 Each pair of sleeves shall be packed in an individual container of sufficient strength to properly protect the sleeves from damage in transit. The end of the container shall be marked with the name of the manufacturer or supplier, type, class, style, size, and color.

TEST METHODS

16. Sequence of Testing

16.1 The following order of procedure is suggested for testing rubber insulating sleeves:

- 16.1.1 Inspection of the surfaces in accordance with Section 11.
- 16.1.2 The dimensions in accordance with Section 17.
- 16.1.3 Electrical proof tests in accordance with 18.5.2 or 18.6.2.
- 16.1.4 Breakdown voltage tests in accordance with 18.5.4.
- 16.1.5 Ozone resistance tests in accordance with 18.7.
- 16.1.6 Chemical and physical property tests in accordance with Section 19.

17. Dimension Measurements

17.1 Thickness:

17.1.1 Thickness measurements shall be made at eight or more points uniformly distributed over the total area of the sleeve.

17.1.2 Thickness measurements shall be made on complete sleeves with a micrometer graduated to within 0.025 mm (0.001 in.), having an anvil about 6 mm (0.25 in.) in diameter and a presser foot  $3.17 \pm 0.25$  mm ( $0.125 \pm 0.001$  in.) in diameter. The presser foot shall exert a total force of  $0.83 \pm 0.03$  N ( $3.0 \pm 0.1$  ozf). Sufficient support shall be given the sleeve so that it will present an unstressed, flat surface between the anvil faces of the micrometer.

NOTE 2—A dial-type micrometer graduated in millimetres or inches and mounted in a manner similar to that shown in Fig. 3 is particularly convenient for making these measurements.

17.2 Other Dimensions:

17.2.1 *Straight Taper Sleeves*—Dimensions of straight taper sleeves, as illustrated in Fig. 1 and specified in Table 4, shall be determined with the sleeve in a flattened condition (that is, with one side firmly and uniformly pressed against the other). A convenient device for measuring is a board with a center line

upon which the sleeve is placed so that  $D_1$  equals  $D_2$  and  $E_1$  equals  $E_2$ , in which case  $C_1$  will be greater than  $C_2$ .

17.2.1.1 *Dimension A*—The overall length shall be measured from the outside edge of the wrist opening to the outside edge of the shoulder opening, parallel to the center line.

17.2.1.2 *Dimension B*—The underarm length shall be measured from the outside edge of the cuff opening to the lowest point of the underarm opening along the center line.

17.2.1.3 *Dimension C*—The shoulder opening width shall be the sum of  $C_1$  and  $C_2$  minus twice the thickness of the sleeve, measured perpendicular to the center line as shown in Fig. 1.

17.2.1.4 *Dimension D*—The wrist opening width shall be the sum of  $D_1$  and  $D_2$  minus twice the thickness of the sleeve, measured perpendicular to the center line as shown in Fig. 1.

17.2.2 *Curved Elbow Sleeves*—Dimensions of curved elbow sleeves, as illustrated in Fig. 2 and specified in Table 4, shall be determined with the sleeve in a flattened condition (that is, with one side firmly and uniformly pressed against the other). The sleeve shall be oriented along a line from the midpoint of the wrist opening through the center of the uppermost button hole.

17.2.2.1 *Dimension A*—The overall length shall be measured from the outside edge at the midpoint of the wrist opening to the outside edge of the shoulder opening, parallel to the orientation line.

17.2.2.2 *Dimension B*—The underarm length shall be measured from the outside edge at the midpoint of the wrist opening to the lowest point of the shoulder, parallel to the orientation line.

17.2.2.3 *Dimension C*—The shoulder opening width shall be measured as the maximum width at the shoulder opening minus twice the sleeve thickness.

17.2.2.4 *Dimension D*—The wrist opening width shall be measured as the outside width above the reinforcing edge at the wrist opening minus twice the sleeve thickness.

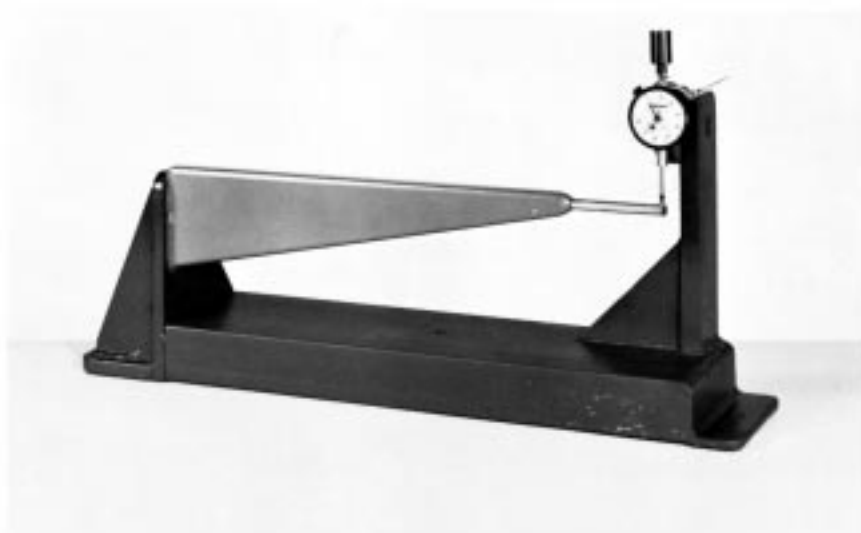


FIG. 3 Dial-Micrometer for Measuring Sleeve Thickness

**18. Electrical Tests**

18.1 All electrical tests shall be performed on sleeves right side out and at room temperature. Four methods of mounting sleeves are provided, with test limitations on some of the methods. Electrode to electrode clearances shall be as specified in Table 4.

NOTE 3—Both a-c and d-c proof-test procedures are included in this section. It is intended that one mounting method and one testing procedure be selected for the electrical acceptance tests. The method and procedure selected shall be at the option of the purchaser, and the supplier should be so notified of the selection.

18.2 **Precaution:** It is recommended that the test apparatus be designed to afford the operator full protection in the performance of his duties. Reliable means of de-energizing and grounding the high-voltage circuit shall be provided. It is particularly important to incorporate a positive means of grounding the high-voltage section d-c test apparatus due to the likely presence of high-voltage capacitance charges at the conclusion of the test.

**18.3 Electrodes:**

NOTE 4—Water electrodes should be free of air bubbles and air pockets, particularly in contact with the sleeves. Other electrodes should fit sleeves as snugly as possible and without distortion. Areas not in contact with the electrodes should be dry to prevent flashovers.

**18.3.1 Water Electrodes, Inverted Mounting:**

18.3.1.1 The small end of the sleeve shall be inverted and pulled through to the large end to form an annular trough as shown in cross section in Fig. 4. The sleeve shall be immersed in water and the trough filled with water until the levels both inside and outside the trough are the same. Particular care should be taken to avoid any sharp folds in the sleeve, which may cause premature dielectric breakdown at these points. This mounting should not be used above 10 kV ac or 50 kV dc.

18.3.2 **Water Electrodes, Sling Mounting**—A roll or rod of nonconductive material having a specific gravity heavier than water shall be placed across the sleeve at about the midpoint between the cuff and underarm edge. The sleeve shall be immersed in water with the roll in place and filled with water until the water levels are the same both inside and outside the

sleeve and the cuff and underarm edges are equidistant above the water line as shown in cross section in Fig. 5. Particular care should be taken to avoid any sharp folds in the sleeves, which may cause premature dielectric breakdown at these points. This mounting should not be used above 10 kV ac or 50 kV dc.

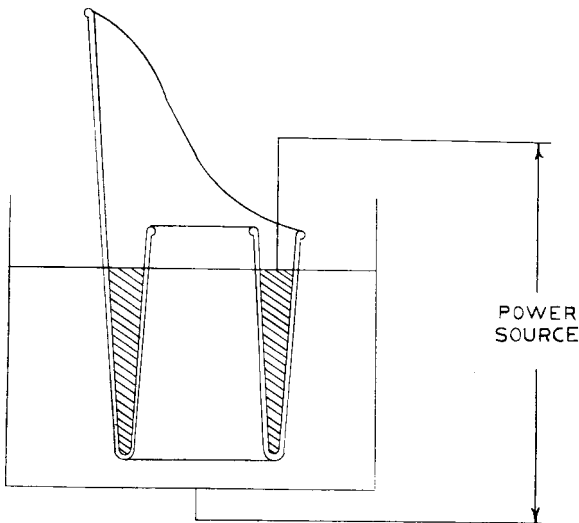
18.3.3 **Water Electrodes, Hammock Mounting**—The sleeve shall be hung in the test machine so that the top of the shoulder area, the top of the underarm and the cuff edge are all in a horizontal plane, parallel to the surface of the water in the test tank. Fill the sleeve with water and immerse the sleeve to the test position, allowing proper flashover clearance for the test voltage used. When testing molded style sleeves, install the sleeve in the test position so that sleeve mold marks are located above and below each other, rather than side to side. This prevents the sleeve from creasing at the mold marks and creating a stress point. A rod or pipe should be placed across the top surface of the sleeve at approximately the midpoint between the cuff and underarm edge to prevent sharp folds in the sleeve. See Fig. 6.

18.3.4 **Water Electrodes, Straight Mounting**—A layer of high dielectric strength liquid having a specific gravity greater than 1.0 and insoluble in water shall be placed in the test tank to a depth of approximately 100 mm (4 in.). The tank shall then be filled with water to the desired level. The sleeve shall be immersed with the small end first into the water until the cuff end is below the interface between the two liquids as shown in cross section in Fig. 7, such that the clearances between electrodes listed in Table 5 are met. The dielectric liquid separates and electrically insulates the inside water electrode from the outside water electrode. This mounting may be used for all voltages, both a-c and d-c.

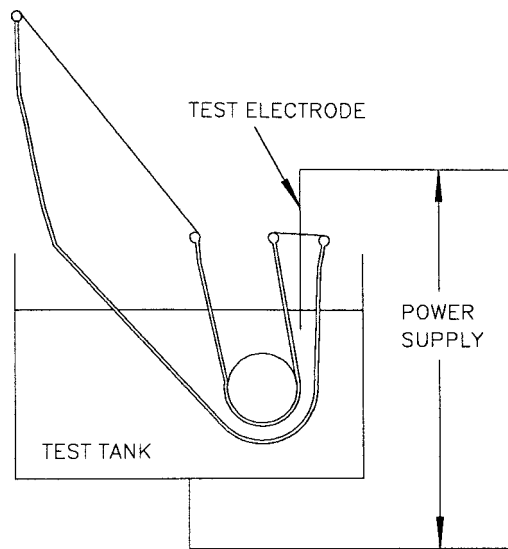
NOTE 5—Hanger systems may be obtained from most test equipment manufacturers to facilitate the hammock mounting method.

NOTE 6—Some dielectric liquids are toxic therefore, the manufacturer's recommendations should be followed.

NOTE 7—One satisfactory dielectric liquid is trichlorotrifluoroethane (refrigerant-113). Prolonged contact of the sleeve with the dielectric liquid should be avoided as the sleeves may swell. Repeated testing may result



**FIG. 4 Water Electrodes, Inverted Mounting**



**FIG. 5 Water Electrodes, Sling Mounting**

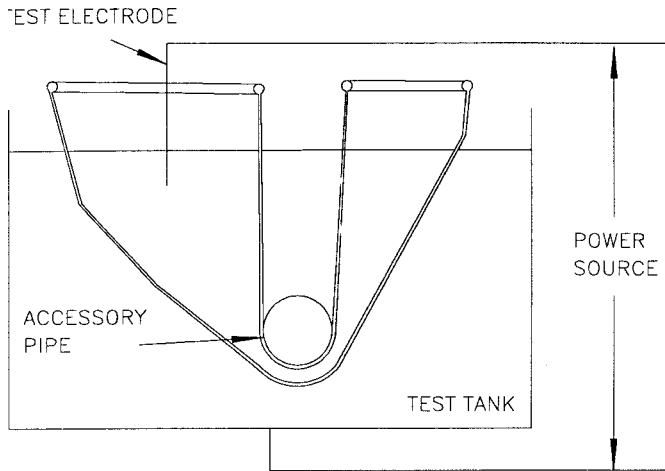


FIG. 6 Water Electrodes, Hammock Mounting

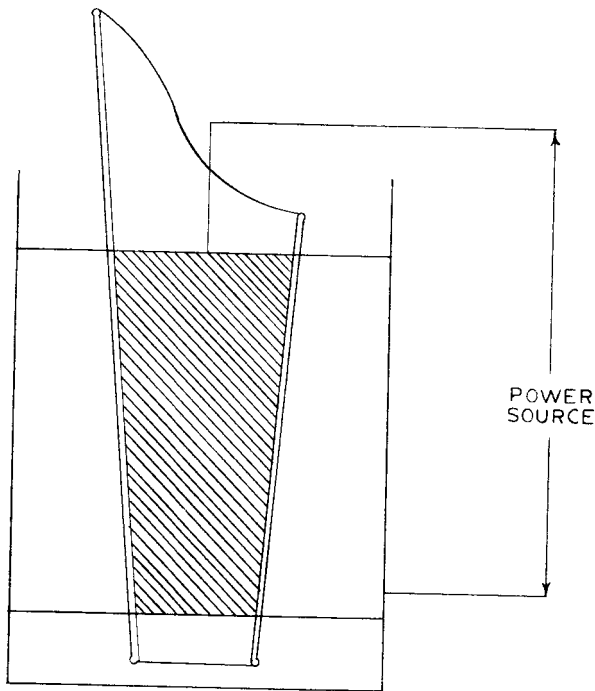


FIG. 7 Water Electrodes, Straight Mounting

TABLE 5 Clearances Between Electrodes <sup>A,B</sup>

Class	A-C Proof Test		D-C Proof Test	
	mm	in.	mm	in.
0	76	3	76	3
1	76	3	102	4
2	127	5	152	6
3	178	7	203	8
4	254	10	254	10

<sup>A</sup>Clearance is the shortest electrical path from electrode to electrode around the open edge of the sleeve. Permissible tolerance equals  $\pm 25$  mm ( $\pm 1.0$  in.).

<sup>B</sup>In those cases where atmospheric conditions make the specified clearances impractical, the clearances may be increased by a maximum of 50 mm (2.0 in.).

in loss of dielectric strength due to water dielectric mixing, so separation time or other means may be needed. Care should be taken to prevent the sleeves from folding back out of the dielectric liquid.

18.3.5 *Dry Electrodes, Straight Mounting*—The electrodes shall consist of two electrically conductive plates or shapes,

constructed to conform closely to the inside and outside of the sleeve. Any edges on these shapes shall be so rounded as to eliminate sharp nicks and protuberances. The sleeve shall be drawn snugly and without stretching over the inner electrode and the outer electrode placed around it and adjusted to a snug fit as shown in cross section in Fig. 8. For versatility in testing sleeves of different sizes the electrodes can be longer than those indicated, in which case masking of the edges with nonconductive material will permit testing of the shorter sleeves. This mounting method shall not be used for a-c testing of Type I sleeves because of potential ozone generation.

18.4 *Test Equipment:*

18.4.1 The test equipment used in both the proof and dielectric breakdown tests shall be capable of supplying an essentially stepless and continuously variable voltage to the test specimen. Motor-driven regulating equipment is convenient and tends to provide uniform rate-of rise to the test voltage. The test apparatus should be protected by an automatic circuit-breaking device designed to open promptly on the current produced by breakdown of a specimen under test. This circuit-breaking device should be designed to protect the test equipment under any conditions of short circuit. The equipment shall be inspected at least annually to ensure that its general condition is acceptable and to verify the characteristics and accuracy of the testing voltages.

18.4.2 Sleeve failure indicators or accessory circuits shall be designed to give positive indication of failure and shall require resetting by the operator before tests can be continued.

18.5 *A-C Tests:*

18.5.1 *Voltage Supply and Regulation:*

18.5.1.1 The desired test voltage may be most readily obtained from a step-up transformer energized from a variable low-voltage source. The transformer and its control equipment shall be of such size and design that, with the test specimen in the circuit, the crest factor (ratio of maximum to mean

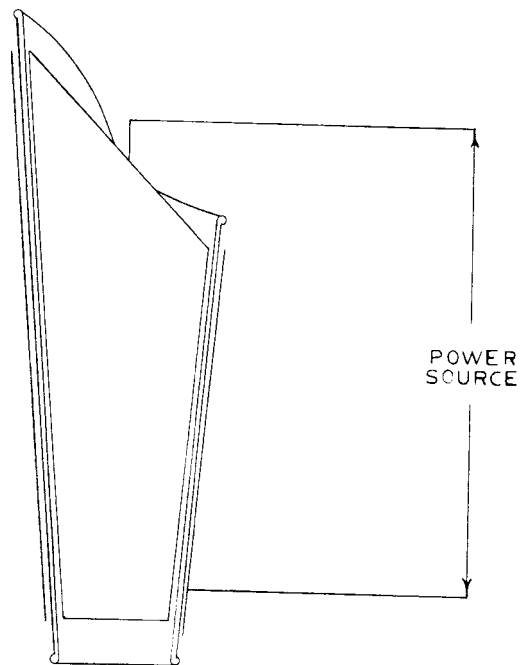


FIG. 8 Dry Electrodes, Straight Mounting

effective) of the test voltage shall differ by not more than 5 % from that of a sinusoidal wave over the upper half of the range of the test voltage.

18.5.1.2 The accuracy of the adopted voltage-measuring circuit shall be within  $\pm 2$  % of full scale. The correct rms value of the sinusoidal voltage wave form applied to the sleeve may be measured by one of the following methods: (1) a voltmeter used in conjunction with a calibrated instrument transformer connected directly across the high-voltage circuit, (2) a calibrated electrostatic voltmeter connected directly across the high-voltage circuit, or (3) an a-c meter connected in series with appropriate high-voltage type resistors directly across the high-voltage circuit.

18.5.1.3 The crest factor may be checked by the use of a peak-reading voltmeter connected directly across the high-voltage circuit; or, if an electrostatic voltmeter or a voltmeter in conjunction with an instrument potential transformer is connected across the high-voltage circuit, a standard sphere gap may be sparked over and the corresponding voltage compared with the reading of the rms voltmeter.

#### 18.5.2 A-C Proof Test:

18.5.2.1 Each sleeve shall be given a proof test in accordance with the requirements of 9.1. The proof-test voltage shall be initially applied at a low value and gradually increase at a constant rate-of-rise of approximately 1000 V/s ac until the prescribed test voltage level is reached or failure occurs. The test period starts at the instant that the prescribed testing voltage is reached. The applied voltage should be reduced to at least half value, unless electrical failure has already occurred, at the end of the test period before opening the test circuit.

#### 18.5.3 A-C Breakdown Test:

18.5.3.1 This test shall be in accordance with 9.2 of this specification and the latest revision of Test Method D 149. When there are variations in testing specifications this specification and Test Method D 149, this specification shall take precedence. The specimens shall be tested in air between metal electrodes, 50 mm (2 in.) in diameter and 25 mm (1 in.) thick, with edges rounded to 6 mm (0.25 in.). The breakdown test voltage shall be applied at a low value and increase at a constant rate-of-rise of approximately 1000 V/s ac until the prescribed minimum breakdown voltage is reached or failure occurs. The maximum voltage observed prior to failure shall be considered the breakdown voltage.

#### 18.6 D-C Tests:

##### 18.6.1 Voltage Supply and Regulation:

18.6.1.1 The d-c test voltage shall be obtained from a d-c source capable of supplying the required voltage. The peak to peak a-c ripple component of the d-c proof-test voltage shall not exceed 2 % of the average voltage value under no-load conditions.

18.6.1.2 The accuracy of the voltage measuring circuit shall be within  $\pm 2$  % of full scale. The d-c proof-test voltage shall be measured by a method that provides the average value of the voltage applied to the sleeve. It is recommended that the voltage be measured by the use of a d-c meter connected in series with appropriate high-voltage type resistors across the high-voltage circuit. An electrostatic voltmeter of proper range may be used in place of the d-c meter-resistor combination.

##### 18.6.2 D-C Proof Test:

18.6.2.1 Each sleeve shall be given a proof test in accordance with the requirements of 9.1. The d-c proof-test voltage shall be applied in the same manner as for a-c proof tests except with a rate-of-rise of approximately 3000 V/s dc.

##### 18.7 Ozone Resistance Tests:

18.7.1 The ozone resistance test shall be made in accordance with one of the following methods to ensure conformance of Type II sleeves with the requirements of 9.3.

18.7.1.1 *Method A*—The ozone resistance test shall be made in accordance with Test Method D 1149, using Procedure A of Test Method D 518 to prepare the specimen. The specimen should be cut to a 12 by 100-mm (0.5 by 4-in.) rectangular size. Procedure A shall be followed using a simple elongation test piece of 20 % extension. The ozone concentration shall be maintained at  $50 \pm 5$  mPa partial pressure ( $50 \pm 5$  ppm by volume at standard atmospheric pressure) for a 3 h test period. Type II sleeve shall show no effect from ozone exposure during this test period.

18.7.1.2 *Method B*—The ozone resistance test shall be made on a 100 by 150-mm (4 by 6-in.) specimen of the sleeve material prepared from a sample suitably conditioned by lying flat for 24 h. The specimen should be draped over a 25-mm (1-in.) diameter metal tube of sufficient length to completely underlie the specimen, while possessing additional length for the required mounting supports. The metal tubing is electrically grounded. The free ends of the specimen shall be clamped beneath the tubing electrode so that an intimate contact is established between the specimen and the tubing along the upper half of the cylindrically shaped electrode surface. A piece of flat aluminum sheet foil, approximately 50 by 100 mm (2 by 4 in.), shall be placed over the draped specimen so as to provide adequate separation distance to prevent flashover between the foil and the metal tubing. An electrode wire shall be connected to the aluminum foil. The outer electrode (metal foil) shall be energized at approximately 15 kV ac (rms) from a stable 60-Hz source. The 15-kV potential may be derived from a suitably rated potential transformer energized from its low-voltage winding through a continuously variable autotransformer. An overcurrent protective device should be incorporated into the low-voltage control circuit in case of an electrical breakdown. The ozone resistance of the specimen should be measured qualitatively, by inspection, after a 1-h exposure period in the test apparatus at the 15-kV potential. At least two specimens from each sample sleeve selected in accordance with 13.2. Two specimens should not be taken from the same section of the sample sleeve.

NOTE 8—The rate of ozone degradation by use of Method B is inversely proportional to the relative humidity of the surrounding air. Empirical data indicate, however, that visible ozone effects will be evident over a broad range of ambient humidities under these test conditions.

## 19. Chemical and Physical Tests

### 19.1 Chemical Tests:

19.1.1 The composition of the rubber hydrocarbon portion of Type I sleeves may be determined using the test methods in Test Methods D 297.

### 19.2 Physical Tests:

19.2.1 Physical tests shall be performed to determine the



physical properties specified in Section 8. The sleeve samples should be conditioned by storing in a flat position for 24 h at room temperature,  $23 \pm 4^\circ\text{C}$  ( $73 \pm 7^\circ\text{F}$ ).

19.2.2 The tensile strength, tensile stress at 200 % elongation, and tension set test shall be performed in accordance with Test Methods D 412. The test specimen shall conform in dimensions to Die C. The elongation in the tension set shall be 400 % with grip separation at a rate of  $500 \pm 50$  mm ( $20 \pm 2$  in./min).

19.2.3 The tear resistance test shall be performed in accordance with Test Method D 624. The test specimen shall conform to the dimensions of Die C.

19.2.4 The puncture resistance test shall be performed to determine the ability of the sleeve material to withstand puncture.

19.2.4.1 A sleeve specimen shall be cut to fit between the opposing faces of two flat metal plates having concentric openings. The thickness of each test specimen shall be measured at its approximate center using a micrometer having the characteristics described in Test Methods D 412. One of the plates shall have a circular opening 6 mm (0.25 in.) in diameter to allow the passage of a stainless steel needle. The other plate shall have an opening 25 mm (1.0 in.) in diameter to provide a fixed free area through which the specimen can elongate while being subjected to the pressure of the needle point. The

edges of the openings should be rounded to a radius of approximately 0.8 mm (0.03 in.). The needle shall be made from 5-mm (0.19-in.) diameter Type 304 stainless steel rod. The rod shall be machined at one end to produce a taper with an included angle of 12 deg with the tip of the tapered end rounded to a radius of 0.8 mm (0.03 in.). The needle shall be initially positioned perpendicularly to the specimen so that the point contacts the specimen through the small hole in the plate. The needle shall be driven into and through the specimen at a continuous rate of approximately 8.3 mm/s (20 in./min). The maximum force required to perform the puncturing operation shall be calculated to the nearest 2 N ( $\frac{1}{2}$  lbf). The puncture resistance shall be measured by dividing the puncturing force by the specimen thickness and record in units of newtons per meter (or pounds-force per inch).

19.2.5 The accelerated aging tests shall be performed in accordance with Test Method D 573. After being subjected to a temperature of  $70 \pm 2^\circ\text{C}$  ( $158 \pm 3.6^\circ\text{F}$ ) in circulating air for 7 days, the tensile strength and elongation of the specimen shall not be less than 80 % of the original.

19.2.6 The durometer test shall be performed in accordance with Test Method D 1415 or Test Method D 2240.

19.2.7 The moisture absorption test shall be performed in accordance with Test Method D 570, using the 24 h immersion procedure at a temperature of  $23 \pm 4^\circ\text{C}$  ( $73 \pm 7^\circ\text{F}$ ).

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