



# Standard Specification for Vulcanized Fibre Sheets, Rods, and Tubes Used for Electrical Insulation<sup>1</sup>

This standard is issued under the fixed designation D 710; 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.

*This standard has been approved for use by agencies of the Department of Defense.*

## 1. Scope

1.1 This specification covers vulcanized fibre (Note 1) sheets, round rods, and round tubes of such grades suitable for use as electrical insulation.

NOTE 1—The variant spelling “fibre” has been approved by Committee D-9 for use in this standard.

1.2 The values stated in inch-pound units are to be regarded as the standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation<sup>2</sup>

D 619 Test Methods for Vulcanized Fibre Used for Electrical Insulation<sup>2</sup>

D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between  $-30^{\circ}\text{C}$  and  $30^{\circ}\text{C}$ <sup>3</sup>

D 952 Test Method for Bond or Cohesive Strength of Sheet Plastics and Electrical Insulating Materials<sup>3</sup>

D 3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials<sup>4</sup>

### 2.2 Other Documents:<sup>5</sup>

IEEE Publication No. 1, “General Principles for Temperature Limits in the Rating of Electrical Equipment.”

## 3. Terminology

### 3.1 Definitions:

3.1.1 *vulcanized fibre, n*—a material made from chemically gelatinized cellulosic paper or board using zinc chloride as the gelatinizing agent.

3.1.1.1 *Discussion*—The zinc chloride is subsequently removed by leaching. The resulting product, after being dried and finished by calendering, is a material of partially regener-

ated cellulose in which the fibrous structure is retained in varying degrees depending on the grade of paper used and on the processing conditions. Material up to about 25 mm in thickness is produced by bonding multiple layers of paper (or board) after chemical treatment. Vulcanized fibre does not contain vulcanized rubber or sulfur as the name might imply. Thin vulcanized fibre has sometimes been termed “fish paper.”

## 4. Grades

4.1 Three grades of vulcanized fibre are covered, as follows:

4.1.1 *Bone Grade*—This grade is characterized by the greater hardness and stiffness associated with higher density. It machines more smoothly and with less tendency to separate the plies in difficult machining operations than the other grades. It is made in thickness of  $\frac{1}{32}$  to  $\frac{1}{4}$  in. (0.79 to 6.35 mm).

4.1.2 *Commercial Grade*—This grade is considered as the general-purpose grade and is sometimes referred to as mechanical and electrical grade. It possesses good physical and electrical properties and can be fabricated satisfactorily by punching, turning, and forming operations. It is made in thicknesses from 0.010 to  $\frac{1}{4}$  in. (0.25 to 6.35 mm).

4.1.3 *Electrical Insulation Grade*—This grade is intended primarily for electrical applications and others involving difficult bending or forming operations. It is made in thicknesses from 0.004 to  $\frac{1}{8}$  in. (0.10 to 3.2 mm). Thin material of this grade is sometimes referred to as “fish paper.”

4.2 The three grades of fibre are available in laminated sheet form in greater thicknesses than those listed in 4.1.1 to 4.1.3. Laminated (or built-up) fibre is composed of a number of plies bonded together with a suitable adhesive. It retains all the basic properties of solid fibre, including high arc resistance on edges and faces, and in addition has better dimensional stability and less warpage. Laminated fibre is usually furnished when the thickness is over  $\frac{1}{4}$  in. (6.35 mm), and may be furnished in thicknesses down to  $\frac{1}{8}$  in. (3.2 mm). Thicknesses up to 4 in. (102 mm) are commercially available.

4.3 Thin sheet material, up to  $\frac{1}{16}$  in. thick is available in a lower density uncalendered condition which may not meet the requirements of this specification.

## 5. Forms and Colors

5.1 Vulcanized fibre is available in the forms and colors listed in Table 1.

<sup>1</sup> This specification is under the jurisdiction of ASTM Committee D-9 on Electrical and Electronic Insulating Materials and is the direct responsibility of Subcommittee D09.07 on Flexible and Rigid Insulating Materials.

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

<sup>3</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>4</sup> *Annual Book of ASTM Standards*, Vol 10.02.

<sup>5</sup> Available from The Institute of Electrical and Electronics Engineers, Inc., 345 E. 47th St., New York, NY 10017.

TABLE 1 Forms and Colors Available

Grades	Forms <sup>A</sup>	Colors <sup>B</sup>
Bone	sheets and rods, tubes	gray gray, black, red
Commercial	sheets and rods	gray, black, red
Electrical Insulation	sheets	gray

<sup>A</sup> Sheets and rods are available in both single-layer and laminated form. Thin sheets are available in both rolls and flat sheets in thicknesses up to 1/16 in. (1.6 mm).

<sup>B</sup> In any of these standard colors, considerable variation of shade may be expected.

6. Chemical Composition

6.1 The material shall conform to the requirements for chemical composition prescribed in Table 2.

7. Detail Requirements

7.1 *Sheets*—Sheet material, calendered only, unless otherwise specified, shall conform to the requirements as to physical and electrical properties prescribed in Tables 3-9.

7.1.1 *Bond Strength (Laminated Sheets Only)*—Tested in accordance with Test Method D 952 shall conform to the following requirements:

Thicknesses	Psi, (MPa) min
All	800 (5.5)

7.2 *Round Rods*—Round rods shall conform to the requirements as to physical properties prescribed in Tables 10 and 11, and Table 12.

7.3 *Round Tubes*—Round tubes shall conform to the requirements as to physical and electrical properties prescribed in Tables 13 and 14. Density of tubing shall conform to the requirements prescribed in Table 6 for the respective grade and thickness.

8. Sheet Sizes and Permissible Variations

8.1 Sheets shall be furnished in the manufacturer’s standard sheet sizes.

NOTE 2—The range of manufacturer’s standard sizes for the various grades and thicknesses are shown in Table 15.

8.2 When sheets and rolls are trimmed to a specified width, the maximum permissible variation in width is ±1/2 in. (±12.7 mm).

8.3 When sheets are trimmed to a specified length, the maximum permissible variation in length is ±1/2 in.

8.4 The maximum permissible variations in widths of strips cut from sheets by the indicated operations are as prescribed in Table 16.

8.5 The maximum permissible variation in thickness of full sheets is as prescribed in Table 17.

8.6 The maximum permissible variations in thickness of sheets cut in halves, thirds, or quarters are as shown in Table 17.

TABLE 2 Chemical Requirements

Grade	Color	Zinc Chloride, max, %	Ash max, %	Silica Content, max, %
All	gray, black	0.1	1.5	0.3
	red	0.1	7	0.3

TABLE 3 Flexural Strength Requirement for Sheets, min, psi (MPa)

Nominal Thickness in. (mm)	Bone Grade		Commercial Grade	
	Length-wise	Cross-wise	Length-wise	Cross-wise
1/16 (1.59) up to 1/8 (3.18), incl	16 000 (110)	14 000 (97)	15 000 <sup>A</sup> (103)	13 000 <sup>A</sup> (90)
Over 1/8 (3.18) to 1/2 (12.7), incl	15 000 (103)	13 000 (90)	14 000 (97)	12 000 (83)
Over 1/2 (12.7) to 1 (25.4), incl	...	...	13 000 (90)	11 000 (76)

<sup>A</sup> These two values also apply to Electrical Insulation Grade.

TABLE 4 Water Absorption and Dielectric Strength Requirements for Sheets

Grade	Nominal Thickness, in. (mm)	Water Absorption, <sup>A</sup> max, %		Dielectric Strength, <sup>B</sup> min, V/mil (kV/mm)
		2 h	24 h	
Bone	1/32 (0.79)	55	63	175 (6.9)
	1/16 (1.59)	30	55	175 (6.9)
	1/8 (3.18)	20	48	150 (5.9)
	3/16 (4.76)	17	42	100 (3.9)
	1/4 (6.35)	14	37	100 (3.9)
Commercial	1/32 (0.79)	60	68	175 (6.9)
	1/16 (1.59)	52	66	175 (6.9)
	1/8 (3.18)	35	61	150 (5.9)
	3/16 (4.76)	24	56	100 (3.9)
	1/4 (6.35)	20	52	100 (3.9)
	Electrical insulation	0.004 to 0.007 (0.10 to 0.18), incl	...	...
	over 0.007 to 0.040 (0.18 to 1.02), incl	...	...	250 (9.8)
	over 0.040 to 1/8 (1.02 to 3.18), incl	...	...	175 (6.9)
	1/32 (0.80)	60	68	...
	1/16 (1.59)	52	66	...
	1/8 (3.17)	35	61	...
	1/4 (6.35)	20	52	100 (3.9)
	5/16 (7.94)	17	47	100 (3.9)
	3/8 (9.52)	15	43	100 (3.9)
	7/16 (11.11)	14	39	50 (2.0)
	1/2 (12.7)	13	36	50 (2.0)
	5/8 (15.88)	11	31	<sup>A</sup>
	3/4 (19.05)	10	27	<sup>A</sup>
	7/8 (22.22)	8	23	<sup>A</sup>
	1 (25.4)	8	21	<sup>A</sup>
	1 1/4 (31.8)	8	18	<sup>A</sup>
	1 1/2 (38.1)	8	17	<sup>A</sup>
	2 (50.8) and over	8	17	<sup>A</sup>

<sup>A</sup> For intermediate thicknesses, the value for the next smaller thickness shall apply.

<sup>B</sup> For intermediate thicknesses, the value for the next larger thickness shall apply.

9. Rod Sizes and Permissible Variations

9.1 Furnish rods in the same nominal sizes as sheets. Cut rods from sheet, the length being limited by the length of the sheet.

9.2 The maximum permissible variations in diameters of rods are as shown in Table 18.

9.3 The maximum permissible variations in lengths of circular sawed pieces of rods are as shown in Table 19.

**TABLE 5 Bursting Strength Requirements for Sheets, min, psi (MPa)**

Nominal Thickness, in. (mm)	Bone Grade	Commercial Grade	Electrical Insulation Grade
0.005 (0.13)	...	...	65 (0.4)
0.007 (0.18)	...	...	95 (8.7)
0.010 (0.25)	...	125 (0.9)	125 (0.9)
0.012 (0.30)	...	150 (1.0)	150 (1.0)
0.015 (0.38)	...	185 (1.3)	185 (1.3)
0.020 (0.51)	...	250 (1.7)	250 (1.7)
0.030 (0.76)	325 (2.2)	375 (2.6)	375 (2.6)
0.045 (1.14)	470 (3.2)	560 (3.9)	560 (3.9)
0.060 (1.52)	550 (3.8)	750 (5.2)	750 (5.2)

**TABLE 6 Density Requirements for Sheets, min, g/cm<sup>3A</sup>**

Nominal Thickness or Diameter, in. (mm)	Commercial Grade		Electric Insulation Grade	
	Uncalendered	Calendered	Uncalendered	Calendered
Under 0.010 (0.25)	...	...	0.90	1.00
0.010 to 0.015 incl, (0.25 + 0.38),	1.05	1.10	1.00	1.10
Over 0.015 to 3/32 incl, (0.38 to 2.38),	1.10	1.15	1.10	1.15
Over 3/32 to 1/8 incl, (2.38 to 3.18),	1.15	1.20	1.15	1.20
Over 1/8 to 5/16 incl, (3.18 to 15.88),	...	1.20	...	...
Over 5/16 to 1 incl, (15.88 to 25.4),	...	1.10	...	...
Over 1 to 1 1/4 incl, (25.4 to 31.8),	...	1.05	...	...
Over 1 1/4 (31.8)	...	1.01	...	...

<sup>A</sup> The minimum density of all forms and thicknesses of bone grade shall be 1.30 g/cm<sup>3</sup>.

**TABLE 7 Tearing Strength Requirements for Sheets, Electric Insulation Grade**

Nominal Thickness, in. (mm)	Machine Direction, min, g	Cross Direction, min, g
0.005 (0.13)	75	100
0.007 (0.18)	150	175
0.010 (0.25)	225	275
0.012 (0.30)	275	335
0.015 (0.38)	350	425

**TABLE 8 Impact Strength Requirements for Sheets**

Grade	Nominal Thickness, in. (mm)	Impact Strength, Izod, Edgewise Notched, min, ft-lb/in. J/m of notch	
		Lengthwise	Crosswise
Bone	1/16 to 1/4 (1.59 to 6.35)	1.4 (75)	1.0 (53)
Commercial	1/16 to 1/4 (1.59 to 6.35)	1.6 (85)	1.2 (64)
Electrical insulation	1/16 to 1/8 (1.59 to 3.2)	1.6 (85)	1.2 (64)

## 10. Tube Sizes and Permissible Variations

10.1 The sizes of tubing are as shown in Table 20 and Table 21.

10.2 The maximum permissible variations in inside and outside diameters of tubes are as shown in Table 22.

10.3 The maximum permissible variations in length of circular sawed pieces of tubes are as shown in Table 23.

## 11. Workmanship

11.1 The material shall be uniform in quality and consistent

**TABLE 9 Hardness Requirements for Sheets 1/16 in. (1.6 mm) or More in Thickness**

Grade	Rockwell Hardness, min
Bone	R 80
Commercial	R 50

**TABLE 10 Tensile Strength Requirements for Round Rods, min, psi (MPa)**

Nominal Diameter, in. (mm)	Bone Grade	Commercial Grade
1/8 to 1/2 (3.18 to 12.7), incl	8500 (59)	8000 (55)
Over 1/2 (12.7)	...	7000 (48)

**TABLE 11 Water Absorption Requirements for Round Rods**

Grade	Nominal Diameter, in. (mm)	Water Absorption, max, %	
		2 h	24 h
Bone	1/16 to 3/16 (1.59 to 4.76), incl	35	75
	over 3/16 to 1/4 (4.76 to 6.35), incl	15	50
Commercial	1/16 to 3/16 (1.59 to 4.76), incl	40	80
	over 3/16 to 1/2 (4.76 to 12.7), incl	20	60
	over 1/2 to 1 (12.7 to 25.4), incl	10	30
	over 1	8	25

**TABLE 12 Density Requirements for Round Rods**

Grade	Nominal Diameter, in. (mm)	Density g/cm <sup>3</sup> , min
Bone	1/16 to 3/32 (1.59 to 2.38), incl	1.15
	over 3/32 (2.38)	1.30
Commercial	over 3/32 to 5/8 (2.38 to 15.88), incl	1.20
	over 5/8 to 1 (15.88 to 25.4), incl	1.10
	over 1 to 1 1/4 (25.4 to 31.8), incl	1.05
	over 1 1/4 (31.8)	1.01

**TABLE 13 Compressive Strength Requirement for Round Tubes**

Grade	Nominal Wall Thickness, in. <sup>A</sup> (mm)	Axial Compressive Strength, min, psi (MPa)
Bone and commercial	up to 1/8 (3.18), incl	11 000 (76)
	over 1/8 to 3/16 (3.18 to 7.94), incl	12 000 (83)

<sup>A</sup> Wall thickness 1/32 in. min; outside diameter 2.0 in. max.

with the properties prescribed in this specification. It shall be free of blisters, and reasonably free of wrinkles, cracks, scratches, and dents.

## 12. Sampling

12.1 To determine conformance with the requirements of this specification, sample lots in accordance with Inspection Level S-2 of Practice D 3636.

## 13. Test Methods

13.1 Condition vulcanized fibre and test in accordance with Test Methods D 619.

## 14. Inspection

14.1 The purchaser and supplier shall agree upon the inspection as part of the purchase contract.

**TABLE 14 Water Absorption and Dielectric Strength Requirements for Round Tubes**

Grade	Nominal Wall Thickness, in. (mm)	Water Absorption, max, %		Dielectric Strength, min, V/mil (kV/mm)
		2 h	24 h	
Bone and commercial	up to 1/16 (1.59)	...	...	175 (6.9)
	over 1/16 to 1/8 (1.59 to 3.18), incl	...	...	150 (5.9)
	1/32 to 1/8 (0.79 to 3.18), incl	50	75	...
	over 1/8 to 1/4 (3.18 to 6.35), incl	20	50	100 (3.9)
	over 1/4 to 5/16 (6.35 to 7.94), incl	10	25	100 (3.9)

**TABLE 15 Range of Manufacturers' Sheet Sizes**

NOTE 1—Due to variations in the size of manufacturing equipment, there is some variation in the length and width of manufacturers' standard sheet sizes. Consult manufacturers' catalogs for sizes available. The ranges of manufacturers' standard sheet sizes are as follows:

Grade	Width, in. (mm)	Length, in. (mm)
Bone	40 to 54	66 to 86
	(1016 to 1322)	(1676 to 2184)
Commercial	45 to 56	72 to 90
	(1143 to 1422)	(1829 to 2286)
Electrical insulation	46 to 56	80 to 90
	(1168 to 1422)	(2032 to 2286)
Laminated form	48	39 to 120
	(1219)	(991 to 3048)

**TABLE 16 Permissible Variations in Widths of Strip Cut from Sheets of All Grades, Plus or Minus, in.<sup>A</sup>**

Width, in. (mm)	Slit (Ribbon Rolls)	Sheared	Band Sawed	Smooth Sawed
3/16 (4.76) and under	0.010	0.015	0.020	0.006
1/4 to 1/2 (6.35 to 12.7), incl	0.015	0.020	0.030	0.008
5/16 to 1 (14.29 to 25.4), incl	0.020	0.030	0.045	0.010
1 1/8 to 2 (28.58 to 50.8), incl	0.030	0.040	0.060	0.012
Over 2 to 4 (50.8 to 101.6)	0.040	0.050	0.075	0.014

<sup>A</sup> On strip of widths not listed in this table, the permissible variations shall be the same as for the next greater width.

## 15. Rejection and Rehearing

15.1 Material that fails to meet the requirements of this specification is subject to rejection. When the number of defectives for any test are in excess of the acceptance number for that test as determined by the AQL value agreed upon between the supplier and the user, this shall constitute a basis for rejection.

15.2 Report rejection to the producer or supplier promptly and in writing. In the case of dissatisfaction with the actions taken as a result of these tests, the producer or supplier may make a claim for a rehearing.

## 16. Certification

16.1 When specified in the purchase order or contract, furnish a producer's or supplier's certification to the purchaser that the material was manufactured, sampled, tested, and inspected in accordance with this specification, and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

## 17. Keywords

17.1 electrical insulation; fish paper; rigid rods; rigid sheets; rigid tubes; vulcanized fibre

**TABLE 17 Permissible Variations in Thickness of Full Sheets and Sheets Cut in Halves, Thirds, and Quarters of all Grades<sup>A</sup>**

Nominal Thickness, in. (mm)	Full Sheets, plus or minus, in. (mm)	1/2, 1/3, 1/4 Sheets, plus or minus, in. (mm)
0.004 to 0.040 (0.10 to 1.02)	10 %	8 %
0.041 to 0.049 (1.04 to 1.24)	0.004 (0.10)	8 %
0.050 to 0.062 (1.27 to 1.57)	0.005 (0.13)	0.004 (0.10)
0.063 to 0.094 (1.60 to 2.39)	0.007 (0.18)	0.005 (0.13)
0.095 to 0.125 (2.41 to 3.18)	0.010 (0.25)	0.008 (0.20)
0.126 to 0.188 (3.20 to 4.78)	0.025 (0.64)	0.020 (0.50)
0.189 to 0.250 (4.80 to 6.35)	0.030 (0.76)	0.025 (0.64)
over 1/4 to 3/8 (6.35 to 9.5), incl	0.035 (0.89)	...
over 3/8 to 1/2 (9.5 to 12.7), incl	0.040 (1.02)	...
over 1/2 to 5/8 (12.7 to 15.9), incl	0.045 (1.14)	...
over 5/8 to 3/4 (15.9 to 19.0), incl	0.055 (1.40)	...
over 3/4 to 1 (19.0 to 25.4), incl	0.070 (1.78)	...
over 1 to 1 1/4 (25.4 to 31.8), incl	0.090 (2.29)	...
over 1 1/4 to 1 1/2 (31.8 to 38.1), incl	0.110 (2.79)	...
over 1 1/2 to 1 3/4 (38.1 to 44.4), incl	0.130 (3.30)	...
over 1 3/4 to 2 (44.4 to 50.8), incl	0.140 (3.56)	...
over 2 to 2 1/4 (50.8 to 57.2), incl	0.160 (4.06)	...
over 2 1/4 to 2 1/2 (57.2 to 63.5), incl	0.175 (4.44)	...
over 2 1/2 to 2 3/4 (63.5 to 69.9), incl	0.190 (4.83)	...
over 2 3/4 to 3 (69.9 to 76.2), incl	0.210 (5.33)	...
over 3 to 3 1/4 (76.2 to 82.6), incl	0.225 (5.72)	...
over 3 1/4 to 3 1/2 (82.6 to 88.9), incl	0.240 (6.10)	...
over 3 1/2 to 3 3/4 (88.9 to 95.3), incl	0.260 (6.60)	...
over 3 3/4 to 4 (95.3 to 101.6), incl	0.280 (7.11)	...

<sup>A</sup> On sheets of nominal thickness not listed in this table, the permissible variations shall be the same as for the next greater thickness.

**TABLE 18 Permissible Variations in Diameter of Round Rods of All Grades, Plus or Minus, in.**

Nominal Diameter, in. (mm)	Bone Grade	Commercial Grade
1/16 to 1/4 (1.59 to 6.35), incl	0.005	0.005
Over 1/4 to 1/2 (6.35 to 12.7), incl	0.006	0.006
Over 1/2 to 1 (12.7 to 25.4), incl	...	0.006
Over 1 to 2 (25.4 to 50.8), incl	...	0.010

**TABLE 19 Permissible Variations in Length of Rods of All Grades**

Nominal Length, in. (mm)	Permissible Variations in Length as Cut, plus or minus, in. (mm)
0 to 3 (76.2), incl	0.015 (0.38)
Over 3 to 6 (76.2 to 152.4), incl	0.020 (0.51)
Over 6 to 12 (152.4 to 304.8), incl	0.030 (0.76)
Over 12 to 24 (304.8 to 609.6), incl	0.035 (0.89)
Over 24 to 48 (609.6 to 1219.2), incl	0.040 (1.02)
Over 48 to 84 (1219.2 to 2133.6), incl	0.062 (1.57)

**TABLE 20 Standard Steps in Inside and Outside Diameters of Tubes of All Grades**

Nominal Inside Diameter, in. (mm)	Diameters Available in Steps of, in. (mm)	Nominal Outside Diameter, in. (mm)	Diameters Available in Steps of, in. (mm)
1/8 to 3/8 (3.18 to 9.52), incl	1/64 (0.40)	3/16 to 1/2 (4.76 to 12.7), incl	1/64(0.40)
13/32 to 1 (10.32 to 25.4), incl	1/32 (0.79)	17/32 to 1 1/4 (13.49 to 31.75), incl	1/32 (0.79)
1 1/16 (26.99) and over	1/16 (1.59)	1 5/16 (33.34) and over	1/16(1.59)

**TABLE 21 Wall Thickness of Tubes of All Grades, in.<sup>A</sup>**

Nominal Inside Diameter, in. (mm)	Min	Max
1/8 (3.18)	0.020	1/8
9/32 (3.97)	0.020	1/8
3/16 (4.76)	0.020	1/8
7/32 (5.56)	0.020	1/8
1/4 (6.35)	0.020	1/4
9/32 (7.14)	1/32	1/4
5/16 (7.94)	1/32	1/4
11/32 (8.73)	1/32	1/4
3/8 (9.52)	1/32	1/4
13/32 (10.32)	1/32	1/4
7/16 (11.11)	1/32	1/4
15/32 (11.96)	1/32	1/4
1/2 (12.7)	1/32	1/4
9/16 (14.29)	1/32	1/4
5/8 (15.88)	1/32	1/4
1 1/16 (17.46)	1/32	1/4
3/4 (19.05)	1/32	9/32
13/16 (20.64)	1/32	9/32
7/8 (22.22)	1/32	9/32
1 (25.4)	1/32	9/32
1 1/8 (28.58)	1/32	9/32
1 1/4 (31.75)	1/32	9/32
1 3/8 (34.92)	1/16	9/32
1 1/2 (38.1)	1/16	5/16
4 (101.6) and over	1/8	5/16

<sup>A</sup> For intermediate sizes, values for the next smaller size shall apply.

**TABLE 22 Permissible Variations in Inside and Outside Diameters of Tubes of All Grades, Plus or Minus, in.<sup>A</sup>**

Nominal Size of Tubing, Inside Diameter, in. (mm)	Outside Diameter, All Wall Thicknesses	Inside Diameter, Wall Thicknesses as Listed, in. (mm)			
		1/16	1/8	3/16	Over 3/16
1/4(6.35) and under	0.004 (0.10)	0.004 (0.10)	0.005 (0.13)	0.006 (0.15)	...
17/64 to 1 (6.75 to 25.4), incl	0.005 (0.13)	0.005 (0.13)	0.006 (0.15)	0.007 (0.18)	0.008 (0.26)
1 1/16 to 2 (26.99 to 50.8), incl	0.008 (0.20)	0.008 (0.20)	0.008 (0.20)	0.010 (0.25)	0.010 (0.25)
2 1/16 to 4 (52.39 to 101.6), incl	0.010 (0.25)	0.010 (0.25)	0.010 (0.25)	0.015 (0.38)	0.015 (0.38)

<sup>A</sup> On tubes of nominal diameters not listed in this table, the permissible variations are the same as for the next greater diameter.

**TABLE 23 Permissible Variations in Length of Tubes of All Grades as Cut, Plus or Minus, in.**

Nominal Length, in. (mm)	Diameter, in. (mm)	
	0 to 3	Over 3 to 6
0 to 3 (76.2), incl	0.015 (0.38)	0.020 (0.51)
Over 3 to 6 (76.2 to 152.4), incl	0.020 (0.51)	0.025 (0.64)
Over 6 to 12 (152.4 to 304.8), incl	0.030 (0.76)	0.035 (0.89)
Over 12 (304.8)	0.035 (0.89)	0.045 (1.14)

## APPENDIX

### (Nonmandatory Information)

#### X1. ENGINEERING DATA

X1.1 The following information and engineering data are considered to be of value to the purchaser of the material covered by this specification to better acquaint him with what is to be expected in operations involving handling and storage of vulcanized fibre.

#### X1.2 Thermal Expansion:

X1.2.1 The coefficient of thermal expansion per degree Celsius as determined by Test Method D 696, is approximately as follows:

Direction of Measurement	Coefficient of Thermal Expansion
Machine direction	0.00002
Cross direction	0.00003

#### X1.3 Modulus of Elasticity:

X1.3.1 Typical values of modulus of elasticity in tension for ¼-in. (6.4 mm) vulcanized fibre are as follows:

Direction	Modulus of Elasticity in Tension, psi (MPa)
Machine direction	1 200 000 (8270)
Cross direction	800 000 (5515)

X1.3.2 Typical values of modulus of elasticity in flexure for ¼-in. vulcanized fibre are as follows:

Direction	Modulus of Elasticity in Flexure, psi (MPa)
Machine direction	1 000 000 (6890)
Cross direction	700 000 (9830)

#### X1.4 Dimensional Change with Change in Moisture Content:

X1.4.1 The dimensions of vulcanized fibre increase as the moisture content increases in accordance with certain definite relationships. The amount of change for each 1 % of change in moisture content is 1 % in thickness, 0.25 % in width, and 0.1 % in length. Although the dimensional change tends to run slightly greater in higher density grades than in lower density grades, the difference is so slight that the figures given above are generally applicable. It should be understood that these values, at best, are approximate.

#### X1.5 Equilibrium Moisture Content:

X1.5.1 Vulcanized fibre adjusts its moisture content to correspond with the atmospheric humidity to which it is

exposed. The moisture content of vulcanized fibre is determined by the procedure given in Test Methods D 619 and is expressed as a percentage of the dry weight of the test specimen employed.

X1.5.2 The approximate amount of moisture which vulcanized fibre will hold at equilibrium under various relative humidity conditions at approximately 23°C is indicated by the curve shown in Fig. X1.1. This curve applies to the various grades of vulcanized fibre in normal use, although the rate of absorption tends to vary, with the lower density grades absorbing moisture faster than the higher density grades.

NOTE X1.1—In the winter season vulcanized fibre is often stored in a heated room after the fibre has reached moisture equilibrium in the cold atmosphere. Unless moisture is added to the storage room, the vulcanized fibre will tend to reach a new lower moisture equilibrium.

#### X1.6 Recommended Storage Conditions:

X1.6.1 For general uses, vulcanized fibre should be stored where it will maintain its normal moisture content of approximately 5 to 8 %.

X1.6.2 If subjected to extremely damp conditions, it will pick up moisture and tend to warp out of shape and to increase its dimensions slightly.

X1.6.3 If subjected to extremely dry conditions, such as the low humidity that develops in heated rooms during the winter season, it will tend to dry out. This tends to cause warpage and slight shrinkage in all dimensions as well as some increase in stiffness and hardness.

X1.6.4 Avoid storing fibre under extremely damp or extremely dry conditions. Approximately 50 % relative humidity is recommended.

#### X1.7 Electrical Characteristics:

X1.7.1 Vulcanized fibre possesses excellent arc-extinguishing and nontracking characteristics which make it particularly suitable in many kinds of equipment where these properties are required, for example, arc chutes for small circuit breakers, lightning arrestors, both high and low voltage fuses of many types and expulsion type high voltage cutouts. An increase in moisture content usually improves the arc-extinguishing and nontracking characteristics.

X1.7.2 Moisture Content influences the voltage breakdown, dc resistivity and ac permittivity and dissipation factor of hard fibre to an extent that makes it difficult to evaluate these

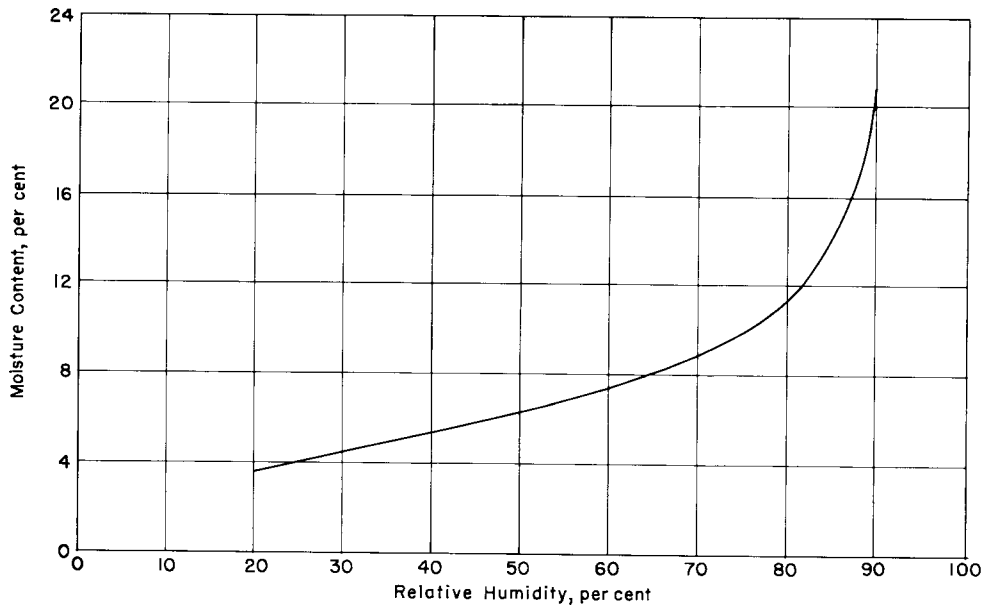


FIG. X1.1 Typical Curve Showing Equilibrium Moisture Content of Vulcanized Fibre Under Various Humidities at 23°C

properties in a standardized manner. Under relatively wet conditions, these characteristics will be negatively affected as compared to dry conditions. This characteristic could possibly limit certain applications unless previously approved by testing.

X1.8 Resistance to Heat:

X1.8.1 By experience, vulcanized fibre has been found to have a temperature index of 110 for mechanical grades and 115 for electrical grades.

X1.8.2 For optimum performance, it is desirable that the normal moisture content be maintained. A reduction in moisture content from the normal range produces slight shrinkage, warpage, and a decrease in toughness as indicated by the impact test, and produces an increase in such properties as

compressive strength, flexural strength, modulus of elasticity, hardness, and tensile strength. Slight deviations in moisture content from the normal do not produce any permanent harmful effects. Vulcanized fibre is superior in heat resistance to cellulose insulation of the unconverted type.

X1.9 Tensile Strength:

X1.9.1 Typical values of tensile strength of sheets are given in Table X1.1.

X1.9.2 Typical tensile strength of round tubes is 12 000 psi for all sizes having wall thickness of 1/32 in. (1.5 mm) min, and outside diameter of 2 in. (51 mm) max.

X1.10 Compressive Strength:

X1.10.1 Typical values for compressive strength of sheets and round rods are given in Table X1.2.

TABLE X1.1 Typical Values of Tensile Strength of Sheets, psi (MPa)

Thickness, in. (mm)	Bone Grade		Commercial and Electric Insulation Grades	
	Crosswise	Lengthwise	Crosswise	Lengthwise
Up to 1/8	8 000 (56)	14 000 (97)	7 500 (52)	13 500 (93)
Over 1/8 (3.18) to 1/2 (12.7), incl	7 000 (48)	11 000 (76)	7 000 (48)	11 000 (76)
Over 1/2 (12.7)	...	...	6 000 (41)	7 000 (48)

TABLE X1.2 Typical Values for Compressive Strength of Sheets and Round Rods, psi (MPa)

Grade	Sheets (Flatwise) (all thicknesses)	Round Rods (Axial) (all diameters)
Bone	30 000 (207)	12 000 (83)
Commercial	25 000 (172)	10 000 (69)

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