



Designation: D709 – 17

# Standard Specification for Laminated Thermosetting Materials<sup>1</sup>

This standard is issued under the fixed designation D709; 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 U.S. Department of Defense.*

## 1. Scope\*

1.1 This specification covers laminated thermosetting materials consisting of two or more plies or layers of reinforcing material bonded by a thermosetting synthetic resin. Examples of such reinforcement are cellulose paper, cotton fabric, glass fabric, and synthetic fiber fabrics. These materials are available in the form of sheets, rolled and molded tubes, and molded rods.

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

NOTE 1—This specification resembles IEC 60893-3 in title only. The content is significantly different.

1.3 The following safety hazards caveat pertains only to the test methods described in 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.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

[D229 Test Methods for Rigid Sheet and Plate Materials Used for Electrical Insulation](#)

[D257 Test Methods for DC Resistance or Conductance of Insulating Materials](#)

[D348 Test Methods for Rigid Tubes Used for Electrical Insulation](#)

[D349 Test Methods for Laminated Round Rods Used for Electrical Insulation](#)

[D495 Test Method for High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation](#)

[D621 Test Methods for Deformation of Plastics Under Load \(Withdrawn 1994\)<sup>3</sup>](#)

[D668 Test Methods of Measuring Dimensions of Rigid Rods and Tubes Used for Electrical Insulation](#)

[D883 Terminology Relating to Plastics](#)

[D1180 Method of Test for Warpage of Sheet Plastics \(Withdrawn 1988\)<sup>3</sup>](#)

[D1711 Terminology Relating to Electrical Insulation](#)

[D2303 Test Methods for Liquid-Contaminant, Inclined-Plane Tracking and Erosion of Insulating Materials](#)

[D2304 Test Method for Thermal Endurance of Rigid Electrical Insulating Materials](#)

[D3636 Practice for Sampling and Judging Quality of Solid Electrical Insulating Materials](#)

[D6054 Practice for Conditioning Electrical Insulating Materials for Testing \(Withdrawn 2012\)<sup>3</sup>](#)

### 2.2 IEEE Standards:<sup>4</sup>

[1 General Principles for Temperature Limits in the Rating of Electric Equipment](#)

[98 Guide for the Preparation of Test Procedures for the Thermal Evaluation and Establishment of Temperature Indices of Solid Electrical Insulating Materials](#)

[99 Guide for the Preparation of Test Procedures for the Thermal Evaluation of Insulation Systems for Electric Equipment](#)

[101 Guide for the Statistical Analysis of Thermal Life Test Data](#)

### 2.3 NEMA Standards:<sup>5</sup>

[LI 1-1971 Industrial Laminated Thermosetting Products](#)

[LI 5-1969 Temperature Indices of Industrial Thermosetting Laminates](#)

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

Current edition approved April 1, 2017. Published April 2017. Originally approved in 1943. Last previous edition approved in 2013 as D709 – 16. DOI: 10.1520/D0709-17.

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> The last approved version of this historical standard is referenced on [www.astm.org](http://www.astm.org).

<sup>4</sup> Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331, <http://www.ieee.org>.

<sup>5</sup> Available from National Electrical Manufacturers Association (NEMA), 1300 N. 17th St., Suite 1752, Rosslyn, VA 22209, <http://www.nema.org>.

\*A Summary of Changes section appears at the end of this standard

### LI 3-1961 High-Temperature Properties of Industrial Thermosetting Laminates

#### 2.4 Military Specifications:<sup>6</sup>

**MIL-I-24768** Insulation, Plastics, Laminated, Thermosetting, General Specifications for

#### 2.5 IEC Standard:

**Publication 60893-3** Specification for Industrial Laminated Sheets Based on Thermosetting Resins for Electrical Purposes<sup>7</sup>

### 3. Terminology

3.1 *Definitions*—For definitions of terms used in this specification, refer to Terminologies **D883** or **D1711**.

### 4. Types and Grades

4.1 Laminated materials covered by this specification are classified in accordance with the types of reinforcement used in their manufacture, and the electrical, mechanical, and heat-resisting characteristics of the finished products (**Note 2**).

**NOTE 2**—Further descriptive information regarding these various types and grades of laminated thermosetting materials is given in **Table 1** and **Appendix X1 – Appendix X3**. **Appendix X3** also includes tables covering engineering information on other properties of the various grades of laminated thermosetting products that are not included in these specification requirements.

### 5. Forms

5.1 Laminated thermosetting materials are available in four forms: sheets, tubes (**Note 3**), rods (**Note 4**), and molded shapes (**Note 5**), as indicated in **Table 2**. This specification covers the material in three forms: sheets, tubes of two classes (rolled and molded), and molded rods. The classes of tubes desired shall be specified by the purchaser in the contract or order. In cases where the purchaser desires a particular class of molded rod the purchaser shall so specify.

**NOTE 3**—Tubes are made of laminations of fibrous sheet impregnated material, rolled upon mandrels under tension or between heated pressure rolls, or both. They are of two classes, rolled and molded. Rolled tubes are oven-baked after rolling on the mandrels. Molded tubes are cured in molds under heat and pressure.

**NOTE 4**—Molded rods are composed of laminations of impregnated sheet material molded in cylindrical molds under heat and pressure, and then ground to size. Molded rods are of two classes made by winding the impregnated sheet convolutely before molding or by forming strips in the molding operation.

Machined rods, manufactured from certain grades of sheet material, are not covered by this specification. In rods machined from sheets, the laminations are parallel chords of a circular cross-section. In general, the properties of these rods conform to those of the grade of sheet stock from which they are cut. This type of rod has the potential to be low in flexural strength when stress is applied perpendicular to the lamination.

**NOTE 5**—Molded shapes are composed of impregnated sheet materials cut into various sizes and shapes to fit the contours of a mold, and molded under heat and pressure. In special cases some macerated material is used in combination with impregnated sheet materials, depending upon the design of the piece. The requirements of this specification, particularly with regard to mechanical properties, cannot be considered as applying to

molded shapes, except for rectangular and square tubes, since such properties will depend to a considerable extent upon the design of the piece.

### 6. General Requirements

6.1 *Materials and Workmanship*—Laminated material shall be uniform in quality. It shall be free of blisters, wrinkles, or cracks and shall be reasonably free of other small defects such as scratches, heat marks, and so forth, as defined in Terminology **D883**. Tubes of any grade having wall thickness greater than ½ in. (13 mm) and molded paper-base rods (Grades XX and XXX) having diameters greater than 1 in. (25 mm) have the potential to show checks or cracks between the laminations on machined or sawed edges.

6.2 *Finish and Color*—Requirements for finish (**Note 6**) and color (**Note 7**) shall be as specified by the purchaser in the contract or order.

**NOTE 6**—The various forms and grades of laminated thermosetting material are available in the finishes shown in **Table 3**.

**NOTE 7**—The various types and grades of laminated thermosetting material are available in the colors shown in **Table 4**. Where MIL-P specifications are involved, natural color only shall be supplied.

6.3 *Warp or Twist*—The warp or twist shall not exceed the values prescribed in **Table 5**.

6.4 *Punching Properties*—The grades of material differ in their suitability for punching, but thin pieces of any of the grades are permitted to be punched in simple shapes, provided good punching practice is used, including sharp, close-clearance dies, proper stripper plates, and proper heating conditions. When using good punching practice as outlined below, the various grades shall punch satisfactorily in thickness up to and including the maximum limits as prescribed in **Table 6**. Where punching properties better than those listed in **Table 6** are required for particular parts, this shall be subject to agreement between the purchaser and the manufacturer. In good punching practice the edges of the piece shall be no closer to the edge of the strip than twice the thickness of the sheet, the holes shall be no smaller in diameter than the thickness of the sheet nor have square corners, and the distance between the holes or between the holes and the edge of the piece shall be no less than the thickness of the sheet. For thicker materials, depending upon the grade, heating the material to a temperature of 120 to 140°C (approximately 15 min for material ⅛ in. (3 mm) in thickness) is generally necessary for best punching results, although in Grade XP or XPC it is possible that this will make the material too soft. In this case, better results are likely to be obtained by heating at lower temperatures or for a shorter time. If more than 2 min elapse between the time the strip leaves the heating medium and the last piece is punched, results will be poor.

**NOTE 8**—The punching properties of the cotton fabric-base grades and of the paper-base grades classed as punching stock are somewhat better than those of the other glass or nylon fabric-base grades. All grades can be punched in thin thicknesses under suitable conditions.

6.5 *Machining Properties*—In general, most of the grades can be drilled, tapped, sawed, and machined. Grades X, XP, XPC, A, G-7, and N-1 are not recommended for drilling and

<sup>6</sup> Available from Standardization Documents Order Desk, Bldg. 4 Section D, 700 Robbins Ave., Philadelphia, PA 19111-5094 Attn: NPODS.

<sup>7</sup> Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, <http://www.ansi.org>.

**TABLE 1 Types and Grades of Laminated Thermosetting Materials**

D709 Grade Designation	MIL-I-24768 Specification Sheet Number and Grade Designation <sup>A</sup>	Description
Type I—Cellulose Paper-Base Phenolic Resin (Unless Noted)		
X	/12 Type PBM	mechanical
XP	/19 Type PBM-P	mechanical; hot-punching stock
XPC	/20 Type PBM-PC	mechanical; cold-punching and cold-shearing stock
XX	/11 Type PBG	electrical and mechanical
XXP	/21 Type PBG-P	electrical and mechanical; hot-punching stock
XXX	/10 Type PBE	electrical and high humidity
XXXP	/22 Type PBE-P	electrical and high humidity; hot-punching stock
XXXPC	/23 Type PBE-P	punchable at lower temperature than Grade XXXP
FR-1	/24 Type PBM-PF	paper-base, flame-resistant, similar to Grade XP
FR-2	/25 Type PBE-PCF	paper-base, flame-resistant, similar to Grade XXXP
FR-3	/26 Type PEE	flame-resistant, epoxy resin; electrical and mechanical
ES-1	...	mechanical; engraving stock usually melamine binder
ES-2	...	mechanical; engraving stock usually melamine binder
ES-3	...	mechanical; engraving stock usually melamine binder
Type II—Cellulose Fabric-Base Phenolic Resin		
C	/16 Type FBM	mechanical
CE	/14 Type FBG	mechanical and electrical
L	/15 Type FBI	mechanical; fine machining
LE	/13 Type FBE	mechanical and electrical; fine machining
Type IV—Glass-Base		
G-3	/18 Type GPG	continuous filament-type glass cloth; phenolic resin, general purpose
G-5	/8 Type GMG	continuous filament-type glass cloth, melamine binder; general purpose; good arc and flame resistance
G-7	/17 Type GSG	continuous filament-type glass cloth, silicone resin binder; good mechanical strength, heat and arc resistance; low dielectric losses and high insulation resistance under humid conditions
G-9	/1 Type GME	continuous filament-glass cloth, melamine binder. Superior to Grade G-5 under wet conditions, good arc and flame resistance
G-10	/2 Type GEE	continuous filament-type glass cloth, epoxy resin binder; high mechanical strength good insulation resistance, dielectric loss, and dielectric strength under dry and humid conditions
G-11	/3 Type GEB	continuous filament-type glass cloth, heat-resistant epoxy binder; properties similar to Grade G-10 but higher flexural strength retained at elevated temperatures
FR-4	/27 Type GEE-F	continuous filament-glass cloth with a flame-resistant epoxy resin binder; properties similar to G-10
FR-5	/28 Type GEB-F	continuous filament-glass cloth with a heat- and flame-resistant epoxy resin binder; properties similar to G11
GPO-1	/4 Type GPO-1P	Glass mat with polyester resin binder, for general purpose
GPO-2	/5 Type GPO-2P	Glass mat with polyester resin binder, for general purpose and flame resistance
GPO-3	/6 Type GPO-3P	Glass mat with polyester resin binder, for general purpose, flame resistance and tracking resistance
GPO-1P	/31 Type GPO-N-1P	Glass mat with polyester resin binder, for general purpose, has better punching performance than standard GPO
GPO-2P	/32 Type GPO-N-2P	Glass mat with polyester resin binder, for general purpose, and flame resistance, has better punching performance than standard GPO
GPO-3P	/33 Type GPO-N-3P	Glass mat with polyester resin binder, for general purpose, flame resistance and tracking resistance has better punching performance than standard GPO
Type V—Nylon-Base		
N-1	/9 Type NPG	nylon cloth-base, phenolic resin binder; excellent electrical properties under high humidity; good impact
Type VI—Composite-Base Laminates		
CEM-1	/29 Type CEM-1	cellulose paper core, glass surfaces, flame-resistant resin (see X1.28)
CEM-3	/30 Type CEM-3	non-woven glass core, glass surfaces, flame-resistant resin (see X1.29)

<sup>A</sup> Individual Specification Sheets are subsidiary documents of the main MIL-I-24768 standard, and are designated as MIL-I-24768/1, /2, and so forth. Revisions of this specification are designated by suffix letters added to the MIL-P or LP Specification number, A for the first revision, B for the second, and so forth. Reference shall accordingly be made to the latest edition of the specification.

tapping parallel with laminations. Grades XXX, CE, and LE are best suited to these operations.

## 7. Detail Requirements for Sheets

7.1 Sheet material shall conform to the requirements for physical and electrical properties prescribed in [Tables 7-12](#).

7.2 *Rate of Burning*—Tests shall be conducted on laminates from 1/32 to 1/4 in. (0.8 to 6.4 mm) in thickness in accordance with Method I of Test Methods [D229](#). The rate of burning shall be Class I for Grades FR-1, FR-2 and FR-3, and Class O for Grades FR-4, FR-5, CEM-1, G-5, G-7, G-9, and GPO-2.