

MILITARY SPECIFICATION · INCH-POUND

MIL-I-24768

Insulation, Plastics, Laminated, Thermosetting; General Specification For

This specification is approved for use by all departments and agencies of the Department of Defense.

DATE	AMSC	FSC	SUPERSEDING
25 FEB 1992	N/A	5970	See Section 6

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1. Scope

1.1 Scope. This specification covers thermosetting plastic laminated insulation materials for mechanical and electrical military applications.

1.2 Classification. The form and type of insulation shall be as specified in the applicable specification sheet (see 3.1 and 6.2.1).

1.2.1 Types. The types of insulation grouped according to the base material used, shall be as follows:

A. COTTON FABRIC BASE, PHENOLIC-RESIN BINDER

FBE	Cotton Fabric Base, Phenolic-Resin, Electrical Grade
FBG	Cotton Fabric Base, Phenolic-Resin, General Purpose
FBI	Cotton Fabric Base, Phenolic-Resin, Machining Applications
FBM	Cotton Fabric Base, Phenolic-Resin, Mechanical Grade

B. GLASS FABRIC BASE, EPOXY-RESIN BINDER

GEE	Glass Fabric Base, Epoxy-Resin, Electrical Grade
GEB	Glass Fabric Base, Epoxy-Resin, High Temperature Electrical Grade
GEE-F	Glass Fabric Base, Epoxy-Resin, Flame Resistant, Electrical Grade
GEB-F	Glass Fabric Base, Epoxy-Resin, High Temperature, Flame Resistant, Electrical Grade

C. GLASS FABRIC BASE, MELAMINE-RESIN BINDER

GME	Glass Fabric Base, Melamine-Resin, Electrical Grade
GMG	Glass Fabric Base, Melamine-Resin, General Purpose

D. GLASS MAT BASE, POLYESTER-RESIN BINDER

GPO N-1	Glass Mat Base, Polyester-Resin, Mechanical Grade
GPO N-2	Glass Mat Base, Polyester-Resin, Low Flammability and Self-extinguishing Properties, General Purpose
GPO N-3	Glass Mat Base, Polyester-Resin, Track Resistance, Low Flammability and Self-extinguishing Properties, General Purpose
GPO N-1P	Glass Mat Base, Polyester-Resin, Mechanical Grade, Punching Characteristics
GPO N-2P	Glass Mat Base, Polyester-Resin, Low Flammability, Self-extinguishing Properties, Punching Characteristics
GPO N-3P	Glass Mat Base, Polyester-Resin, Track Resistance, Low Flammability, Self-extinguishing Properties, Punching Characteristics

E-H. SILICONE, PTFE, PHENOLIC AND NYLON FABRIC BASES

GSG	Glass Fabric Base, Silicone-Resin, General Purpose
GTE	Glass Fabric Base, Polytetrafluoroethylene-Resin, Electrical Grade
GPG	Glass Fabric Base, Phenolic-Resin, General Purpose
NPG	Nylon Fabric Base, Phenolic-Resin, General Purpose

I. PAPER BASE, PHENOLIC-RESIN BINDER

PBE	Paper Base, Phenolic-Resin, Electrical Grade
PBG	Paper Base, Phenolic-Resin, General Purpose
PBM	Paper Base, Phenolic-Resin, Mechanical Grade
PBM-P	Paper Base, Phenolic-Resin, Hot Punching Stock, Mechanical Grade
PBM-PC	Paper Base, Phenolic-Resin, Cold Punching and Shearing Stock, Mechanical Grade
PBG-P	Paper Base, Phenolic-Resin, Hot Punching Stock, General Purpose
PBE-P	Paper Base, Phenolic-Resin, Hot Punching Stock Electrical Grade
PBE-PC	Paper Base, Phenolic-Resin, Cold Punching Stock, Electrical Grade
PBM-PF	Paper Base, Phenolic-Resin, Hot Punching Stock, Flame Resistant, Mechanical Grade
PBE-PCF	Paper Base, Phenolic-Resin, Cold Punching Stock, Flame Resistant, Electrical Grade

J-K. PAPER AND CONTINUOUS FILAMENT GLASS CLOTH, EPOXY-RESIN BINDER

PEE	Paper Base, Epoxy-Resin, Flame Resistant, Electrical Grade
CEM-1	Glass Cloth Base, Epoxy-Resin, Cellulose Core
CEM-3	Glass Cloth Base, Epoxy-Resin, Non-woven Core

1.2.2 Form of Insulation. The Insulation forms shall be as follows:

Form R Rods	Form S Sheets	Form TRR Tubes, rolled, round	Form TMR Tubes, molded, round
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1.2.3 Sizes. The sizes of insulation shall be as specified in the individual specification sheets (see 3.1).

2. Applicable Documents

2.1 Government Documents.

2.1.1 Specifications and Standards. The following specification and standards form a part of this document to the extent specified herein. Unless otherwise specified, the issues of these documents shall be those listed in the issue of the Department of Defense Index of Specification and Standards (DODISS), and supplement thereto, cited in the solicitation (see 6.2).

SPECIFICATIONS — FEDERAL

PPP-F-320	Fiberboard, Corrugated and Solid, Sheet Stock (Container Grade) and Cut Shapes
UU-P-268	Paper, Kraft, Wrapping

SPECIFICATIONS — MILITARY

MIL-P-116	Preservation, Methods of
MIL-L-19140	Lumber and Plywood, Fire Retardant Treated

STANDARDS — FEDERAL

FED-STD-406	Plastics: Methods of Testing
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STANDARDS — MILITARY

MIL-STD-104	Limits for Electrical Insulation Color
MIL-STD-105	Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-130	Identification Marking of U.S. Military Property
MIL-STD-1186	Cushioning, Anchoring, Bracing, Blocking and Waterproofing with Appropriate Test Methods
MIL-STD-2073-1	DOD Material Procedures for Development and Application of Packaging Requirements

(See supplement 1 for list of associated specifications.)

(Unless otherwise indicated, copies of federal and military specification, standards, and handbooks are available from the Standardization Documents Order Desks, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.2 Other Publications. The following documents form a part of this document to the extent specified herein. Unless otherwise specified, the issues of the documents which are DOD adopted shall be those listed in the issue DODISS specified in the solicitation. Unless otherwise specified, the issues of documents not listed in the DODISS shall be the issue of the non-government documents which is current on the date of the solicitation (see 6.2).

NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION (NEMA)

LI-1	Industrial Laminated Thermosetting Products
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(Application for copies should be addressed to the National Electrical Manufacturers Association, 2101 L Street, NW, Washington, DC 20037.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

D 150	Standard test methods for AC loss characteristics and permittivity (dielectric constant) of solid electrical insulating materials; (DOD adopted)
D 229	Standard method of testing rigid sheet and plate materials used for electrical insulation; (DOD adopted)
D 256	Standard test methods for impact resistance of plastics and electrical insulating materials; (DOD adopted)
D 257	Standard test methods for D-C resistance or conductance of insulating materials; (DOD adopted)
D 348	Standard methods of testing rigid tubes used for electrical insulation
D 349	Standard laminated round rods used for electrical insulation
D 374	Standard test methods for thickness of solid electrical insulation
D 495	Standard test method for high-voltage, low-current, dry are resistance of solid electrical insulation; (DOD adopted)
D 570	Standard test method for water absorption of plastics; (DOD adopted)
D 618	Standard methods of conditioning plastics and electrical insulating materials for testing; (DOD adopted)
D 668	Standards methods of measuring dimensions of rigid rods and tubes used for electrical insulation
D 792	Standard tests methods for specific gravity, relative density and density of plastics by displacement; (DOD adopted)
D 877	Standard test method for dielectric breakdown voltage of insulating liquids using disk electrodes; (DOD adopted)
D 3951	Standard practice for commercial practice; (DOD adopted)
D 2303	Standard test method for liquid-contaminant, inclined-plane tracking and erosion of insulation materials
D 2304	Standard method for thermal evaluation of rigid electrical insulating materials
G 21	Standard recommended practice for determining resistance of synthetic polymeric materials to fungi; (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.)

UNIFORM CLASSIFICATION COMMITTEE AGENT

Uniform Freight Classification Ratings, Rules and Regulations

(Application for copies should be addressed to the Uniform Classification Committee Agent, Room 1106, 222 South Riverside Plaza, Chicago, IL 60606.)

(Non-government Standards and other publications are normally available from the organization which prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for associated detail specifications, specification sheets or MS standards), the test of this specification shall take precedence. Nothing in this document, however, shall supersede applicable laws and regulations unless a specific exemption has been obtained.

3. Requirements

3.1 Specification sheets. The individual item requirements shall be as specified herein and in accordance with the applicable specification sheets. In the event of any conflict between requirements of this specification and the specification sheets, the latter shall govern.

3.2 First article. When specified (see 6.2) a sample shall be subjected to first article inspection (see 4.5 and 6.5).

3.3 Material. The material shall be as specified herein and in accordance with the applicable specification sheets (see 3.1).

3.3.1 Sheets. Sheets shall consist of a base or filler, properly impregnated with a thermosetting-resin compound or binder, and processed to conform to the specification sheets.

3.3.2 Rods. Rods shall be composed of laminations of impregnated sheet material which have been molded in cylindrical molds under high pressure and temperature and then ground to size.

3.3.3 Tubes. Tubes shall be formed by rolling impregnated sheet materials upon mandrels between heat pressure rolls and then either oven-baking for rolled tubes or pressing the material in a heated mold for molded tubes until the curing or setting of the resins into the infusible form is completed.

3.3.4 Recovered materials. Unless otherwise specified herein, all materials incorporated in the products covered by this specification shall be new and may be fabricated using material produced from recovered materials to the maximum extent practicable without jeopardizing the intended use. The term "recovered materials" means materials which have been collected or recovered from solid waste and reprocessed to become a source of raw materials, as opposed to virgin raw materials. None of the above shall be interpreted to mean that the use of used products is allowed under this specification unless otherwise specified.

3.4 Physical Characteristics. The insulation material shall be of the construction and dimensions, and have the property values specified herein and in the applicable specification sheet (see 3.1).

3.4.1 Machinability. The laminated material shall be such that it can be drilled, tapped, sawed, and machined in all directions without cracking, splitting or otherwise impairing the material for general use. The nature of laminated materials necessitates special precautions when drilling or tapping parallel to laminations.

3.4.1.1 Fine machining applications. The laminated materials FBI and FBE shall be suitable for fine machining applications requiring close tolerances.

3.4.2 Color. Unless otherwise specified (see 3.1 and 6.2), laminated materials designated GSG, FBE, FBG, FBI, FBM, and NPG shall be natural in color, which may vary from white to light brown. Natural color is the color produced by a combination of a natural undyed base or filler and the resin used. The brown color due to heat treatment of glass fibers may be streaked or mottled, provided it can be shown that a non-uniform color does not impair the performance characteristics of the material. The color for the other materials shall conform to MIL-STD-104 if rated above 2000 volts, and natural color if used below 2000 volts.

3.4.3 Uniformity. All material of any lot shall be uniform in texture, finish, and specified properties.

3.4.4 Surface finish.

3.4.4.1 Laminated sheets. Unless otherwise specified (see 6.2), the surface finish of laminated sheets shall be semigloss as produced by the laminating process.

3.4.4.2 Laminated tubes and rods. Unless otherwise specified (see 6.2), tubes shall be furnished in the following finishes.

3.4.4.2.1 Ground. Ground finish is applied by a fine grinding wheel or belt and is free from any pronounced scratches.

3.4.4.2.2 Buffed. Buffed finish is somewhat more glossy than the ground finish and is obtained by buffing the tube or rod immediately after grinding, using a small amount of shellac or other polishing compound on the buffer.

3.4.4.2.3 Varnished. Varnished finish is obtained by coating the rod or tube with varnish and then air-drying or baking. Due to the operations involved with a varnished finish, the physical and electrical properties may change greatly.

3.4.5 Surface defects.

3.4.5.1 Laminated sheets. Sheets shall be free from internal and external blisters, wrinkles, or cracks and other small defects such as scratches, dents, or heat marks. If the insulation material contains a glass fabric, differential coloration of various warp or filler threads of the glass fabric or the filament of the non-woven parallel alignment fibers may cause streaks.

3.4.5.2 Laminated tubes and rods. Laminated tubes shall be free from blisters, pronounced mandrel scores, loose layers, resin pockets, voids, and heat marks. Rolled tubes shall be free from wrinkles. Molded tubes shall be free from seam cracks. Rods shall be free from blisters, mold seam cracks, voids, and resin pockets. Tubes with a wall thickness greater than 0.500 inch or rods with a diameter greater than 1.000 inch may show checks or cracks between the laminations on machined or sawed edges. Edges, drilled holes, and machined, milled or ground faces of laminated rods and tubes shall be smooth and shall present a neat appearance.

3.4.6 Warp or Twist.

3.4.6.1 Standard 36 by 36 inches laminated sheets. The warp or twist of material as delivered, shall not exceed the values of table I. Percentage of warp is given in terms of lateral dimensions (length and width) of the material and percentage of twist is given in terms of dimensions from one corner to the opposite corner.

TABLE I. WARP OR TWIST.

Thickness (inches)	Maximum Variation (percent)
0.031 to 0.061	5.00
0.062 to 0.124	2.50
0.125 to 0.250	1.00 ¹
0.251 to 0.750	0.50
0.751 to max.	0.25

¹ The value for type GSG shall be 1.5 percent.

3.4.6.2 Non-Standard Sheets. The warp or twist of laminated sheets other than 36 inches shall be determined using the following formula:

$$\frac{D_x}{D_{36}} = \frac{L_x^2}{(36)^2}$$

D_x = Permissible deviation from straight edge in inches for the given length

D_{36} = Permissible deviation in inches for 36 inch lengths

L_x = The given length in inches

3.4.6.3 Laminated tube and rods. The warp material furnished in the tube or rod form, as delivered, shall not exceed the values specified in table II. Percentage of warp is specified in terms of a 36-inch length of material. Measurement of warpage shall be as specified in ASTM D 668.

TABLE II. WARP.

Outside Diameter (inch)	Maximum Variation (percent)
0.125 to 0.250	2.00
0.251 to 0.750	1.00 ¹
0.751 to max.	0.50

¹ The value for type GSG shall be 1.5 percent.

3.4.7 Length and Width.

3.4.7.1 Laminated Sheets. Unless otherwise specified (see 3.1), the contractor's standard sizes between 18 and 50 inches in width and 36 and 96 inches in length will be acceptable. The length and width of sheets may vary $\pm$ one inch from the contractor's standard size. Non-uniform standard sheet dimensions caused by cutting specimens for tests required by this specification shall not be cause for rejection, unless particular dimensions are specified. When particular sheet dimensions are specified (see 6.2), the permissible variation from specified length or width shall be as shown in table III.

3.4.7.2 Laminated Tubes and Rods. Unless otherwise specified (see 6.2), tubes and rods shall be furnished in contractor's standard lengths, with a tolerance of $\pm$ one inch.

3.4.7.2.1 Tubes. When specified (see 6.2), the tubes shall be furnished cut to length, circular-sawed, within the tolerances shown in table IV. Dimensions shall be measured as specified in ASTM D 688.

3.4.7.2.2 Rods. When specified (see 6.2), rods shall be furnished cut to length within the tolerances shown in table V. Dimensions shall be measured as specified in ASTM D 668.

TABLE III. PERMISSIBLE VARIATIONS IN LENGTH OR WIDTH.

Thickness (inches)	Permissible variation ($\pm$ inch)		
	6 inches and under	6.001 to 23.999 inches	24 inches and over
Up to 0.250	0.010	0.015	0.031
0.251 to 0.500	0.012	0.017	0.031
0.501 to 1.000	0.015	0.020	0.031
1.001 to 1.500	0.018	0.030	0.062
1.501 to 3.500	0.022	0.040	0.062

TABLE IV. TOLERANCES OF CUT ROUND TUBES.

Tube Length (inches)	Tolerances ($\pm$ inch) — Outside Diameter (inches)			
	Min. to 2.000	2.001 to 4.000	4.001 to 8.000	8.001 to max.
Min. to 3.000	0.010	0.010	0.030	—
3.001 to 6.000	0.010	0.015	0.030	—
6.001 to 12.000	0.015	0.020	0.030	—
12.001 to 48.000	0.031	0.031	0.047	—
48.001 to 72.000	0.062	0.078	0.094	0.188
72.001 to 96.000	0.094	0.094	0.125	0.250

TABLE V. TOLERANCES OF CUT RODS.

Rod Length (inches)	Tolerances ($\pm$ inch) — Outside Diameter	
	0.125 to 1.999 inches	2 to 4 inches
Min. to 3.000	0.010	0.010
3.001 to 6.000	0.010	0.015
6.001 to 12.000	0.015	0.020
12.001 to 48.000	0.030	0.031

3.4.8 Thickness and diameter.

3.4.8.1 Laminated Sheets. Sheets shall be furnished in the nominal thickness as specified (see 3.1 and 6.2). At least 90 percent of the area of the sheet shall be within the variations specified and at no point shall the thickness, as measured, vary from the nominal thickness by a value greater than 125 percent of tolerance specified. Dimensions shall be measured as specified in ASTM D 374.

3.4.8.2 Laminated Rods and Tubes. The diameter of rods and the inside diameter, outside diameter and wall thickness of round tubes shall be as specified (see 3.1 and 6.2). Tolerances for tubes shall be as specified in table VI and VII. Tolerances for rods shall be as specified in table VIII. Dimensions shall be measured as specified in ASTM D 668.

TABLE VI. DIAMETRAL TOLERANCES FOR ROUND TUBES.

Type	Nominal Diameter (inches)	Inside Diameter ($\pm$ inch)		
		Steel Mandrel ¹	Built-up Mandrel ²	Outside Diameter ($\pm$ inch)
Rolled and molded	0.125 to 0.749	0.003	—	0.005
	0.750 to 1.999	0.004	—	0.005
	2.000 to 4.000	0.008	—	0.008
Rolled only	4.001 to 12.000	0.010	—	0.025
	12.001 to 18.000	0.030	0.060	0.030 ³
	18.001 to 24.000	0.040	0.075	0.035 ³
	24.001 to 48.000	0.060	0.090	0.040 ³

¹ The GMG tubes are made on steel mandrels only.

² In the absence of mandrel of the precise size required, tubes of that size can sometimes be made on a built-up mandrel. In such cases, this is accomplished by winding a phenolic laminate rolled tube on the next smaller size steel mandrel and then curling and grinding the tube to the desired size.

³ Tubes from 12.001 to 48.000 inches outside diameter shall be turned to the prescribed permissible variations in outside diameter.

TABLE VII. STEPS IN INSIDE AND OUTSIDE DIAMETERS.

Type ¹	Inside Diameter (inches) ²	Outside Diameter (inches)	Increments of sizes of tubes (inch)
Rolled tubes	0.125 – 1.000	—	0.031
	1.001 – 3.000	—	0.062
	3.001 – 6.000	—	0.125
	6.001 – 8.000	—	0.250
	8.001 – 25.000	—	0.500
Molded tubes	0.125 – 1.000	0.188 – 1.000	0.031
	1.001 – 3.000	1.001 – 3.000	0.062
	3.001 – 3.875	3.001 – 4.000	0.125

¹ No standards have been developed for type GMG tubes with an inside diameter greater than 8.000 inches.

² In the range of inside diameters from 8.001 to 25.000, standard steps of 0.500 inch are indicated. In some cases, these inside diameters can only be achieved by the use of built-up mandrels.

TABLE VIII. DIAMETRAL TOLERANCES FOR RODS.

Diameter (inches)	Tolerances ($\pm$ inch)
0.125 to 1.999	0.005
2.000 to 4.000	0.008

3.4.9 Marking.

3.4.9.1 Laminated Sheets. Each full sized sheet shall be legibly marked on the right-hand corner on each side with the contractor's name or trademark and the insulation type as specified in 1.2.1. Such markings shall not be obliterated by normal processing nor shall they affect the physical or electrical properties of the base material. The contractor's name or trademark shall be in accordance with MIL-STD-130.

3.4.9.2 Laminated Tubes and Rods. Each bundle of tubes or rods shall be identified with the contractor's name or trademark and the insulation type as specified in 1.2.1. The contractor's name or trademark shall be in accordance with MIL-STD-130.

3.5 Property Values

3.5.1 Dielectric Breakdown

The laminated material shall exceed the minimum dielectric breakdown voltage as specified in the applicable specification sheets (see 3.1 and 4.6.4).

3.5.2 Dielectric Strength

The laminated material shall exceed the minimum dielectric strength voltage as specified in the applicable specification sheets (see 3.1 and 4.6.5).

3.5.3 Dielectric Constant (permittivity)

The maximum dielectric constant of the laminated material shall not exceed the value as specified in the applicable specification sheets (see 3.1 and 4.6.6).

3.5.4 Dissipation Factor

The laminated material shall not exceed the maximum dissipation factor as specified in the applicable specification sheets (see 3.1 and 4.6.6).

3.5.5 Volume Resistivity

The laminated material shall exceed the minimum volume resistivity as specified in the applicable specification sheets (see 3.1 and 4.6.7).

3.5.6 Surface Resistance

The laminated material shall exceed the minimum surface resistance as specified in the applicable specification sheets (see 3.1 and 4.6.8).

3.5.7 Arch Resistance (dry tracking)

The laminated material shall exceed the minimum time limit required for arc resistance as specified in the applicable specification sheets (see 3.1 and 4.6.9).

3.5.8 Tracking Resistance (wet tracking)

The minimum time to track to the one-inch mark shall be not less than the value specified in the applicable specification sheets (see 3.1 and 4.6.10).

3.5.9 Impact Strength

The laminated material shall exceed the minimum impact strength as specified in the applicable specification sheets (see 3.1 and 4.6.11).

3.5.10 Flexural Strength

The laminate material shall exceed the minimum flexural strength as specified in the applicable specification sheets (see 3.1 and 4.6.12).

3.5.11 Thermal Endurance

The flexural strength shall be not less than the value specified in the applicable specification sheets (see 3.1 and 4.6.13).

3.5.12 Compressive Strength

The average minimum compressive strength of the laminated material shall be not less than the value specified in the applicable specification sheets (see 3.1 and 4.6.14).

3.5.13 Bonding Strength

The laminated material shall exceed the minimum bonding strength as specified (see 3.1 and 4.6.15).

3.5.14 Specific Gravity

The minimum specific gravity of the laminated material shall be not less than the value specified in the applicable specification sheets (see 3.1 and 4.6.16).

3.5.15 Water Absorption

The laminated material shall not exceed the maximum water absorption as specified in the applicable specification sheets (see 3.1 and 4.6.17).

3.5.16 Silicone Content

The silicone content shall not exceed the value specified in the applicable specification sheets (see 3.1 and 4.6.18).

3.5.17 Flammability.

3.5.17.1 Burning Rate. The burning rate of the laminated sheets shall be either class 0 or class 1 as specified in the applicable specification sheets (see 3.1 and 4.6.19.1).

3.5.17.2 Flam Resistance. The average ignition time shall be not less and the average burning time shall be not greater than the specified in the applicable specification sheets (see 3.1 and 4.6.19.2).

3.5.18 Fungus Resistance. The laminated material shall resist the growth of fungi and shall have a visual rating of "0" (see 4.6.20).

3.6 Workmanship. Laminated rods, tubes, and sheet materials shall be manufactured and processed in a careful and workmanlike manner and shall be free from defects which may affect the appearance of serviceability. The resin shall be completely bonded to the base material and shall show no exposed reinforcement.