

PLASTIC SHEET, COPPER FACED  
Glass Fabric Reinforced Epoxy Resin, Flammability Controlled

1. SCOPE:

1.1 Form: This specification covers epoxy-resin-impregnated glass fabric laminates in the form of sheet clad on one or both sides with electrolytically-deposited copper foil.

1.2 Application: Primarily for use in etched, printed circuits used in electrical and electronic equipment where low moisture absorption and superior bond strength are required.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The latest issue of Aerospace Material Specifications (AMS) shall apply. The applicable issue of other documents shall be as specified in AMS 2350.

2.1 SAE Publications: Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

SAE Technical Board rules provide that: "All technical reports, including standards approved and practices recommended, are advisory only. Their use by anyone engaged in industry or trade or their use by governmental agencies is entirely voluntary. There is no agreement to adhere to any SAE standard or recommended practice, and no commitment to conform to or be guided by any technical report. In formulating and approving technical reports, the Board and its Committees will not investigate or consider patents which may apply to the subject matter. Prospective users of the report are responsible for protecting themselves against liability for infringement of patents."

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2.2 ASTM Publications: Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

- ASTM D149 - Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
- ASTM D150 - A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials
- ASTM D229 - Testing Rigid Sheet and Plate Materials Used for Electrical Insulation
- ASTM D495 - High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation
- ASTM D568 - Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position
- ASTM D570 - Water Absorption of Plastics
- ASTM D618 - Conditioning Plastics and Electrical Insulating Materials for Testing
- ASTM D709 - Laminated Thermosetting Materials
- ASTM D790 - Flexural Properties of Plastics and Electrical Insulating Materials
- ASTM D1825 - Etching and Cleaning Copper Clad Electrical Insulating Materials and Thermosetting Laminates for Electrical Testing
- ASTM D3636 - Sampling and Judging Quality of Solid Electrical Insulating Materials
- ASTM G21 - Determining Resistance of Synthetic Polymeric Materials to Fungi

2.3 U.S. Government Publications: Available from Commanding Officer, Naval Publications and Forms Center, 5801 Tabor Avenue, Philadelphia, PA 19120.

2.3.1 Military Specifications:

MIL-F-55561 - Foil, Copper, Cladding for Printed Wiring Boards

2.3.2 Military Standards:

MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

2.4 Other Publications: Available from Underwriters' Laboratories, Inc., 333 Pfingsten Road, Northbrook, IL 60602.

UL94 - Flammability of Plastic Materials for Parts in Devices and Appliances

3. TECHNICAL REQUIREMENTS:

3.1 Materials:

3.1.1 Construction: The sheet shall be constructed of laminations of glass fabric thoroughly impregnated with an epoxy resin and properly cured. Face sheets of copper may be applied to one or both faces during the original cure of the laminate or in a subsequent operation.

3.1.2 Designations: Sheet shall be designated according to the following numbering system:

- a. Material
- b. Copper foil thickness (in.) (mm)
- c. Total thickness (in.) (mm)
- d. Thickness tolerances required - Normal (N) or Close (C)
- e. No. of sides laminated with copper foil

Example: EGL1-0.125N-2

Means: Sheet, faced epoxy glass fabric laminated, 0.0014 in. (0.035 mm) thick copper foil, total sheet thickness of 0.125 in. (3.15 mm), normal thickness tolerances and copper foil on both sides.

3.1.3 Color: The color of the plastic laminate shall be natural, unless otherwise specified.

3.1.4 Copper Faces: Shall be electrolytically deposited copper foil conforming to MIL-F-55561, Type I.

3.2 Properties: Sheet shall conform to the following requirements. Tests shall be performed on the sheet supplied and in accordance with specified test methods, insofar as practicable. Specimens shall be conditioned in accordance with ASTM D618, Procedure A, prior to testing. For specimens requiring removal of copper faces before testing (See 4.5.1), the conditioning shall follow removal of the copper. Where requirements vary with thickness, use the value for the next lower thickness for thicknesses not specified.

3.2.1 Dielectric Strength:

3.2.1.1 Perpendicular to Laminations,

ASTM D149

Short Time Test, min  
Nominal Sheet Thickness  
 Inch (Millimetres)

0.031	(0.75)	600 V per mil (23.6 kV/mm)
0.062	(1.55)	500 V per mil (19.7 kV/mm)
0.125	(3.15)	425 V per mil (16.7 kV/mm)
0.250	(6.25)	400 V per mil (10.0 kV/mm)

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3.2.1.2	Parallel to Laminations, Stepwise Test, min		ASTM D229
3.2.1.2.1	As received	45 kV per in. (1.96 kV/mm)	
3.2.1.2.2	After 48 hr immersion in distilled water at 122°F + 4 (50°C + 2)	30 kV per in. (1.17 kV/mm)	
3.2.2	Dielectric Constant at 1 MHz, max	5.4	ASTM D150
3.2.3	Dissipation Factor at 1 MHz, max	0.035	ASTM D150
3.2.4	Arc Resistance, min	60 sec	ASTM D495
3.2.5	Insulation Resistance, min	1000 megohm	4.5.2
3.2.6	Flexural Strength, min		ASTM D790
3.2.6.1	Lengthwise, at 25°C + 5 (77°F + 10)	50,000 psi (345 MPa)	
3.2.6.2	Crosswise, at 25°C + 5 (77°F + 10)	40,000 psi (275 MPa)	
3.2.7	Peel Strength, min		4.5.3
	As Received		
	<u>Nominal Foil Thickness</u>		
	Inch (Millimetres)		
	0.0014 (0.035)	8 lb per in. (1400 N/m) of width	
	0.0028 (0.070)	10 lb per in. (1750 N/m) of width	
3.2.8	Solder Bath Resistance	No softening, splitting, blistering, or delamination; peel strength as in 3.2.7	4.5.4
3.2.9	Temperature Cycling Resistance	No blistering; peel strength as in 3.2.7	4.5.5

3.2.10 Solvent Resistance No softening, blistering or lifting of base laminate and residual surface adhesive 4.5.6

3.2.11 Copper Porosity Not more than 3 resin spots 0.015 in. (0.4 mm) or less in diameter spaced not less than 1 in. (25 mm) apart for each 12 x 12 in. (300 x 300 mm). No resin spot greater than 0.015 in. (0.4 mm). The total point count shall be less than 30 for any 12 x 12 in. (300 x 300 mm). 4.5.7

3.2.12 Water Absorption in 24 hr, max ASTM D570

<u>Nominal Sheet Thickness</u>		
Inch	(Millimetres)	
0.031	(0.75)	0.50%
0.062	(1.55)	0.30%
0.125	(3.15)	0.18%
0.250	(6.25)	0.15%

3.2.13 Flame Resistance (see 8.1): 4.5.8

3.2.13.1 Average Time of Burning, max

<u>Nominal Sheet Thickness</u>		
0.030 in. (0.75 mm) and under		30 sec
Over 0.030 in. (0.75 mm)		25 sec

3.2.13.2 Average Extent of Burning, max

<u>Nominal Sheet Thickness</u>		
0.030 in. (0.75 mm) and under		3 in. (75 mm)
Over 0.030 in. (0.75 mm)		2 in. (50 mm)

3.2.14 Fungus Resistance No fungus growth ASTM G21

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3.3 Quality: Sheet, as received by purchaser, shall be uniform in quality and condition and free from blisters, cracks, holes, cuts, wrinkles, delamination, unbonded areas, corrosion, excess bonding material, and other defects detrimental to usage of the sheet. Discoloration of the copper faces is acceptable. The bonded copper faces shall be of such smoothness as not to reveal visible evidence of the underlying glass fabric weave.

3.4 Tolerances:

3.4.1 Length and Width: Shall not vary more than +1.0 in. (+25 mm), -0 from that ordered except where test specimens have been removed.

3.4.2 Thickness:

3.4.2.1 Copper face standard thicknesses and tolerances shall be as follows:

TABLE I

Nominal Thickness Inch	Tolerance, Inch	
	plus	minus
0.0014	0.0004	0.0002
0.0028	0.0007	0.0003

TABLE I (SI)

Nominal Thickness Millimetre	Tolerance, Millimetre	
	plus	minus
0.035	0.010	0.005
0.070	0.018	0.008

3.4.2.2 Sheet Thickness: The total thickness of the finished sheet, including copper faces, shall be in accordance with the following: sheet conforming to the normal thickness tolerances shall be supplied, unless otherwise specified. When other thicknesses are specified, the tolerance for the next greater thickness shall apply.

3.4.2.2.1 Normal Thickness Tolerances:

TABLE II

Nominal Thickness Inch	Tolerance, Inch, Plus and Minus			
	Copper on One Side Only		Copper on Both Sides	
	0.0014 in.	0.0028 in.	0.0014 in.	0.0028 in.
0.031	0.0055	0.0065	0.0065	0.0075
0.062	0.0065	0.0075	0.0075	0.0085
0.125	0.011	0.012	0.012	0.013

TABLE II (SI)

Nominal Thickness Millimetres	Tolerance, Millimetre, Plus and Minus			
	Copper on One Side Only		Copper on Both Sides	
	0.035 mm	0.070 mm	0.035 mm	0.070 mm
0.75	0.140	0.165	0.165	0.190
1.55	0.165	0.190	0.190	0.216
3.15	0.28	0.30	0.30	0.33

3.4.2.2.1.1 At least 90% of the sheet shall be within the specified tolerance and at no point shall the thickness vary from the nominal thickness by more than 125% of the specified tolerances.

3.4.2.2.2 Close Thickness Tolerances:

TABLE III

Nominal Thickness Inch	Tolerance, Inch, Plus and Minus			
	Copper on One Side Only		Copper on Both Sides	
	0.0014 in.	0.0028 in.	0.0014 in.	0.0028 in.
0.031	0.004	0.005	0.005	0.006
0.062	0.005	0.006	0.006	0.006
0.125	0.006	0.007	0.007	0.008

TABLE III (SI)

Nominal Thickness Millimetres	Tolerance, Millimetre, Plus and Minus			
	Copper on One Side Only		Copper on Both Sides	
	0.035 mm	0.070 mm	0.035 mm	0.070 mm
0.75	0.10	0.13	0.13	0.15
1.55	0.15	0.15	0.15	0.15
3.15	0.15	0.18	0.18	0.20

3.4.2.2.2.1 Specified tolerances shall be applicable over 100% of the area of the sheet.

3.4.3 Warp and Twist: Shall not exceed the following values for either thickness of copper, based on 36 in. (900 mm) length, determined in accordance with ASTM D229 or ASTM D709.

TABLE IV

<u>Nominal Sheet Thickness</u>		<u>Maximum Deviation, Percent</u>	
		<u>Copper on One Side Only</u>	<u>Copper on Both Sides</u>
<u>Inch</u>	<u>(Millimetres)</u>		
0.031 to 0.060, excl	(0.75 to 1.50, excl)	3.60	1.80
0.060 to 0.125, excl	(1.50 to 3.15, excl)	1.80	0.90
0.125 to 0.250, incl	(3.15 to 6.25, incl)	0.70	0.35

3.4.3.1 When it is desired to compare the actual deviation for any length, the following formula may be used:

$$D = 0.00077 \times D_{36} \times L^2$$

Where, D Permissible deviation from the straight edge in inches (millimetres) for the given length  
 D<sub>36</sub> Maximum deviation in inches (millimetres) for 36 in. (900 mm) length (from Table IV)  
 L The given length in inches (millimetres)

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of sheet shall supply all samples for vendor's tests and shall be responsible for performing all required tests. Results of such tests shall be reported to the purchaser as required by 4.6. Purchaser reserves the right to sample and to perform any confirmatory testing deemed necessary to ensure that the sheet conforms to requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for dielectric constant (3.2.2), dissipation factor (3.2.3), peel strength (3.2.7), solder bath resistance (3.2.8), copper porosity (3.2.11), and tolerances (3.4) are classified as acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Test to determine conformance to requirements for arc resistance (3.2.4), temperature cycling resistance (3.2.9), and water absorption (3.2.12) are classified as periodic tests and shall be performed at a frequency selected by the vendor unless frequency of testing is specified by purchaser.

4.2.3 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification are classified as preproduction tests and shall be performed on the initial shipment of sheet to a purchaser, when a change in material and/or processing requires reapproval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

4.2.3.1 For direct U.S. Military procurement, substantiating test data and, when requested, preproduction test material shall be submitted to the cognizant agency as directed by the procuring activity, the contracting officer, or the request for procurement.

4.3 Sampling: Shall be as follows:

4.3.1 For Acceptance Tests: Sufficient sheet shall be taken at random from each lot to perform all required tests. The number of tests for each requirement shall be as specified in the applicable test procedure or, if not specified therein, not less than three.

4.3.1.1 A lot shall be all sheet produced in a single production run from the same batches of raw materials under the same fixed conditions and presented for vendor's inspection at one time. Not more than 4 sq ft (0.37 m<sup>2</sup>) shall be cut from each thickness in a shipment for testing. The size of the portion of sheet removed shall be stated on the outside of the package. The unit of product for determining sample size for testing (See ASTM D3636) shall not exceed 150 lb (68 kg) of sheet. Sheet may be packaged and delivered in smaller quantities under a basic lot approval provided the lot identification is maintained.

4.3.1.2 When a statistical sampling plan and acceptance quality level (AQL) have been agreed upon by purchaser and vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3.1 and the report of 4.6.1 shall state that such plan was used.

4.3.2 For Periodic and Preproduction Tests: As agreed upon by purchaser and vendor.

4.4 Approval:

4.4.1 Sample sheet shall be approved by purchaser before sheet for production use is supplied, unless such approval be waived by purchaser. Results of tests on production sheet shall be essentially equivalent to those on the approved sample.

4.4.2 Vendor shall use ingredients, manufacturing procedures, processes, and methods of inspection on production sheet which are essentially the same as those used on the approved sample sheet. If necessary to make any change in ingredients, in type of equipment for processing, or in manufacturing procedures, vendor shall submit for reapproval a statement of the proposed changes in material and/or processing and, when requested, sample sheet. Production sheet made by the revised procedure shall not be shipped prior to receipt of reapproval.

4.5 Test Methods:

- 4.5.1 Test Specimen Preparation: Specimens for dielectric strength (both directions), dielectric constant, and flexural strength shall have the copper facing removed in accordance with ASTM D385.
- 4.5.2 Insulation Resistance:
- 4.5.2.1 Circuit Test Specimens: Test specimens 2.00 x 2.50 in. (50.0 x 62.5 mm) x thickness of the sheet shall be made as shown in Fig. 1 or be the equivalent.
- 4.5.2.2 Specimen Preparation: Apply suitable resist to each test panel and develop Fig. 1 wiring pattern in accordance with best commercial practice. Remove unwanted copper in accordance with ASTM D1825 except that the final rinse shall be for 15 - 20 minutes. Immediately remove iron salts by immersing the wet panel in 10% oxalic acid at room temperature for 5 - 10 min. with occasional agitation. Rinse panel for at least 1 hr in running water at 15° - 30°C (60° - 90°F) and 15 - 20 min. in running water at 75° - 90°C (170° - 190°F). Dry for 2 - 2 1/2 hr in a forced circulating-air oven maintained at 65° - 80°C (150° - 180°F) and cool in a desiccator to room temperature and approximately 50% relative humidity. Drill necessary holes and solder lead wires into the holes using a pencil-type soldering iron or gun and water-white, unactivated rosin flux, filling the hole with a plug of solder. Remove excess flux and other contaminants by rinsing in clean mixture of 90% by volume ethanol and 10% by volume distilled water. Air dry. Care should be exercised to avoid touching critical areas of the clean specimen with bare hands.
- 4.5.2.3 Insulation Resistance Measurement: Mount test specimens in a circulating-air humidity chamber (provided with suitable specimen lead wire insulators on the chamber) maintained at a relative humidity of  $92\% \pm 2$  at  $65^{\circ}\text{C} \pm 2$  ( $150^{\circ}\text{F} \pm 4$ ) and expose for 18 hr  $\pm 1$ . Lower the relative humidity to  $87\% \pm 2$  while holding the temperature constant and stabilize the specimens at this condition for 2 - 2 1/4 hours. Apply 500 V direct current between terminal leads and maintain electrification time for at least 1 minute. Immediately thereafter, measure insulation resistance using a suitable megohm bridge (See 8.2). Measurements shall be performed while the relative humidity is  $87\% \pm 2$ .
- 4.5.3 Peel Strength:
- 4.5.3.1 Specimens conforming to Fig. 2 shall be cut from each sample sheet. The specimens shall be etched so that the strips on one specimen are lengthwise and the strips on the second specimen for the same clad side are crosswise. The specimens shall be bonded to a 0.063-in. (1.6-mm) thick aluminum alloy plate or any suitable rigid substrate if necessary to prevent bending of the base material during testing. The base material for Fig. 2 may extend 1 in. (25 mm) in a lengthwise direction to provide space for a hanghole. The metal foil shall be peeled back approximately 1 in. (25 mm) starting from the wider end of each strip, so that the

## 4.5.3.1 (Continued):

line of peel is perpendicular to the edge of the specimen. Each specimen shall be clamped or held on a horizontal surface with the peeled metal strip projecting upward 1 in. (25 mm). The end of the strip shall be gripped between two knurled jaws of a clamp with a chain attached to a force-indicator dial, or a tensile tester which has been adjusted to compensate for the weight of the chain and clamp.

4.5.3.2 Test Procedure: The load-recording device shall be capable of a direct reading with a precision not less than 0.1 lb per in. (17.5 N/m) of width. For nominal 1/32 in. (0.8 mm) lines, this value is 0.00325 lb (0.60 N). The jaws shall cover the full width of the strip and shall be clamped parallel to the line of peel. The force shall be exerted in a vertical plane and shall not deviate from the perpendicular by more than 5 degrees. The metal foil shall be pulled from the base material at a speed of 2 in. + 0.1 (50 mm + 3) per min.; the minimum load shall then be observed, converted to pounds-per-inch (N/m) of width and shall be considered the peel strength for the strip. If the full width of the strip does not peel, the results for that strip shall be discarded and another strip tested. The actual line widths shall be measured and recorded so that they may be used to calculate the peel strength. The peel strength for any specimen is the average of four strips on one side of the specimen: however, any strip more than 1.5 lb per in. (263 N/m) less than the specified minimum shall constitute a failure.

4.5.4 Solder Bath Resistance: Specimens as in 4.5.3.1 shall be dipped in liquid flux (rosin in alcohol) and then floated on the surface of molten solder with the copper face to be tested down. The solder shall be maintained at  $255^{\circ}\text{C} + 5$  ( $490^{\circ}\text{F} + 9$ ). After 20 sec exposure to the molten solder, the specimen shall be removed, visually examined, and tested as in 4.5.3.2.

4.5.5 Temperature Cycling Resistance: Specimens as in 4.5.3.1 shall be visually examined for evidence of blistering or delamination of the metal foil, or blistering of the base material, after exposure to five complete temperature cycles. Each cycle shall be 30 min. + 1 at  $125^{\circ}\text{C} + 3$  ( $260^{\circ}\text{F} + 5$ ), 15 min. + 1 at  $25^{\circ}\text{C} + 1$  ( $77^{\circ}\text{F} + 2$ ), 30 min. + 1 at  $-65^{\circ}\text{C} + 3$  ( $-85^{\circ}\text{F} + 5$ ), and 15 min. + 1 at  $25^{\circ}\text{C} + 1$  ( $77^{\circ}\text{F} + 2$ ). Any specimen failing this cycling test shall be rejected and further testing discontinued. Specimens passing the visual examination after temperature cycling shall be peel tested as 4.5.3.2.

4.5.6 Solvent Resistance: A 1 x 6 in. (25 x 150 mm) specimen, etched and rinsed in accordance with ASTM D1825 and dried, shall be vapor degreased for at least 30 sec, sprayed with recirculated degreaser solvent for at least 90 sec, and examined.

- 4.5.7 Copper Porosity: One half of a standard size sheet shall be vapor degreased and air dried. Lightly scrub the copper surfaces with a slurry of pumice and water, rinse thoroughly, and air dry. Handle board so that the copper surfaces are free of fingerprints, dust, and other contaminants. Examine in a dark room, using ultraviolet light, for fluorescent resin spots.
- 4.5.8 Flame Resistance (See 8.1):
- 4.5.8.1 Procedure for Laminates 0.030 in. (0.75 mm) and Under in Nominal Thickness: The flammability test shall be conducted in accordance with ASTM D568 with the exception that a 5-sec ignition time shall be used. The total burning time shall be recorded starting from the time the bottom of the flame reaches the lower gage mark until the flame either extinguishes or the bottom of the flame reaches the upper gage mark. A hole approximately 0.12 in. (3 mm) in diameter shall be drilled in the approximate center of the narrow dimension of the specimen at a point approximately 0.75 in. (19 mm) from the edge. A thin wire shall be fastened to the hole and a 100-g weight attached to the wire so that the weight hangs approximately 5 in. (125 mm) below the sample.
- 4.5.8.2 Procedure for Laminates Over 0.030 in. (0.75 mm) in Nominal Thickness: Flammability shall be tested in accordance with UL 94. The preconditioning procedure shall be changed to 24 hr at  $125^{\circ}\text{C} \pm 3$  ( $260^{\circ}\text{F} \pm 5$ ).
- 4.6 Reports:
- 4.6.1 The vendor of sheet shall furnish with each shipment three copies of a report showing the results of tests to determine conformance to the acceptance tests requirements and stating that the sheet conforms to the other technical requirements of this specification. This report shall include the purchase order number, AMS 3599, vendor's identification number, size, and quantity.
- 4.6.2 The vendor of finished or semi-finished parts shall furnish with each shipment three copies of a report showing the purchase order number, AMS 3599, contractor or other direct supplier of sheet, supplier's identification number, part number, and quantity. When sheet for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of sheet to determine conformance to the requirements of this specification and shall include in the report either a statement that the sheet conforms or copies of laboratory reports showing the results of tests to determine conformance.
- 4.7 Resampling and Retesting: If any specimen used in the above tests fails to meet the specified requirements, disposition of the sheet may be based on the results of testing three additional specimens for each original nonconforming specimen. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the sheet represented and no additional testing shall be permitted. Results of all tests shall be reported.