SAE Aerospace
An SAE International Group

AEROSPACE MATERIAL SPECIFICATION

SAE AMS 3599A

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Superseding AMS 3599

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.

1.3 Classification: This specification covers two types of copper-clad epoxy glass laminates, as follows; the type supplied shall be as specified on the drawing or purchase order:

Type I - Copper clad on one face
Type II - Copper clad on both faces

1.4 Safety - Hazardous Materials: While the materials, methods, applications and processes described or referenced in this specification may involve the use of hazardous materials, this specification does not address the hazards which may be involved in such use. It is the sole responsibility of the user to insure familiarity with the safe and proper use of any hazardous materials and to take necessary precautionary measures to ensure the health and safety of all personnel involved.

2. APPLICABLE DOCUMENTS: The following publications form a part of this specification to the extent specified herein. The applicable issue of other publications shall be the issue in effect on the date of the purchase order.

TO PLACE A DOCUMENT ORDER: **Tel: 877-606-7323 (inside USA and Canada)**
Tel: 724-776-4970 (outside USA)
Fax: 724-776-0790
Email: custsvc@sae.org
SAE WEB ADDRESS: **http://www.sae.org**

2.1 ASTM Publications: Available from ASTM, 1916 Race Street, Philadelphia, PA 19103-1187.

ASTM D 149 - Dielectric Breakdown Voltage and Dielectric Strength of Solid Electrical Insulating Materials at Commercial Power Frequencies
ASTM D 150 - A-C Loss Characteristics and Permittivity (Dielectric Constant) of Solid Electrical Insulating Materials
ASTM D 229 - Testing Rigid Sheet and Plate Materials Used for Electrical Insulation
ASTM D 495 - High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation
ASTM D 568 - Rate of Burning and/or Extent and Time of Burning of Flexible Plastics in a Vertical Position
ASTM D 570 - Water Absorption of Plastics
ASTM D 618 - Conditioning Plastics and Electrical Insulating Materials for Testing
ASTM D 709 - Laminated Thermosetting Materials
ASTM D 790 - Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials
ASTM D 790M - Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials (Metric)
ASTM D 1825 - Etching and Cleaning Copper-Clad Electrical Insulating Materials and Thermosetting Laminates for Electrical Testing
ASTM D 3636 - Sampling and Judging Quality of Solid Electrical Insulating Materials
ASTM G 21 - Determining Resistance of Synthetic Polymeric Materials to Fungi

2.2 U.S. Government Publications: Available from Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

2.2.1 Military Specifications:

MIL-C-81302 - Cleaning Compound, Solvent, Trichlorotrifluoroethane

2.2.2 Military Standards:

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

2.3 The Institute for Interconnecting and Packaging Electronic Circuits (IPC) Publication: Available from IPC, 7380 North Lincoln Ave., Lincolnwood, IL 60646.

IPC-CF-150 - Copper Foil for Printed Wiring Applications
IPC-S-804 - Solderability Test Methods for Printed Wiring Boards

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:
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a. Material, ASTM D 709, FR-4
b. Copper foil weight, ounces per square foot (kg/m^2)
c. Base laminate (without metal cladding) thickness, inch (mm)
d. Thickness tolerances required - Normal (N) or Close (C)
e. Number of sides laminated with copper foil

Example: EGL1-0.125N-2

Means: Sheet, faced epoxy glass fabric laminated, 1 ounce per square foot (0.3 kg/m^2) [0.0014 inch (0.036 mm)] thick copper foil, nominal base thickness of 0.125 inch (3.18 mm) without cladding, normal thickness tolerances and copper foil on two sides.

3.1.3 Color: The plastic laminate shall be natural in color.

3.1.4 Copper Faces: Shall be electrolytically deposited copper foil conforming
Ø to IPC-CF-150, Class 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 D 618, 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, Short Time Test, minimum — ASTM D 149

Nominal Sheet Thickness		
Inch	Millimetres	
0.031	0.79	600 V per mil (23.6 kV/mm)
0.062	1.57	500 V per mil (19.7 kV/mm)
0.125	3.18	425 V per mil (16.7 kV/mm)
0.250	6.35	400 V per mil (15.7 kV/mm)

3.2.1.2	Parallel to Laminations, Stepwise Test, minimum		ASTM D 229
3.2.1.2.1	As received	45 kV per inch (1.77 kV/mm)	
3.2.1.2.2	After 48 hour immersion in distilled water at 50°C ± 2 (122°F ± 4)	30 kV per inch (1.18 kV/mm)	
3.2.2	Dielectric Constant at 1 MHz, maximum	5.4	ASTM D 150
3.2.3	Dissipation Factor at 1 MHz, maximum	0.035	ASTM D 150
3.2.4	Arc Resistance, minimum	60 seconds	ASTM D 495
3.2.5	Insulation Resistance, minimum	1000 megohms	4.5.2
3.2.6	Flexural Strength, minimum		ASTM D 790 or ASTM D 790M
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 (276 MPa)	
3.2.7	Peel Strength, minimum		4.5.3

As Received

Nominal Foil Thickness		
Inch	Millimetres	
0.0014	0.036	8 pounds force per inch of width (1401 N/m of width)
0.0028	0.071	10 pounds force per inch of width (1751 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 Ø	Not more than 3 resin spots 0.005 inch (0.13 mm) greater in diameter spaced not less than 1 inch (25 mm) apart for each 12-inch (305-mm) square area. No resin spot with an included area greater than a 0.015-inch (0.38-mm) diameter circle.	4.5.7
3.2.12 Copper Surface Ø	Shall be free of imperfections that may affect serviceability The total point count for pits and dents shall be less than 30 for any 12-inch (305-mm) square area.	

3.2.12.1 The Point Count System is as follows:
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Largest Dimension of Pits and Dents		
Inch	Millimetres	Point Value
0.005 to 0.010, incl	0.13 to 0.25, incl	1
Over 0.010 to 0.020, incl	0.25 to 0.51, incl	2
Over 0.020 to 0.030, incl	0.51 to 0.76, incl	4
Over 0.030 to 0.040, incl	0.76 to 1.02, incl	7
Over 0.040	Over 1.02	30

3.2.13 Water Absorption in 24 hours, maximum ASTM D 570

Nominal Base Laminate Thickness		
Inch	Millimetres	Weight Gain, %
0.031	0.79	0.50
0.062	1.57	0.30
0.093	2.36	0.25
0.125	3.18	0.18
0.250	6.35	0.15

3.2.14 Flame Resistance (See 8.2) Maximum Average 4.5.8

Nominal Sheet Thickness	Time of Burning	Extent of Burning	
		Inches	mm
Up to 0.030 inch (0.76 mm)	30 seconds	3	76
Over 0.030 inch (0.76 mm)	25 seconds	2	51

3.2.15 Fungus Resistance No fungus growth ASTM G 21

3.2.16 Solderability: When laminates are tested as specified in 4.5.9, the
Ø metal clad surfaces shall not exhibit nonwetting, nor greater than 5% dewetting.

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 imperfections 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 inch (+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 shown in Table I:
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TABLE I

Nominal Thickness Inch	Thickness Tolerance, Inch plus	minus	Weight Oz/ft^2	Weight Tolerance, plus or minus Oz/ft^2
0.0014	0.0002	0.0001	1.00	0.100
0.0028	0.0004	0.0002	2.00	0.200

TABLE II

Nominal Thickness Millimetre	Thickness Tolerance, mm plus	minus	Weight Kg/m^2	Weight Tolerance Kg/m^2
0.036	0.005	0.003	0.30	0.03
0.071	0.010	0.005	0.61	0.06

3.4.2.2 Sheet Thickness: The nominal base laminate thickness of the finished
Ø sheet, excluding copper faces, shall be in accordance with Table II. Sheet conforming to the normal thickness tolerances shall be supplied. Tolerance is applied over the base plus cladding with no additional tolerance for cladding allowed.

TABLE II

Base Laminate (Without Cladding) Thickness, Inch	Tolerance, Inch, Plus and Minus	
	Normal Tolerance[1]	Close Tolerance[2]
Up to 0.0409 incl	0.0065	0.0040
Over 0.0409 to 0.0659 incl	0.0075	0.0050
Over 0.0659 to 0.1009 incl	0.0090	0.0070
Over 0.1009 to 0.1409 incl	0.0120	0.0090
Over 0.1409 to 0.250 incl	0.0220	0.0120

TABLE II (SI)

Base Laminate (without cladding) Thickness Millimetres	Tolerance, mm Plus and Minus	
	Normal[1]	Close[2]
Up to 1.039 inclusive	0.165	0.102
Over 1.039 to 1.674 inclusive	0.190	0.127
Over 1.674 to 2.563 inclusive	0.229	0.178
Over 2.563 to 3.579 inclusive	0.305	0.229
Over 3.579 to 6.350 inclusive	0.559	0.305

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.

2/ Specified tolerances shall be applicable over 1007. of the area of the sheet.

3.4.3 Warp and Twist: Shall not exceed the following values in Table III for either thickness of copper, based on 36-inch (914-mm) length, determined in accordance with ASTM D 229 or ASTM D 709.

TABLE III

Nominal Sheet Thickness		Maximum Deviation, Percent	
Inch	Millimetres	Copper on One Side Only	Copper on Both Sides
0.031 to 0.047, incl	0.79 to 1.19, incl	12	5
Over 0.047 to 0.062,incl	Over 1.19 to 1.57, incl	10	5
Over 0.062 to 0.125,incl	Over 1.57 to 3.15, incl	8	3
Over 0.125 to 0.250,incl	Over 3.15 to 6.35, incl	5	1.5

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

$$D = C \times W \times L^2$$

Where, D = Permissible deviation from the straight edge in inches (mm) for the given length
W = Maximum deviation in percent
L = The given length in inches (mm)
C = 1/3600 for D in inches; 1/91,400 for D in millimetres

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of sheet shall supply all samples Ø for vendor's tests and shall be responsible for performing all required tests. 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 for peel strength (3.2.7), solder bath Ø resistance (3.2.8), copper porosity (3.2.13), quality (3.3), and tolerances (3.4) are acceptance tests and shall be performed on each lot.

4.2.2 Periodic Tests: Test for arc resistance (3.2.4), temperature cycling Ø resistance (3.2.9), water absorption (3.2.12), and solderability (3.2.16) are 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 for all technical requirements are preproduction tests and shall be performed on the initial shipment of sheet to a purchaser, when a change in ingredients 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 cognizant agency as directed by the procuring activity, contracting officer, or request for procurement.

4.3 Sampling and Testing: Shall be as follows: Ø

4.3.1 For Acceptance Tests: Sufficient sheet shall be taken at random from each lot to perform all required tests. The number of determinations 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 square feet (0.37 m^2) 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 D 3636) shall not exceed 150 pounds (68 kg) of sheet. Sheet may be packaged in smaller quantities and delivered under a basic lot approval provided the lot identification is maintained.

4.3.1.2 When a statistical sampling plan has been agreed upon by purchaser and Ø vendor, sampling shall be in accordance with such plan in lieu of sampling as in 4.3.1 and the report of 4.6 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 ingrediants 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 D 1825.

4.5.2 Insulation Resistance:

4.5.2.1 Circuit Test Specimens: Shall be prepared as shown in Figure 1, or equivalent.

4.5.2.2 Specimen Preparation: Apply suitable resist to each test panel and develop Figure 1 wiring pattern in accordance with best commercial practice. Remove unwanted copper in accordance with ASTM D 1825 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 minutes with occasional agitation. Rinse panel for at least 1 hour in running water at 16° - 32°C (60° - 90°F) and 15 - 20 minutes in running water at 77° - 88°C (170° - 190°F). Dry for 2 - 2-1/2 hours in a forced circulating-air oven maintained at 66° - 82°C (150° - 180°F) and cool in a desiccator to room temperature at 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, fill the holes 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% ± 2 at 66°C ± 2 (150°F ± 4) and expose for 18 hours ± 1. Lower the relative humidity to 87% ± 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. Measurements shall be performed while the relative humidity is 87% ± 2.

4.5.3 Peel Strength:

4.5.3.1 Specimen Preparation: Specimens conforming to Figure 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 inch (1.60 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 Figure 2 may extend 1 inch (25 mm) in a lengthwise direction to provide space for a hanghole. The metal foil shall be peeled back approximately 1 inch (25 mm) starting from the wider end of each strip, so that the 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 strip projecting upward 1 inch (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 pound force per inch (17.5 N/m) of width. For nominal 1/32 inch (0.8 mm) lines, this value is 0.00325 pounds force (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 inches ± 1 (51 mm ± 3) per minute; the minimum load shall then be observed, coverted to pounds force 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 pounds force (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 254°C ± 5 (490°F ± 9). After 20 seconds 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 minutes ± 1 at 127°C ± 3 (260°F ± 5), 15 minutes ± 1 at 25°C ± 1 (77°F ± 2), 30 minutes ± 1 at -65°C ± 3 (-85°F ± 5), and 15 minutes ± 1 at 25°C ± 1 (77°F ± 2). Any specimen failing this cycling test shall be rejected. Specimens passing the visual examination after temperature cycling shall be peel tested as 4.5.3.2.

4.5.6 Solvent Resistance: A1 x 6 inch (25 x 152 mm) specimen, etched and Ø rinsed in accordance with ASTM D 1825 and dried, shall be vapor degreased for at least 30 seconds, sprayed with recirculated MIL-C-81302 degreaser solvent for at least 90 seconds, and examined.

4.5.7 Copper Porosity: One-half of a standard size sheet shall be vapor degreased and 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 8.2):

4.5.8.1 Procedure for Laminates 0.030 Inch (0.76 mm) and Under in Nominal Thickness: The flammability test shall be conducted in accordance with ASTM D 568 with the exception that a 5-second 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 inch (3 mm) in diameter shall be drilled in the approximate center of the narrow dimension of the specimen at a point approximately 0.75 inch (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 inches (127 mm) below the sample.

4.5.8.2 Laminates Over 0.030 Inch (0.76 mm) in Nominal Thickness: Flammability shall be tested In accordance with UL94. The preconditioning procedure shall be changed to 24 hours at 127°C ± 3 (260°F ± 5).

4.5.9 Solderability: Specimens shall be tested in accordance with IPC-S-804.
Ø Prior to testing, specimens shall be cleaned as follows: 3-inch (76-mm) square specimens shall be wiped with isopropyl alcohol, immersed in a 20% by volume solution of 22° Baume, technical grade hydrocholoric acid at 21°C + 6 (70°F ± 11) for 15 seconds, immediately rinsed with a cold water spray for 5 seconds and blown dry with filtered, oil-free compressed air.

4.6 Reports: The vendor of sheet shall furnish with each shipment a report showing the results of tests to determine conformance to the acceptance tests requirements and stating that the sheet conforms to other technical requirements. This report shall include the purchase order number, AMS-3599A, manufacturer's identification, size, and quantity.

4.7 Resampling and Retesting: If any specimen used in the above tests fails to
Ø 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. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Packaging and identification:

5.1.1 Packaging of sheet shall be accomplished in such a manner as to ensure that the sheet, during shipment and storage, will not be permanently distorted and will be protected against damage from exposure to weather or any other normal hazard.