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400 COMMONWEALTH DRIVE. WARRENDALE. PA 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 3601C

Issued 2-1-56
Revised 1-1-84

PLASTIC SHEET, COPPER FACED
Glass Fabric Reinforced Epoxy Resin

This specification was declared "NONCURRENT" by the Aerospace Materials Division of SAE, as of 10-16-80. It is recommended, therefore, that this specification not be specified for new designs. The following specification should be considered for applications where the AMS 3601 material would have been suitable:

AMS 3599 - Plastic Sheet, Copper Faced, Glass Fabric Reinforced Epoxy Resin, Flammability Controlled

This cover sheet should be attached to the "C" revision of the subject specification.

This specification is under the jurisdiction of AMS Committee "C" (NOMETCOM).

REAFFIRMED
10/91

Society of Automotive Engineers, Inc.
400 COMMONWEALTH DRIVE, WARRENDALE, PA. 15096

AEROSPACE MATERIAL SPECIFICATION

AMS 3601C
Superseding AMS 3601B
Issued 2-1-56
Revised 12-15-74

PLASTIC SHEET, COPPER FACED
Glass Fabric Reinforced Epoxy Resin

1. SCOPE:

1.1 Form: This specification covers epoxy-resin-impregnated glass laminates in the form of sheets 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

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 Society of Automotive Engineers, Inc., 400 Commonwealth Drive, Warrendale, Pennsylvania 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods

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

ASTM D149 - Dielectric Breakdown Voltage and Dielectric Strength of Electrical Insulating Materials at Commercial Power Frequencies
ASTM D150 - A-C Loss Characteristics and Dielectric Constant (Permittivity) of Solid Electrical Insulating Materials
ASTM D229 - Testing Rigid Sheet and Plate Materials Used for Electrical Insulation
ASTM D495 - High-Voltage, Low Current, Arc Resistance of Solid Electrical Insulating Materials
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

3. TECHNICAL REQUIREMENTS:

3.1 Material and Fabrication: The sheets 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.

3.1.1 Color: Unless otherwise specified, the color of the plastic laminate shall be natural.

3.1.2 Copper Faces: Shall be electrolytically deposited copper foil of not less than 99.50% purity.

3.2 Properties: Sheet shall conform to the following requirements; tests shall be performed on the sheet supplied and in accordance with the listed test methods, insofar as practicable. Specimens shall be conditioned in accordance with ASTM D618, Procedure A prior to being tested. 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, perpendicular to laminations (when specified), Short Time Test, min		ASTM D149
Nominal Thickness Inch (mm)		
0.031 (0.79)	600 V/mil (23620 V/mm)	
0.062 (1.57)	500 V/mil (19690 V/mm)	
0.125 (3.18)	425 V/mil (16730 V/mm)	
3.2.2 Dielectric Strength, parallel to laminations, Stepwise Test, min		ASTM D229
As Received	45 kV/in. (1.76 kV/mm)	
After 48 hr immersion in distilled water at 122° F ± 4 (50° C ± 2.2)	30 kV/in. (1.17 kV/mm)	
3.2.3 Dielectric Constant at 1 MHz, max	5.2	ASTM D150
3.2.4 Power Factor at 1 MHz, max	0.020	ASTM D150
3.2.5 Arc Resistance, min	100 sec	ASTM D495
3.2.6 Insulation Resistance, min	1000 megohm	4.5.2
3.2.7 Flexural Strength, flatwise, min		ASTM D790
at 77° F (25° C)	50,000 psi (344.8 MPa)	
at 300° F (148.9° C) after 1 hr at 300° F (148.9° C)	50% of value at 77° F (25° C)	
3.2.8 Compressive Strength, flatwise, min	30,000 psi (207 MPa)	ASTM D229
3.2.9 Bond Strength, min		4.5.3
As Received and After Solder Bath Resistance		
Nominal Foil Thickness Inch (Millimetres)		
0.0014 (0.036)	7 lb per in. width (1226 N/m)	
0.0028 (0.071)	8 lb per in. width (1401 N/m)	

3.2.10	Solder Bath Resistance	No softening, splitting, blistering, or delamination	4.5.4
3.2.11	Solvent Resistance	No softening, blistering, or lifting of base laminate and residual surface adhesive	4.5.5
3.2.12	Heat Resistance	No blistering	4.5.6
3.2.13	Copper Porosity	No more than 3 resin spots, spaced no less than 1 in. (25 mm) apart for each 18 x 18 in. (457 x 457 mm). No resin spot with an included area larger than a 0.5 in. (13 mm) diameter circle.	4.5.7

3.2.14 Water Absorption in 24 hr, max — ASTM D570

Nominal Thickness		
Inch	(Millimetres)	
0.031	(0.79)	0.50%
0.062	(1.57)	0.30%
0.125	(3.18)	0.18%

3.3 Quality: Sheet 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. Discoloration of the copper faces shall not be considered objectionable. The bonded copper faces shall be of such smoothness as to reveal no 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	Tolerance, Inch	
Inch	plus	minus
0.0014	0.0004	0.0002
0.0028	0.0007	0.0003

TABLE I (SI)

Nominal Thickness	Tolerance, Millimetre	
Millimetre	plus	minus
0.036	0.010	0.005
0.071	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 furnished, unless otherwise specified. When other thicknesses are specified, the tolerance for the next greater standard 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	
	0.036 mm	0.071 mm	0.036 mm	0.071 mm
0.79	0.140	0.165	0.165	0.190
1.57	0.165	0.190	0.190	0.216
3.18	0.28	0.30	0.30	0.33

3.4.2.2.1.1 At least 90% of the sheet shall be within the tolerance given and at no point shall the thickness vary from the nominal thickness by a value greater 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
0.060	0.006	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	
	0.036 mm	0.071 mm	0.036 mm	0.071 mm
0.79	0.10	0.13	0.13	0.15
1.52	0.15	0.15	0.15	0.15
3.18	0.15	0.18	0.18	0.20

3.4.2.2.2.1 Specified tolerances shall be furnished 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. (914 mm) length, determined in accordance with ASTM D229 or ASTM D709.

TABLE IV

Nominal Sheet Thickness		Maximum Deviation, Percent	
Inch	(Millimetres)	Copper on One Side Only	Copper on Both Sides
0.031 to 0.060, excl	(0.79 to 1.52, excl)	3.60	1.80
0.060 to 0.125, excl	(1.52 to 3.18, excl)	1.80	0.90
0.125 to 0.250, incl	(3.18 to 6.35, incl)	0.72	0.36

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

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

Where, D = permissible deviation from the straightedge in inches (millimetres) for the given length
D_{36} = maximum deviation in inches (millimetres) for 36 in. (914 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 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 perform such confirmatory testing as he deems necessary to assure that the sheet conforms to the requirements of this specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to dielectric constant (3.2.3), power factor (3.2.4), bond strength (3.2.9), solder bath resistance (3.2.10), solvent resistance (3.2.11), copper porosity (3.2.13), and tolerance (3.4) requirements are classified as acceptance or routine control tests.

4.2.2 Qualification Tests: Tests to determine conformance to all technical requirements of this specification are classified as qualification or periodic control tests and may be the basis for approval of the product (See 4.4.1).

4.3 Sampling: Shall be as follows; no more than 4 sq ft (0.3716 m^2) shall be cut for testing from each thickness in a shipment and the size of the portion of material removed shall be stated on the outside of the package.

4.3.1 Acceptance Tests: From each lot, the following quantities of specimens shall be taken; 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 submitted for inspection at one time.

4.3.1.1 Dielectric Strength: Five specimens for each direction in which tests are required.

4.3.1.2 Dielectric Constant and Power Factor: Four specimens.

4.3.1.3 Bond Strength: Four specimens for each copper-clad face.

4.3.1.4 Solder Bath Resistance: Three specimens for each copper-clad face.

4.3.1.5 Copper Porosity and Solvent Resistance: One specimen for each test.

4.3.2 Qualification Tests: As agreed upon by purchaser and vendor. The number of specimens for each Ø test shall be as follows:

Ø 4.3.2.1 Arc Resistance: Five specimens.

Ø 4.3.2.2 Insulation Resistance: Three specimens.

Ø 4.3.2.3 Flexural Strength: Five specimens in each direction.

Ø 4.3.2.4 Compressive Strength: Four specimens.

Ø 4.3.2.5 Heat Resistance: One specimen.

Ø 4.3.2.6 Water Absorption: Three specimens.

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. 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 any change is necessary in ingredients, in type of equipment for processing, or in manufacturing procedures, vendor shall submit for reapproval a statement of the revised materials and processing and, when requested, sample revised sheet. No production sheet made by the revised procedure shall be shipped prior to receipt of reapproval.

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4.5 Test Methods:

4.5.1 Test Specimen Preparation: Specimens for determination of dielectric strength (both directions), dielectric constant and power factor, flexural strength, and compressive strength shall have the copper facing removed by immersing the specimens in vigorously aerated 40 deg Baume' ferric chloride solution at 75° - 100° F (23.9° - 37.8° C). The solution shall be renewed when time for removal exceeds 15 min. for 0.0014 in. (0.036 mm) thickness of copper. After removal of the copper, specimens shall be rinsed immediately for not less than 1 hr in running water at 60° - 90° F (15.6° - 32.2° C).

4.5.2 Insulation Resistance:

4.5.2.1 Circuit Test Specimens: Test specimens the thickness of the material x 2 x 2-1/2 in. (51 x 64 mm) shall be made as shown in Fig. 1, or be the equivalent.

4.5.2.2 Test 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 4.5.1 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 60° - 90° F (15.6° - 32.2° C) and 15 - 20 min. in running water at 170° - 190° F (76.7° - 87.8° C). Dry for 2 - 2-1/2 hr in a forced circulating-air oven maintained at 150° - 180° F (65.6° - 82.2° C) 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 a clean mixture of 90% ethanol and 10% distilled water by volume. 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 149° F ± 4 (65° C ± 2.2) and expose for 18 hr ± 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 DC between terminal leads and maintain electrification time for at least 1 minute. Immediately thereafter, measure insulation resistance using a megohm bridge (General Radio Type 544B or equivalent). Measurements shall be performed while the relative humidity is 87% ± 1.

4.5.3 Bond Strength: The strength of the bond between the copper foil and the base laminate shall be determined at 70° - 85° F (21.1° - 29.4° C) in accordance with the following procedure on specimens as received and on specimens which have been floated on molten solder in accordance with 4.5.4.

4.5.3.1 Etch 1 x 4 in. or 25 x 100 mm specimens, two cut in the lengthwise direction and two cut in the crosswise direction, in accordance with 4.5.1. Grasp the test specimen, on each end, between the thumbs and forefingers and flex each side of the specimen 5 times. During flexing, the center of the specimen shall deflect at least 0.25 in. (6.4 mm) beyond the ends (flexing of specimens over 0.093 in. (0.24 mm) thick is not required). The copper foil shall be peeled back from one end of the specimen for approximately 2 in. or 50 mm, with the line of peel perpendicular to the edge of the specimen. The specimen shall be supported in a horizontal plane, with the peeled copper strip down, between two solid supports adjusted to provide a 0.75 in. (19.0 mm) span. The end of the peeled strip shall be clamped between two rubber-faced jaws. The jaws shall cover the full width of the strip and shall be clamped parallel to the line of peel. Starting with no load, a load shall be applied to the gripping tab using a uniform pulling rate not exceeding 2 in. per min. (0.85 mm/s). The direction of the load applied to the tab shall not deviate from the perpendicular by more than 5 deg (0.087 rad.). The load required to produce separation of the copper foil from the base material shall be recorded as the bond strength. The full width of the strip shall peel; otherwise, the results shall be discarded and the test repeated.

4.5.3.2 Alternate Method of Test: The specimen shall be supported in a horizontal plane with the peeled copper strip down between two solid supports adjusted to provide a 0.75 in. (19.0 mm) span. The end of the peeled strip shall be clamped between rubber-faced jaws to which is attached a lightweight container. The total mass of the clamp and the container shall not exceed 1 lb (454 g). The jaws shall cover the full width of the strip and shall be clamped parallel to the line of peel. Sand (or equivalent) shall be poured into the container at a rate of approximately 2 lb per min. (15 g/s), until the strip begins to peel, and the container shall then be weighed. The full width of the strip shall peel; otherwise, the results shall be discarded and the test repeated.

4.5.4 Solder Bath Resistance: Etched specimens 1 in. (25 mm) square by the thickness of the material shall be tested. The specimens shall be dipped in liquid flux (rosin in alcohol) and then floated on the surface of a bath of molten solder, with the copper face to be tested down. The solder shall be at a temperature of 490° F ± 10 (254.4° C ± 5.6). After 20 sec, the specimen shall be removed from the solder bath and examined.

4.5.5 Solvent Resistance: A 1 x 6 in. (25 x 152 mm) specimen, etched and rinsed in accordance with 4.5.1 and dried, shall be vapor degreased for at least 1/2 min., sprayed with recirculated degreaser solvent for at least 1-1/2 in., and examined.

4.5.6 Heat Resistance: A 6 x 6 in. (152 x 152 mm) test specimen shall be supported vertically, on a nonmetallic rack in a horizontal-flow, air-circulating oven at 350° F ± 10 (176.7° C ± 5.6) for at least 1/2 hour. The plane of the test specimen shall be parallel to the air flow. At the end of this period, remove the specimen from the oven and examine immediately.

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, etc. Examine in a dark room, using ultra-violet light, for fluorescent resin spots.