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

AEROSPACE MATERIAL SPECIFICATION

AMS 3894B
Superseding AMS 3894A
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GRAPHITE FIBER TAPE AND SHEET
Epoxy Resin Impregnated

1. SCOPE:

1.1 Form: This specification and its supplementary detail specifications cover graphite fibers in the form of tape and sheet impregnated with epoxy resin, the resin to be supplier in a "B" stage condition.

1.2 Application: Primarily for fabricating high-strength and high-modulus composite parts, using either hand-layup or a machine for automated-tape-layup.

1.3 Classification: The tapes and sheets shall be as specified in the applicable detail specifications, wherein each material is defined by property characteristics and continuous service temperature. An example is shown in 8.2. The material covered by each detail specification appears as part of the title.

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, PA 15096.

2.1.1 Aerospace Material Specifications:

AMS 2350 - Standards and Test Methods
AMS 3892 - Fibers, Graphite Tow and Yarn, for Structural Composites
AMS 3898 - Interleaf Carrier Material, Composite Tape

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

ASTM D792 - Specific Gravity and Density of Plastics by Displacement
ASTM D1505 - Density of Plastics by the Density-Gradient Technique
ASTM D2344 - Apparent Horizontal Shear Strength of Reinforced Plastics by Short Beam Method
ASTM D2734 - Void Content of Reinforced Plastics
ASTM D3039 - Tensile Properties of Oriented Fiber Composites
ASTM D3171 - Fiber Content of Reinforced Resin Composites

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

2.3.1 Military Standards:

MIL-STD-105 - Sampling Procedures and Tables for Inspection by Attributes
MIL-STD-794 - Parts and Equipment, Procedures for Packaging and Packing of

2.4 AIA Publications: Available from National Standards Association, Inc., 1321 14th Street, N.W., Washington, DC 20005.

NAS 992 - Reel, Composite Filament Tape, Automated Machine Layup

Printed in U.S.A.

3. TECHNICAL REQUIREMENTS:

3.1 Detail Specifications: The requirements for a specific material shall consist of all the requirements specified herein in addition to the requirements specified in the applicable detail specification. In the case of any conflict between the requirements of this basic specification and an applicable detail specification, the requirements of the detail specification shall govern.

3.2 Material:

3.2.1 Construction: The product shall consist of parallel, unidirectional graphite fibers meeting the requirements of AMS 3892 and its applicable detail specification, impregnated with an epoxy resin meeting the requirements of the applicable detail specification, and arranged in a single in-plane layer.

3.2.2 Ends: The product shall contain no unspliced yarn or tow ends, unless otherwise specified. Splices Ø in the same or adjacent tows or yarns shall be not less than 10 ft (3 m) apart.

3.2.3 Storage Life: The product, when packaged in waterproof, heat-sealed bags, shall meet the requirements of the applicable detail specification after storage as specified therein.

3.2.4 Working Life: The product shall meet the requirements of the applicable detail specification after exposure for a continuous period at the relative humidity and temperature specified therein.

3.2.5 Bending: The product shall withstand without visible material damage, bending through an angle of 180 deg (3.14 rad) around a 1.0-in. (25-mm) diameter mandrel with the fiber direction perpendicular to the axis of bend; magnification of 10X shall be used in examination for damage.

3.3 Properties of Uncured Impregnated Material: The as-received product shall conform to the requirements of this specification and the applicable detail specification. Tests shall be performed on the product supplied in accordance with the test procedures specified herein.

3.4 Properties of Cured Laminate: Test laminates shall conform to the requirements of this specification and the applicable detail specification. Tests shall be performed on specimens cut from laminates prepared and tested in accordance with 4.5.

3.5 Quality: The product shall be uniform in quality and condition, clean, and free from foreign materials Ø and, except as specified in 3.5.1, free from internal and external imperfections detrimental to fabrication, appearance, or performance of parts.

3.5.1 Visual Imperfection Criteria: Visible indications of dry spots, voids, crimps, crossed or broken Ø fibers, twisted fibers, irregular carrier, over-impregnation or incomplete impregnation areas will be unacceptable if the total length of each area exceeds limits, indicated below, for the total tape length of the roll:

Imperfections	Criteria
Filaments not wetted	1% max
Tape not parallel to center line	Parallel within ± 0.5° (±0.009 rad)
Crimps	1% max
Cured resin particles	None permitted
Foreign Materials	None permitted
Color uniformity	Natural Color
Twists* (3.5.1.1)	2% max
Scrim distortion (when scrim is present)	To be determined
Rippled interleaf	To be determined
Resin starved areas	To be determined
Fiber Crossover	To be determined

Ø 3.5.1.1 *Does not refer to twists inherent in the material.

3.6.1 Width: Shall be as specified in Table I.
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TABLE I

Nominal Width Inches	Tolerance Inch
Up to 1.000, excl	As agreed upon
1.000 to 3.000, excl	+0, -0.025
3.000	+0, -0.050
Over 3.000	±0.040 for each 3.000 in. of width

TABLE I (SI)

Nominal Width Millimetres	Tolerance Millimetres
Up to 25.40, excl	As agreed upon
25.40 to 76.20, excl	+0, -0.64
76.20	+0, -1.27
Over 76.20	±1.02 for each 76.20 mm of width

3.6.2 Fiber Alignment and Spacing: Individual fibers, yarns, and tows shall be parallel to the tape center line within ±5 deg (±0.087 rad) along their entire length. Open space between fibers, yarns, and tows shall each be not more than 0.060 in (1.52 mm) long nor more than 10 in. (254 mm) long, cumulative total, for each 10 sq ft (93 dm^2) of product.
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4. QUALITY ASSURANCE PROVISIONS:

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

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to construction (3.2.1), bending (3.2.5), properties of uncured impregnated material (3.3), longitudinal flexural strength, modulus of elasticity in flexure, and short beam shear strength of cured laminate, all at room temperature (3.4), and tolerance (3.6) requirements are classified as acceptance tests.

4.2.2 Qualification Tests: Tests to determine conformance to all technical requirements of this specification and the applicable detail specification are classified as qualification tests, and may be the basis for approval of the product (See 4.4.1).
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4.2.2.1 For direct U.S. Military procurement, substantiating test data and, when requested, qualification test material shall be submitted to the cognizant qualification agency as directed by the procuring activity, the contracting officer, or the request for procurement.
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4.3 Sampling:

4.3.1 Sampling Schedule: Shall be in accordance with Single Sampling for Normal Inspection, General Inspection Level II, with an Acceptable Quality Level (AQL) of 1.5 specified in MIL-STD-105, as ø shown in Table II. Test specimens shall be taken at random throughout the lot. Sampling for qualification testing shall be as agreed upon by purchaser and vendor or otherwise according to Table II.

TABLE II

SAMPLING SCHEDULES

Number of Inspection Units in the Lot	Number of Inspection Units from Which Samples are to be Taken	Accept	Reject
1 - 90	8 (4.3.1.1)	0	1
91 - 280	32	1	2
281 - 500	50	2	3

4.3.1.1 If number of inspection units to be sampled equals or exceeds lot size, inspect each unit.

4.3.2 Lot: A lot shall be all product produced in a single production run from the same batch of raw ø materials under the same fixed conditions and submitted for vendor's inspection at one time.

4.3.2.1 For purposes of traceability, the vendor shall maintain records of the ingredients of each lot for ø a period of not less than 3 years.

4.3.3 Inspection Unit: An inspection unit shall be each 25 lb (11.35kg) of impregnated material or fraction thereof, unless otherwise specified.

4.4 Approval:

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

4.4.2 Vendor shall use ingredients, manufacturing procedures, processes, and methods of inspection on production material which are essentially the same as those used on the approved sample material. ø 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 proposed changes in materials and processing and, when requested, sample material. Production material made by the revised procedure shall not be shipped prior to the receipt of reapproval.

4.5 Test Methods: Tests to determine conformance to this specification shall be conducted as follows:

Requirement	Minimum Number of Specimens per Test	Test Procedure
Volatile Content	1	4.5.2
Total Nonfiber Content	2	4.5.3
Resin Flow	1	4.5.4
Gel Time	1	4.5.5
Tack, Time Adherence	1	4.5.6
Tack, Peel Strength	1	4.5.7
Visual Imperfections	1	4.5.8
Tensile Strength and Modulus of Elasticity	4	ASTM D3039
Compressive Strength and Modulus of Elasticity	4	4.5.9
Flexural Strength and Modulus of Elasticity	4	4.5.10
Short Beam Shear Strength	4	ASTM D2344
Density	3	4.5.11
Void Content	3	ASTM D2734
Fiber Volume	3	ASTM D3171

4.5.1 Preparation of Test Laminates: Test laminates of suitable thickness and area shall be prepared from sufficient plies of impregnated material oriented undirectionally and cured in an autoclave or equivalent at a temperature and pressure to provide optimum properties. Details of time, temperature, rate of heating, and pressures used in the cure cycle shall be noted in the report. The resultant laminate shall be uniform in thickness within ± 0.003 in. (±0.08 mm) and shall have a fiber volume of 60% ± 3. The thickness per ply shall be within ±0.0004 in. (0.010 mm) of the nominal cured thickness, unless otherwise specified, determined from the equation:

$$T = \frac{A}{B}$$

where, T = Thickness per ply in in. (mm)
A = Thickness of test panel in in. (mm)
B = Number of plies in panel

4.5.2 Volatile Content:

4.5.2.1 Cut sufficient material to obtain a specimen weighing approximately 1 g and weigh to the nearest mg (W_1).

4.5.2.2 Suspend the specimen on a removable tray (areas of the tray in contact with the specimen shall be covered with a suitable parting agent film) in a circulating-air oven preheated to the temperature specified in the applicable detail specification for the product being tested. Heat the specimen at that temperature for the time specified in the applicable detail specification.

4.5.2.3 Remove specimen from the tray and place in a desiccator.

4.5.2.4 Cool specimen to room temperature inside the desiccator for at least 30 min. and weigh to the nearest mg (W_2).

4.5.2.5 Calculate volatile content as follows:

$$\text{Volatile Content, \% by weight} = \frac{W_1 - W_2}{W_1} \times 100$$

where, W_1 = Original weight of specimen, mg

W_2 = Final weight of specimen, mg

4.5.3 Total Nonfiber Content:

4.5.3.1 Cut sufficient material to obtain 2 specimens each weighing approximately 1 g, and weigh to the nearest mg (W_3).

4.5.3.2 Place the specimens in separate containers and wash with a suitable boiling solvent for not less than 2 minutes. Time starts when the solvent starts to boil. Decant the solvent. The solvent used shall be selected on the basis of being able to completely dissolve the resin under the conditions of this test. Report the solvent and temperature used.

4.5.3.3 Repeat 4.5.3.2 for 3 complete wash cycles.

4.5.3.4 Dry the specimens by placing them in a circulating-air oven maintained at 325°F ± 10 (162.8°C ± 5.6) for not less than 1 hr, or until weight is constant. Remove and place in desiccator.

4.5.3.5 After 10 min., remove specimens from desiccator and weigh to the nearest mg (W_4).

4.5.3.6 Calculate nonfiber content as follows:

$$\text{Total Nonfiber Content, \% by weight} = \frac{W_3 - W_4}{W_3} \times 100$$

where, W_3 = Original weight of specimen, mg

W_4 = Final weight of specimen, mg

4.5.3.7 Calculate the arithmetic mean of the two determinations as total nonfiber content of the sample. Report both the individual results and the arithmetic mean.

4.5.4 Resin Flow:

4.5.4.1 Cut 2 pieces of material, each piece approximately 2 in. (51 mm) square and weigh to the nearest mg (W_5). Cut 4 pieces of a suitable release bleeder cloth and 2 pieces of porous polytetrafluoroethylene (PTFE) coated glass cloth, each piece approximately 3 in. (76 mm) square.

4.5.4.2 Layup a flow specimen assembly of two layers of bleeder cloth, one layer of PTFE glass cloth, the two pieces of graphite material crossplied at approximately 90 deg (1.57 rad) centered in the middle, one layer of PTFE glass cloth, and two layers of bleeder cloth. Weigh the assembly to the nearest mg (W_6). Material less than 2 in. (51 mm) in nominal width shall be cut and positioned to form an approximately 2 in. (51 mm) square.

4.5.4.3 Place the flow specimen assembly in a heated platen press between nonporous PTFE sheets and cover with a heat resistant elastomeric sheet approximately 0.06 in. (1.5 mm) thick. Heat the assembly at the temperature and pressure recommended by the resin manufacturer for 15 min. ± 0.25, cool to room temperature, and weigh to the nearest mg (W_7).

4.5.4.4 Remove the cured specimen from the bleeder cloth and porous PTFE layers and trim the specimen free from resin flash, taking care not to remove any graphite fibers. Weigh the specimen to the nearest mg (W_8).

4.5.4.5 Calculate the volatile-free resin flow as follows:

$$\text{Resin Flow, \% by weight} = \frac{W_5 - (W_6 - W_7) - W_8}{W_5 - (W_6 - W_7)} \times 100$$

where, W_5 = Original weight of graphite material, mg
W_6 = Original weight of specimen assembly, mg
W_7 = Weight of specimen assembly after press heating, mg
W_8 = Weight of graphite material after trimming, mg

4.5.4.6 Report the test results and the temperature and pressure used in press heating of the specimen assembly.

4.5.5 Gel Time:

4.5.5.1 Cut a piece of material approximately 0.25 in. (6.4 mm) square.

4.5.5.2 Preheat a hot plate to the same temperature ±2°F (±1.1°C) used for resin flow.

4.5.5.3 Place a micro cover glass on the hot plate, allowing 20 sec for it to reach temperature equilibrium. Position the specimen at the center of the micro cover glass and simultaneously commence timing. Within 5 sec, place a second micro cover glass over the specimen. After the resin softens and during the first 30 sec, probe the top micro cover glass and isolate a drop of resin. Observe the fluidity and color of the isolated resin drop periodically (continuously as the end point approaches). The lateral (spreading) movement of the resin upon probing will decrease or regress and the color shade will change as the gel point approaches. Stop the timer at the first indication of resin immobility and record the elapsed time to the nearest second.

4.5.6 Tack, Time Adherence:

4.5.6.1 Cut two pieces of material approximately 1 x 3 in. (25 x 76 mm), retaining the protective film until immediately before using the specimens. Fiber direction shall be parallel to the 1-in. (25-mm) dimension. For material less than 3 in. (76 mm) in nominal width, butt together sufficient pieces of the panel to produce a 3-in. (76-mm) wide specimen.

4.5.6.2 Remove the protective film from one face of one specimen and apply the material to the center of a clean piece of austenitic, corrosion-resistant steel sheet with a commercial 2D finish, any thickness by approximately 4 x 8 in. (102 x 203 mm). Apply light pressure with a squeegee or roller over the backing film. Remove the backing film and apply the second specimen to the first, in exactly the same manner, making sure the opposing faces of the material are not covered with protective backing film. The second layer of narrow material shall be so positioned that the butt joints do not coincide with those of the first layer. Remove the protective film from the exposed surface of the material and maintain the test plate and the long dimension of the test specimen in a vertical position for not less than 30 min. at 70° - 80°F (21.1° - 26.7°C) and 50 - 70% relative humidity.

4.5.6.3 Report results as pass or fail. If a specimen fails to adhere for the test period, record the elapsed time at failure.

Ø 4.5.7 Tack, Peel Strength: Shall be determined as agreed upon by purchaser and vendor.

4.5.8 Visual Imperfections: Shall be determined as follows:

4.5.8.1 Ø Allow a sample of the product, approximately 15 ft (4.5 m) in length lying flat on the table, to be exposed to standard environmental conditions for 10 - 30 min. prior to inspection.

Ø 4.5.8.2 Inspection aids and measuring devices of applicable accuracy may be used as required.

Ø 4.5.8.3 Report the results of the inspection of each sample of material.

4.5.9 Compressive Strength and Modulus of Elasticity: The test method used shall be reported. The method identified as "Celanese Compression Test" is preferred.

4.5.10 Flexural Strength and Modulus of Elasticity:

4.5.10.1 Specimen Preparation: The specimens, taken from the laminate prepared in 4.5.1, shall be 0.080 in. (2.03 mm) nominal thickness, 0.500 in. ± 0.010 (12.70 mm ± 0.25) wide, and 3.00 in. ± 0.03 (76.2 mm ± 0.8) long. Specimen edges shall be ground with abrasive finer than 400 grit to the required length and width dimension. The fiber direction of the specimen shall be parallel to the longitudinal axis of the specimen. Other specimen configurations are acceptable provided that the fiber direction is parallel to the longitudinal axis of the specimen, the thickness of the specimen is equal to, or less than, the width of the specimen, and the length of the specimen is sufficient to provide a span equal to 32 ± 2 times the thickness.

4.5.10.2 Test Procedure: The specimen shall be loaded to failure at a crosshead speed of 0.050 in. ± 0.005 (1.27 mm ± 0.13) per min. in a testing machine with fixture and instrumentation as indicated in Fig. 1. The deflectometer shall be of the linear differential transformer type. Necessary adjustments shall be made so that the deflectometer pushrod is midway between the supports ±0.03 in. (±0.08 mm). The span length shall be 32 ± 2 times the specimen thickness.

4.5.10.3 Calculation Using U.S. Customary Units of Measure: Flexural strength and modulus shall be calculated from the following equations:

$$\text{Flexural Strength, psi} = \frac{3PL}{4bt^2}$$

$$\text{Flexural Modulus of Elasticity, psi} = \frac{11}{64}\,\frac{L^3(\Delta P)}{bt^3(\Delta\delta)}$$

where,
P = Load at failure, lb
L = Span, in.
b = Width, in.
t = Thickness, in.
ΔP = Increment of load, lb
$\Delta\delta$ = Increment of deflection, in. (at midspan)
$\frac{\Delta P}{\Delta\delta}$ = Slope of initial straightline portion of the load deflection curve, lb per in.

4.5.10.4 Calculation Using SI Units of Measure: Flexural strength and modulus shall be calculated from the following equations:

$$\text{Flexural Strength, MPa} = \frac{3PL}{4bt^2}$$

$$\text{Flexural Modulus of Elasticity, MPa} = \frac{11}{64}\,\frac{L^3}{bt^3}\,\frac{(\Delta P)}{(\Delta \delta)}$$

where,
P = Load at failure, N
L = Span, mm
b = Width, mm
t = Thickness, mm
ΔP = Increment of load, N
$\Delta \delta$ = Increment of deflection, mm (at midspan)
$\frac{\Delta P}{\Delta \delta}$ = Slope of initial straightline portion of the load deflection curve, N per mm

4.5.11 Density: Shall be determined in accordance with ASTM D792 using a suitable nonaqueous liquid or in accordance with ASTM D1505 on the test laminate prepared as specified in 4.5.1.

4.6 Reports:

4.6.1 The vendor of the product shall furnish with each shipment three copies of a report showing the results of tests to determine conformance to the acceptance test requirements of this specification and the applicable detail specification, including the identification of the resin system used, the cure cycle and fiber volume of the test laminate, and stating that the product conforms to the other technical requirements of this specifications and the applicable detail specification. This report shall include the purchase order number, material specification number and its applicable detail specification number, their revision letters if any, vendor's material designation, lot number, spool or sheet numbers, date of manufacture, quantity (tape width and length, or sheet width and length and number of sheets), and location of test samples within the lot and spool or sheet.

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, material specification number and its applicable detail specification number, their revision letters if any, contractor or other direct supplier of material, supplier's material designation, part number, and quantity. When material for making parts is produced or purchased by the parts vendor, that vendor shall inspect each lot of material to determine conformance to the requirements of this specification and the applicable detail specification, and shall include in the report a statement that the material conforms, or shall include 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 product may be based on the results of testing three additional specimens for ø each original nonconforming specimen, prepared from the original panel or a newly-prepared panel. Failure of any retest specimen to meet the specified requirements shall be cause for rejection of the product represented and no additional testing shall be permitted. Results of all tests shall be reported.

5. PREPARATION FOR DELIVERY:

5.1 Packaging and Identification:

5.1.1 Tape for Hand Layup: Shall be interleaved with a nonadherent film and wound on spools having a ø hub diameter not less than 3 in. (76 mm). Winding shall be uniform and shall provide for proper unreeling. Each spool shall contain 600 - 1320 ft (183 - 403 m) except that, in any one shipment, up to 20% of the spools may contain lengths as short as 350 ft (107 m). Tape ends shall be secured.