



AEROSPACE MATERIAL SPECIFICATION

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

AMS 3899

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Revised

GRAPHITE FIBER TAPE AND SHEET Polysulfone 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 heat-activated, formable, thermoplastic polysulfone resin.
- 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 8.1. 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
- ASTM D3410 - Compressive Properties of Oriented Fiber Composites
- ASTM D3529 - Resin Solids Content of Carbon Fiber-Epoxy Prepreg
- ASTM D3530 - Volatiles Content of Carbon Fiber-Epoxy Prepreg
- ASTM D3531 - Resin Flow of Carbon Fiber-Epoxy Prepreg

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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 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

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 a polysulfone resin meeting the requirements of the applicable detail specification, and arranged in a single in-plane layer.

3.2.2 Ends: The products shall contain no unspliced yarn or tow ends, unless otherwise specified. Splices 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 herein.

3.3 Properties: The product shall conform to the following requirements:

3.3.1 Resin Impregnated Fiber Tape and Sheet: 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.

3.3.2 Molded Laminates: Shall conform to the requirements of this specification and the applicable detail specification; tests shall be performed on specimens cut from test laminates prepared as specified in 4.5.1. Specimens for elevated temperature tests shall be tested after exposure at the test temperature for 30 min. ± 1 .

3.4 Quality: The product shall be uniform in quality and condition, clean, and free from foreign materials and, except as specified in 3.4.1, free from internal and external imperfections detrimental to fabrication, appearance, or performance of parts.

3.4.1 Visual Imperfection Criteria: Visible indications of dry spots, voids, crimps, crossed or broken 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:

3.4.1 (Cont'd.)

Imperfections	Criteria
Filaments not wetted	1% max
Tape not parallel to center line	Parallel within ± 0.5 deg
Crimps	1% max
Foreign Materials	None permitted
Color uniformity	Natural Color
Twists (3.4.1.1)	2% max
Scrim distortion (when scrim is present)	As agreed upon
Rippled interleaf	As agreed upon
Resin starved areas	As agreed upon
Fiber Crossover	As agreed upon

3.4.1.1 Does not refer to twists inherent in the material.

3.5 Tolerances:

3.5.1 Width: Shall be as specified in Table I.

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

3.5.2 Fiber Alignment and Spacing: Individual fibers, yarns, and tows shall be parallel to the tape center line within ± 5 deg 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 dm²) of product.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product 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 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 the following requirements are classified as acceptance tests and shall be performed on each lot:

Construction
 Volatile Content
 Total Resin Solids
 Resin Flow
 Visual Imperfections
 Longitudinal Flexural Strength at Room Temperature
 Modulus of Elasticity in Flexure
 Short Beam Shear Strength at Room Temperature
 Quality
 Tolerances

- 4.2.2 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 the product to a purchaser, when a change in material or processing requires re-approval as in 4.4.2, and when purchaser deems confirmatory testing to be required.

- 4.2.2.1 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: 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 shown in Table II. Test specimens shall be taken at random throughout the lot.

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

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

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

- 4.3.1.3 Inspection Unit: An inspection unit shall be each 25 lb (11.4 kg) of impregnated material or fraction thereof, unless otherwise specified.

- 4.3.2 For Qualification Tests: As agreed upon by purchaser and vendor.

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. 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 receipt of reapproval.

4.5 Test Methods: Tests to determine conformance to the requirements of this specification and the applicable detail specification shall be conducted as follows:

Requirement	Minimum Number of Specimens per Test	Test Procedure
Volatile Content	1	4.5.2
Total Resin Solids	2	4.5.3
Resin Flow	1	4.5.4
Visual Imperfections	1	4.5.5
Tensile Strength and Modulus of Elasticity	4	ASTM D3039
Compressive Strength and Modulus of Elasticity	4	ASTM D3410
Flexural Strength and Modulus of Elasticity	4	4.5.6
Short Beam Shear Strength	4	ASTM D2344
Density	3	4.5.7
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 unidirectionally and molded in a suitable press or equivalent at a temperature and pressure to provide optimum properties. Details of time, temperature, rate of heating, and pressures used 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 $57\% \pm 3$. The thickness per ply shall be within ± 0.0004 in. (± 0.010 mm) of the nominal 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: Shall be determined in accordance with ASTM D3530, except that the exposure temperature shall be $260^{\circ}\text{C} \pm 5$ ($500^{\circ}\text{F} \pm 9$).

4.5.3 Total Resin Solids: Shall be determined in accordance with ASTM D3529. Suggested solvents are N-methylpyrrolidone (NMP) or dimethyl formamide (DMF).

4.5.4 Resin Flow: Shall be determined in accordance with ASTM D3531, except that the press cycle shall be 288°C (550°F) for 30 min. ± 5 .

4.5.5 Visual Imperfections: Shall be determined as follows:

4.5.5.1 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.

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

4.5.5.3 Report the results of the inspection of each sample of material.

4.5.6 Flexural Strength and Modulus of Elasticity:

4.5.6.1 Specimen Preparation: The specimens, taken from the laminate prepared as in 4.5.1, shall be 0.080 in. (2.03 mm) nominal thickness, 0.500 in. ± 0.010 (12.50 mm ± 0.25) wide, and 3.00 in. ± 0.03 (75 mm ± 0.8) long. Specimen edges shall be ground with abrasive finer than 400 grit (38 μ m) 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.

4.5.6.2 Test Procedure: The specimen shall be loaded to failure at a cross-head 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.

4.5.6.3 Calculations: Flexural strength and modulus shall be calculated from the following equations:

$$\text{Flexural Strength, psi} = \frac{3PL}{4bt^3} \quad (\text{MPa} = \frac{3PL}{4bt^3})$$

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

where, P = Load at failure, lb (N)

L = Span, in. (mm)

b = Width, in. (mm)

t = Thickness, in. (mm)

ΔP = Increment of load, lb (N)

$\Delta \delta$ = Increment of deflection, in. (at midspan) (mm)

$\frac{\Delta P}{\Delta \delta}$ = Slope of initial straightline portion of the load deflection curve, lb per in. (N per mm)

4.5.7 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 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 molding cycle and fiber volume of the test laminate, and stating that the product conforms to the other technical requirements of this specification and the applicable detail specification. This report shall include the purchase order number, material specification number and its applicable detail specification number, 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, 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 each original nonconforming specimen, prepared from the original panel or a newly-prepared panel, using the same procedures and molding cycles as used on the original panels. 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 hub diameter not less than 3 in. (75 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 length as short as 350 ft (107 m). Tape ends shall be secured.

- 5.1.1.1 Location of visually imperfect areas and of splices shall be plainly identified on the material by suitable markers visible on the spool or reel and on the package. The total length of such areas in each roll shall be itemized in the applicable inspection report. Visually imperfect areas shall not be counted in conforming to any requirements for length.

- 5.1.2 Tape for Machine Layup: Shall be interleaved with a nonadherent film conforming to the specified detail specification of AMS 3898 and wound on NAS 992 reels of the type, size, and class specified (See 8.2). Quantity on each reel and marking of visually imperfect areas and of splices shall be as specified in 5.1.1.

- 5.1.2.1 Tape Placement: The tape shall be placed on the interleaf (carrier) material within ± 0.015 in. (± 0.38 mm) of the center line of the interleaf or centered between the perforations (sprocket hole guides) by the same tolerance if perforated carrier is specified. If tape and interleaf are specified to have the same width, the tape shall be placed within 0.015 in. (0.38 mm) of the center line of the interleaf or no greater than 0.030 in. (0.76 mm) from an edge and shall not extend beyond the edge of the interleaf.

- 5.1.3 Sheet: Shall be supplied flat with a suitable nonadherent protective covering or separator film on each face.

- 5.1.4 Identification: Each reel or spool of tape and each sheet shall be identified by attached removable tags using characters of such height as to be clearly legible and which will not be obliterated by normal handling. Each tag shall show not less than the following information:

GRAPHITE FIBER TAPE (or SHEET), POLYSULFONE-RESIN-IMPREGNATED
AMS 3899/* _____

INTERLEAF MATERIAL, AMS 3898/* _____ (when applicable)

NAS 992 REEL, TYPE _____, SIZE _____, CLASS _____ (when applicable)

MANUFACTURER'S MATERIAL DESIGNATION _____

PURCHASE ORDER NUMBER _____

DATE OF MANUFACTURE _____

LOT AND REEL, SPOOL, OR SHEETS NUMBERS _____

TAPE WIDTH _____

QUANTITY _____

* _____ Enter appropriate number or code from applicable detail specification.

- 5.1.5 Package Sealing: Each reel or spool and each sheet shall be sealed in a bag of suitable non-adherent material to prevent penetration of moisture and loss of impregnating resin solvent.