

CARBON (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 supplied 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 SAE, 400 Commonwealth Drive, Warrendale, PA 15096.

2.1.1 Aerospace Material Specifications:

- AMS 2350 - Standards and Test Methods
- AMS 2825 - Material Safety Data Sheets
- AMS 3892 - Fibers, Graphite Tow and Yarn, for Structural Composites
- AMS 3898 - Interleaf Carrier Material, Composite Tape

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."

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

Ø

- ASTM D792 - Specific Gravity and Density of Plastics by Displacement
- ASTM D1505 - Density of Plastics by the Density-Gradient Technique
- ASTM D2344 - Apparent Interlaminar Shear Strength of Parallel Fiber Composites by Short Beam Method
- ASTM D2734 - Void Content of Reinforced Plastics
- ASTM D3039 - Tensile Properties of Fiber-Resin Composites
- ASTM D3171 - Fiber Content of Resin-Matrix Composites by Matrix Digestion
- ASTM D3410 - Compressive Properties of Unidirectional or Crossply Fiber-Resin 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
- ASTM D3532 - Gel Time of Carbon Fiber-Epoxy Prepreg

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 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 in the same yarn or tow shall be not less than 10 ft (3 m) apart. Splices in adjacent yarns or tows shall be not less than 12 in. (300 mm) 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 around 1.0-in. (25-mm) diameter mandrel with the fiber direction perpendicular to the axis of bend; 10X magnification 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 as-supplied in accordance with 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, as received by purchaser, shall be uniform in quality and condition and free from foreign material and, except as specified in 3.5.1, free from internal and external imperfections detrimental to usage of the product.
 - 3.5.1 Visual Imperfection Criteria: Visible indications of dry spots, voids, crimps, crossed or broken fibers, twisted fibers, irregular carrier, over-impregnation or incomplete impregnation areas are not acceptable 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 Deg
Crimps	1% max
Wrinkle	None permitted
Unspliced yarn or tow	None permitted
End-butt spliced yarn or tow	None permitted
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

3.5.1.1 Does not refer to twists inherent in the material.

3.6 Tolerances:

3.6.1 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 25.00, excl	As agreed upon
25.00 to 75.00, excl	+0, -0.60
75.00	+0, -1.25
Over 75.00	± 1.00 for each 75.00 mm of width

3.6.2 Fiber Alignment and Spacing: Individual fibers, yarns, and tows shall be \emptyset 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 0.040 in. (1.00 mm) wide.

4. QUALITY ASSURANCE PROVISIONS:

4.1 Responsibility for Inspection: The vendor of the product shall supply all \emptyset 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 product conforms to the requirements of this specification and the applicable detail specification.

4.2 Classification of Tests:

4.2.1 Acceptance Tests: Tests to determine conformance to requirements for \emptyset construction (3.2.1), ends (3.2.2), bending (3.2.5), properties of uncured impregnated material (3.3), longitudinal flexural strength, modulus of elasticity in flexure, and interlaminar shear strength of cured laminate, all at room temperature (3.4), quality (3.5), and tolerances (3.6) are classified as acceptance tests and shall be performed on each lot.

4.2.2 Preproduction Tests: Tests to determine conformance to all technical requirements of this specification and the applicable detail specification are classified as preproduction tests and shall be performed prior to or on the initial shipment of a product to a purchaser, when a change in material or processing, or both, requires reapproval 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:

4.3.1 For Acceptance Tests:

4.3.1.1 Sampling Schedule: Shall be in accordance with Single Sampling for Normal Inspection, General Inspection Level II, with an Acceptance 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 (4.3.1.1.1)	0	1
91 - 280	32	1	2
281 - 500	50	2	3

4.3.1.1.1 If number of inspection units to be sampled equals or exceeds 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 presented 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 not less than 3 years.

4.3.1.3 Inspection Unit: An inspection unit shall be as noted below, unless otherwise specified. Each shipment shall be sampled for inspection. The inspection unit may vary with continued satisfactory production; however, any rejections will cause the product from that vendor to revert to the initial inspection level as agreed upon by purchaser and vendor.

4.3.1.3.1 Tape:
Ø

Consecutive Spool Number	<u>Inspection Unit</u>	
	sq ft	m ²
1 - 20	2500	230
21 - 40	5000	465
Over 40	15,000	1400

4.3.1.3.2 Broadgoods: A roll is defined as each 3500 sq ft (325 m²) of product, usually in one continuous piece. Multiple rolls of less than 3500 sq ft (325 m²) may be combined to form one roll, not to exceed 3500 sq ft (325 m²).
Ø

Consecutive Roll Number	Inspection Unit
1 - 40	Every roll
41 - 80	Every other roll
Over 80	Every third roll

4.3.2 For Preproduction Tests: Shall be as agreed upon by purchaser and vendor or otherwise according to Table II.
Ø

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 by purchaser. Results of tests on production material shall be essentially equivalent to those on the approved sample material.

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 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 or processing, or both, 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 shall be conducted as follows:

ø

Requirement	Minimum Number of Specimens per Test	Test Procedure
Volatile Content	1	ASTM D3530
Resin Solids Content	2	ASTM D3529
Resin Flow	1	ASTM D3531
Gel Time	1	ASTM D3532
Tack, Time Adherence	1	4.5.2
Tack, Peel Strength	1	4.5.3
Visual Imperfections	1	4.5.4
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	4.5.5
Interlaminar Shear Strength	4	ASTM D2344
Density	3	4.5.6
Void Content	3	ASTM D2734
Fiber Content	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 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 $60\% \pm 3$. 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 Tack, Time Adherence:

4.5.2.1 Cut two pieces of material approximately 1 x 3 in. (25 x 75 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. (75 mm) in nominal width, butt together sufficient pieces of the panel to produce a 3-in. (75-mm) wide specimen.

- 4.5.2.2 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. (100 x 200 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° - 27°C) and 50 - 70% relative humidity.
- 4.5.2.3 Report results as pass or fail. If a specimen fails to adhere for the test period, record the elapsed time at failure.
- 4.5.3 Tack, Peel Strength: Shall be determined as agreed upon by purchaser and vendor.
- 4.5.4 Visual Imperfections: Shall be determined as follows:
- 4.5.4.1 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.
- 4.5.4.2 Inspection aids and measuring devices of applicable accuracy may be used as required.
- 4.5.4.3 Report the results of the inspection of each sample of material.
- 4.5.5 Flexural Strength and Modulus of Elasticity:
- 4.5.5.1 Specimen Preparation: The specimens, taken from the laminate prepared in 4.5.1, shall be 0.080 in. (2.00 mm) nominal thickness, 0.500 in. \pm 0.010 (12.50 mm \pm 0.25) wide, and 3.00 in. \pm 0.03 (75.0 mm \pm 0.8) long. Specimen edges shall be ground with abrasive finer than No. 400 (38 μ m) 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 \pm 2 times the thickness.

- 4.5.5.2 Test Procedure: The specimen shall be loaded to failure at a crosshead speed of 0.050 in. \pm 0.005 (1.25 mm \pm 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 \pm 0.03 in. (\pm 0.8 mm). The span length shall be 32 \pm 2 times the specimen thickness.
- 4.5.5.3 Calculation Using Inch/Pound 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.

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

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

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

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

4.5.6 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 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 specification and the applicable detail specification. This report shall include the purchase order number, AMS 3894C and its applicable detail specification number and revision letter, 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.

4.6.1.1 A material safety data sheet conforming to AMS 2825 or equivalent shall be supplied to each purchaser prior to, or concurrent with, the report of preproduction test results or, if preproduction testing be waived by purchaser, concurrent with the first shipment of impregnated sheet or tape for production use. Each request for modification of formulation shall be accompanied by a revised data sheet for the proposed formulation.

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 3894C and its applicable detail specification number and revision letter, 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 either a statement that the material 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 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. 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 8 in. (200 mm). Winding shall be uniform and shall provide for proper unreeling. Each spool shall contain 600 - 1320 ft (185 - 400 m) except that, in any one shipment, up to 20% of the spools may contain lengths as short as 350 ft (110 m). Tape ends shall be secured.

5.1.1.1 Location of visually imperfect areas and of splices shall be plainly identified on the product 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 8.4). 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. (0.75 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 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), EPOXY-RESIN-IMPREGNATED
 AMS 3894/*
 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 _____

*Insert number of applicable detail specification.