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SURFACE VEHICLE STANDARD

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TEST PROCEDURES FOR AUTOMOTIVE STRUCTURAL COMPOSITE MATERIALS

Foreword—This Document has not changed other than to put it into the new SAE Technical Standards Board Format.

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1. ***Scope***—This SAE Standard is intended to serve as a guide for the collection of physical, mechanical, and thermal properties of fiber-reinforced polymer composite materials for automotive structural applications. This document attempts to utilize test methods applicable to the widest range of structural materials and processes without compromising the integrity of the data being sought. A summary of the material characterization is shown in Section 15.

2. ***References***

2.1 **Applicable Publications**—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE EA-2253—SDRP Data Reporting Program

2.1.2 ASTM PUBLICATIONS—Available from ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959.

ASTM D 618—Conditioning Plastics and Electrical Insulating Materials for Testing
ASTM D 638—Tensile Properties of Plastics
ASTM D 696—Coefficient of Linear Thermal Expansion of Plastics
ASTM D 792—Specific Gravity and Density of Plastics by Displacement
ASTM D 2584—Ignition Loss of Cured Reinforced Resins
ASTM D 3039—Tensile Properties of Fiber Composites
ASTM D 3410—Compression Properties of Fiber Composites
ASTM D 3417—Heats of Fusion and Crystallization of Polymers by Thermal Analysis
ASTM D 3593—Molecular Weight Averages and Distribution of Polymers by GPC Method
ASTM D 4065—Practice for Determining and Reporting Dynamic Mechanical Properties of Plastics
ASTM D 5083—Tensile Properties of Reinforced Thermosetting Plastics Using Straight Sided Specimens
ASTM D 5296—Molecular Weight Averages and Molecular Weight Distribution of Polystyrene by High Performance Size-Exclusion Chromatography
ASTM D 5379—Shear Properties of Composite Materials by the V-notched Beam Method

2.1.3 GENERAL MOTORS PUBLICATION—Available from Boise Cascade, 13301 Stephens Road, Warren, MI 48089.

GM Std 9077-P—Determination of Filler Content

2.1.4 CONFLICTS—In the event of a conflict between the text of this document and the references cited herein, the text of this document shall take precedence.

3. Definitions

3.1 Structural Polymer Composite—Automotive structural polymer composites are considered to be those having a tensile modulus greater than 7 GPa and a tensile strength greater than 100 MPa.

3.2 Planar Isotropic Composites—These materials are defined as being comprised of randomly oriented fibers that will result in properties that are nearly the same in all directions in-plane, but different in the thickness direction. Examples of such materials include liquid molded composites reinforced with continuous strand mats, chopped strand mats, or directed fiber preforms; random fiber sheet molded composites (SMC) and random fiber reinforced thermoplastic composites.

3.3 Orthotropic Composites—These materials do not have the same *x*, *y*, and *z* directional properties. Such materials include liquid molded composites reinforced with unidirectional and bidirectional stitched mats, woven fabrics, knitted fabrics, and directionally reinforced SMC and thermoplastic composites.

3.4 Special Reinforced Composites—Some reinforcements create different symmetry than planar isotropic or orthotropic reinforcements. Examples include some triaxial woven preforms, braided mats, or mixed lay-ups. Test specimen layout definition for these reinforcements is beyond the scope of this document. Sampling of these materials should be done with the prior approval of the customer.

3.5 Ambient Conditions—These are room temperature laboratory conditions, which are assumed to be 23 °C ± 2 °C and 50% ± 5% RH.

4. General Requirements

4.1 Calibrations—All measuring equipment for determining or controlling physical, mechanical, or thermal characteristics shall be calibrated and certified with traceability to the National Institute of Standards and Technology.

4.2 Equivalence—Any substitution of supposed equivalent items, where “or equivalent” is specified herein, must first be approved by the customer.

4.3 Responsibility for Quality—Unless otherwise specified, the supplier is responsible for all quality inspection and for meeting all of the test requirements specified herein. The supplier may use internal testing facilities or any other qualified test agencies.

4.4 Data Reporting—All physical, thermal, and mechanical data and information on the constituent materials and panel molding shall be submitted to the customer using the Supplemental Data Reporting Package (SDRP). All data requested herein shall be manually recorded onto the SDRP forms or entered into the electronic SDRP program for output and transmittal to the customer. Graphs or other requested traces shall also be packaged and sent with the SDRP to the customer.

The SDRP Data Reporting Program (EA-2253) available from SAE as a 3-1/2 in or a 5-1/4 in diskette, is a menu-driven program, which facilitates data entry and reporting using an IBM-compatible personal computer. This program is the preferred method for reporting data.

The SDRP reporting forms are found in Appendix A. These include a “Constituent Materials/Process Data Sheet” (A3-A5) for the raw materials and processing data. This form may be modified as required to provide additional relevant information.

5. Panel Fabrication

5.1 General Panel Requirements

5.1.1 NUMBER OF PANELS—Six panels shall be tested for any given material (a material is defined here as any particular combination of resin, reinforcement, and filler). Sufficient panels should be molded to assure that six panels are available after potential rejections cited in 5.1.4, 5.1.6, 5.3.2, or 5.4.2.

5.1.2 CONSTITUENT MATERIALS—All of the panels shall be from a single production lot of composite using single batches of resin, fiber, filler, and additives. The resin type, all matrix constituents and fibers used in molding are to be clearly defined. RECORD IN SDRP.

5.1.3 PREFORM/MOLD CHARGE LAY-UP—To allow for a direct comparison to be made among material systems, all plies shall be aligned in the same direction. Every ply in a given plaque shall also be the same reinforcement form and product code. Mixed lay-ups may be considered for submittal, but should be discussed with the customer prior to panel fabrication. If multiple plies are used, the plies must be aligned and directionally indicated. The number of plies must also be indicated. RECORD IN SDRP.

5.1.4 PANEL QUALITY—Evidence of a flawed or an improperly prepared test panel shall be cause for discarding the panel prior to testing and fabrication of a replacement panel. Such causes include incorrect lay-up sequence, incorrect cure cycle, incorrect fiber content, fiber misalignment, nonfilling of mold cavity, blisters, excessive porosity, excessive void content, severe panel warpage, resin rich surfaces, thickness variation across the plaque, or compression of the preform towards the surface.

5.1.5 PANEL DIMENSIONS—Nominal panel dimensions shall be 610 mm x 610 mm.

5.1.6 PANEL THICKNESS—Panel thickness shall be 3.2 mm ± 0.2 mm with maximum thickness run out of 0.2 mm.

5.2 Panel Molding—Molding conditions such as injection time, mold temperature, and postcure schedules must be reported. Reaction conditions for the material must be representative of conditions which would be utilized to mold an actual production part and should be reported in complete detail. Panels may be fixtured during postcure if warpage is likely to occur. RECORD IN SDRP.

5.2.1 LIQUID COMPOSITE MOLDING—Thermoplastic or thermoset binders in the preform shall be "set" prior to molding. All panels shall be molded in a center-gated mold. Following the cure, care should be taken to avoid unnecessary flexing of the plaque during demolding. Postcure is permissible, but should be noted in the SDRP.

5.2.2 SMC MOLDING—The structural SMC molding charge must be prepared in a manner consistent with production molding practice. If the material will be used with 80% mold coverage, a similar coverage should be used in the fabrication of test plaques. Using 80% as an example, the charge should consist of one or more plies cut to a square configuration and placed over the central 430 mm x 430 mm area of the mold. The charge should be from properly matured material and should be thermally equilibrated to ambient temperature prior to molding. Following cure, care should be taken to avoid unnecessary flexing of the plaque during demolding. Postcure is permissible but should be noted in the SDRP.

5.2.3 THERMOPLASTIC COMPRESSION MOLDING—Charge preparation and coverage should be similar to the procedure used for thermosetting SMC materials. Charge preheating should be done in a manner similar to actual production molding. Any process deviation used in charge preheating must be noted. Since the cooling rate and dwell time will influence the crystallinity level in some materials, care should be taken to reproduce the thermal cycle encountered in production. Any release agents used in component molding should also be used in plaque molding.

5.3 Orthotropic Composites

5.3.1 FIBER ORIENTATION—The primary fiber direction of the preform or mold charge is defined as 0× and is depicted in Figure 1.

5.3.2 FIBER CONTENT—The preferred fiber content for composites with orthotropic fiber orientation is 45% ± 2% by volume. See Section 14 for conversion between weight percent and volume percent. If this fiber content is not practical, alternative fiber contents of 35% ± 2% or 25% ± 2% by volume may be used. Consult with the customer if none of these fiber contents are acceptable.

5.4 Planar Isotropic Composites

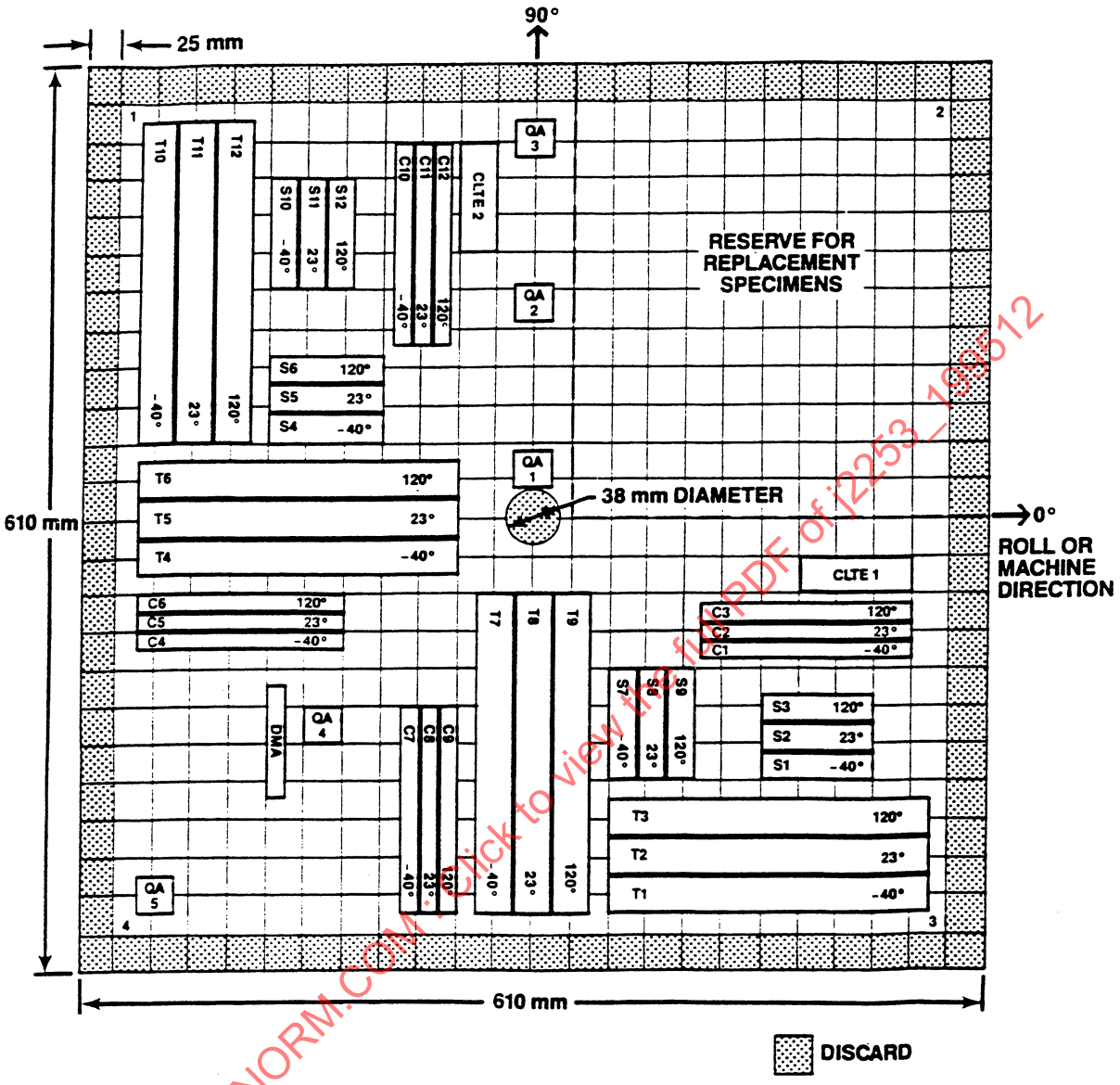
5.4.1 PANEL TEST ORIENTATION—For materials with a nominal planar isotropic fiber orientation, a processing parameter such as roll direction for continuous strand mat products or machine direction for SMC will be defined as 0× as depicted in Figure 1 and designated in the SDRP tables.

5.4.2 FIBER CONTENT—The preferred fiber content for composites with planar isotropic fiber orientation is 25% ± 2% by volume. See Section 14 for conversion between weight percent and volume percent. If this fiber content is not practical, alternative fiber contents of 35% ± 2% or 45% ± 2% by volume may be used. Consult with the customer if none of these fiber contents are acceptable.

6. Material Sampling

6.1 Sampling Procedure—Specimens for physical, thermal, and mechanical tests shall be cut from the panels fabricated according to Section 5 using procedures described in Section 7.

6.2 Specimen Layout—Specific specimen locations for Planar Isotropic Fiber-Reinforced composites and Orthotropic Fiber-Reinforced composites are shown in Figure 1. Samples shall be cut and labeled per the codes indicated in Figure 1. This sample coding scheme is consistent with the SDRP. For liquid-molded panels, the center-gate area shall not be used and should be discarded. For all panels, the 25 mm trim areas shaded in Figure 1 shall not be used for specimen sampling and should be discarded.



SPECIMEN LOCATION TEMPLATE

SPECIMEN DIMENSIONS

TENSILE (T)	215 mm x 25 mm	**COMPRESSION (C)**	140 mm x 12.5 mm
SHEAR (S)	75 mm x 20 mm	**CLTE**	75 mm x 25 mm
DMA	65 mm x 10 mm	**QA**	25 mm x 25 mm

FIGURE 1—SPECIMEN LOCATION

7. Specimen Preparation

7.1 General—The techniques described in this section are recommended requirements to ensure good quality test specimens produced in a consistent manner.

7.2 Rough Cutting—Rough cutting of specimens can be accomplished by machining operations by cutting pieces from the panel to a size approximating the specimen configuration. The specimen layout plan shown in Figure 1 shall be used for specimen location.

7.3 Surface Edge Finishing—Final surface edge preparation can be accomplished by surface grinding. The finish sanding should be done only in the direction of the length of the specimens and the sanding grit size should be 180 grit or finer. Sanding or grinding perpendicular to the length of the specimen may result in lower failure strengths because of high-stress concentrations at the scratch marks. No sanding is required, however, if specimens are cut with a diamond saw using a 180 grit or finer diamond blade and a minimum tip speed of 200 m/min. Water cooling of the saw blade is recommended for all materials, but is required for urethane materials.

7.4 Specimen Conditioning—All specimens shall be conditioned prior to testing per ASTM D 618, Method A. For tests at any temperature other than ambient, specimens shall be further conditioned at the test temperature for 30 min immediately prior to testing.

8. Physical Test Methods

8.1 General—It is desirable that the tests in 8.2 to 8.5 be performed on the same specimens. The specimen size for each test performed shall be 25 mm x 25 mm and shall be taken from the QA locations designated in Figure 1.

8.2 Specific Gravity—Specific gravity shall be determined in accordance with ASTM D 792. RECORD IN SDRP.

8.3 Resin Content—Resin content shall be determined in accordance with ASTM D 2584. See Section 14 for conversion between weight percent and volume percent. RECORD IN SDRP.

8.4 Filler Content—Filler content shall be determined in conjunction with ASTM D 2584. Appropriate procedures (for example, GM Engineering Standard—Materials and Process Procedure GM 9077-P) utilizing acid wash for calcium carbonate filler shall be used to determine the amount of particulate fillers in the composite. See Section 14 for conversion between weight percent and volume percent. RECORD IN SDRP.

8.5 Fiber Content—Fiber content shall be determined in accordance with ASTM D 2584. For reinforcements other than glass fiber, consult the customer. See Section 14 for conversion between weight percent and volume percent. RECORD IN SDRP.

8.6 Panel Thickness—Panel thickness uniformity shall be determined as follows:

a. Measure the thickness of each panel three separate times at each corner (25 mm from each edge) and at a region near the center of the panel (but away from the discarded gate region for liquid-molded panels).
b. Using all three measurements taken, report the average value for that region of the panel. RECORD IN SDRP.

8.7 Crystallinity—For semi-crystalline thermoplastic composites, heat of fusion and heat of crystallization shall be determined in accordance with ASTM D 3417. An appropriate sample shall be taken from an area near the DMA specimen as designated in Figure 1. A Differential Scanning Calorimeter (DSC) shall be used to determine the areas under crystallization exotherm and fusion endotherm. RECORD IN SDRP.

8.8 Molecular Weight—For thermoplastic composites, molecular weight averages and molecular weight distribution shall be determined in accordance with ASTM D 5296. The “universal calibration” principles outlined in ASTM D 3593 or a suitable monodisperse polymeric standard shall be used for calibrating the test equipment. An appropriate sample shall be taken from an area near the DMA specimen as designated in Figure 1. High Performance Size-Exclusion Chromatography (HPSEC) shall be used to determine number and weight average molecular weights and molecular weight distribution. RECORD IN SDRP.

9. Thermal Test Methods

9.1 General—Dynamic Mechanical Analysis (DMA) and Coefficient of Linear Thermal Expansion (CLTE) tests shall be conducted on each of the specimens labeled DMA and CLTE, respectively, in Figure 1.

9.2 DMA Test Method—Dynamic mechanical analysis testing shall be conducted in accordance with ASTM D 4065 with the following provisions or exceptions cited herein.

9.2.1 INSTRUMENTATION—A Rheometrics RDS II or TA System’s (formerly Dupont’s) 983 Dynamic Mechanical Analyzer or instrumentation which provides equivalent results shall be utilized. The instrument utilized in the evaluation shall be calibrated in accordance with the manufacturer’s recommendations.

9.2.2 SAMPLE PREPARATION—Test specimen preparation procedures described in Section 7 shall be followed to ensure good quality specimens.

9.2.3 SAMPLE DIMENSIONS—Sample dimensions for the previously named instruments shall be at least 65 mm x 10 mm x 3.2 mm. Distance between the instrument clamps shall be at least 40 mm. Sample dimensions for testing with other instrumentation may be selected using ASTM D 4065 guidelines.

9.2.4 TEST TEMPERATURE RANGE—A temperature sweep shall be conducted from -50 °C to an upper limit temperature which shall be at least 40 °C above the material’s glass transition or 200 °C, whichever is higher.

9.2.5 HEATING RATE—The heating rate shall be no greater than 5 °C/min (5 °C steps with 1 min equilibration for the previously named Rheometrics instrumentation).

9.2.6 FREQUENCY—The frequency shall be maintained at 1 Hz (6.28 radians/s) for fixed frequency instrumentation.

9.2.7 OTHER TEST PARAMETERS—Strain shall be maintained at a minimum value which allows the measured stress to exceed the lower limit of sensitivity of the transducer. Typical strain levels are 0.02 to 0.2%. When possible, an amplitude of 0.6 mm should be utilized with other fixed frequency instrumentation. Test parameters for resonant frequency experiments (e.g., sample length) should be adjusted so that an initial frequency of 30 Hz at 0.2 mm amplitude is obtained at the onset of the experiment.

9.2.8 GLASS TRANSITION TEMPERATURE—The glass transition temperature (Tg) shall be determined from the storage modulus data. A line is drawn tangent to the storage modulus plateau at temperatures below the transition and a second line is drawn tangent to the storage modulus curve beginning at the transition inflection point, which is approximately midway through the sigmoidal curve associated with the transition. The temperature at which these two tangent lines intersect is reported as the glass transition temperature (see Figure 2).

9.2.9 REPORT—The test report shall include measured transition temperatures and thermograms for either shear moduli (G’, G”, and tan δ) or flexural moduli (E’, E”, and tan δ) versus temperature. One specimen per panel shall be run. RECORD IN SDRP AND PROVIDE THERMOGRAMS.

9.3 Coefficient of Linear Thermal Expansion (CLTE)

9.3.1 CLTE TESTING—Thermal expansion properties shall be measured in accordance with ASTM D 696 with the following provisions and exceptions cited herein.

9.3.2 INSTRUMENTATION—A fused-quartz dilatometer equipped with precise length measuring devices such as Linear Variable Differential Transformer (LVDT) shall be used to record change in length of the specimen as a function of temperature.

9.3.3 SAMPLE DIMENSIONS—The test specimen shall be of constant cross-section and the specimen size is 75 mm x 25 mm x 3.2 mm. Dimensional variation of specimen length shall be limited to 0.25 mm.

9.3.4 SAMPLE PREPARATION—Test specimen preparation procedures described in Section 7 shall be followed to ensure good quality specimens.

9.3.5 PROCEDURE—The CLTE shall be measured and/or reported over the following temperature ranges:

a. -30 to 30 °C
b. 30 to 80 °C
c. 80 to 125 °C

If the instrumentation allows, the change in length should be monitored continuously or in increments of 20 °C over the temperature range of the test.

9.3.6 REPORT—The CLTE shall be reported over the ranges a, b, and c. If the data can be obtained from the instrumentation, a table showing $\Delta l/l$ values at 20 °C intervals should be provided. Use the specimen original length (l) at -30 °C as the “zero” point for $\Delta l/l$. RECORD IN SDRP AND PROVIDE TABULATED DATA.

10. Tensile Testing

10.1 General Description—Tensile testing shall be conducted in general accordance with ASTM D 3039 and ASTM D 5083 with the following provisions or exceptions cited herein. Mechanical properties determined shall include the following: tensile strength, modulus, strain to failure, Poisson’s ratio, and energy to failure at -40 °C, 23 °C, and 120 °C. These tests shall be conducted on each of the appropriately labeled specimens in the numbers and directions indicated in Figure 1.

NOTE—If a material cannot be tested at 120 °C because it is too close to the resin Tg or exceeds the resin Tg, contact the customer to discuss an appropriate lower temperature.

10.2 Apparatus—Grips shall be self-aligning, so that the long axis of the specimen is aligned with the direction of the applied load through the centerline of the grip assembly. The specimen should not have any rotary motion which may induce slippage in the grips. Fine serrations on grip faces have been found to be effective for composite materials. A biaxial extensometer or strain gage accurate to 1% of the measured strain shall be used for measuring Poisson’s ratio. Extensometer or strain gage attachment should not cause damage to the specimen surface.

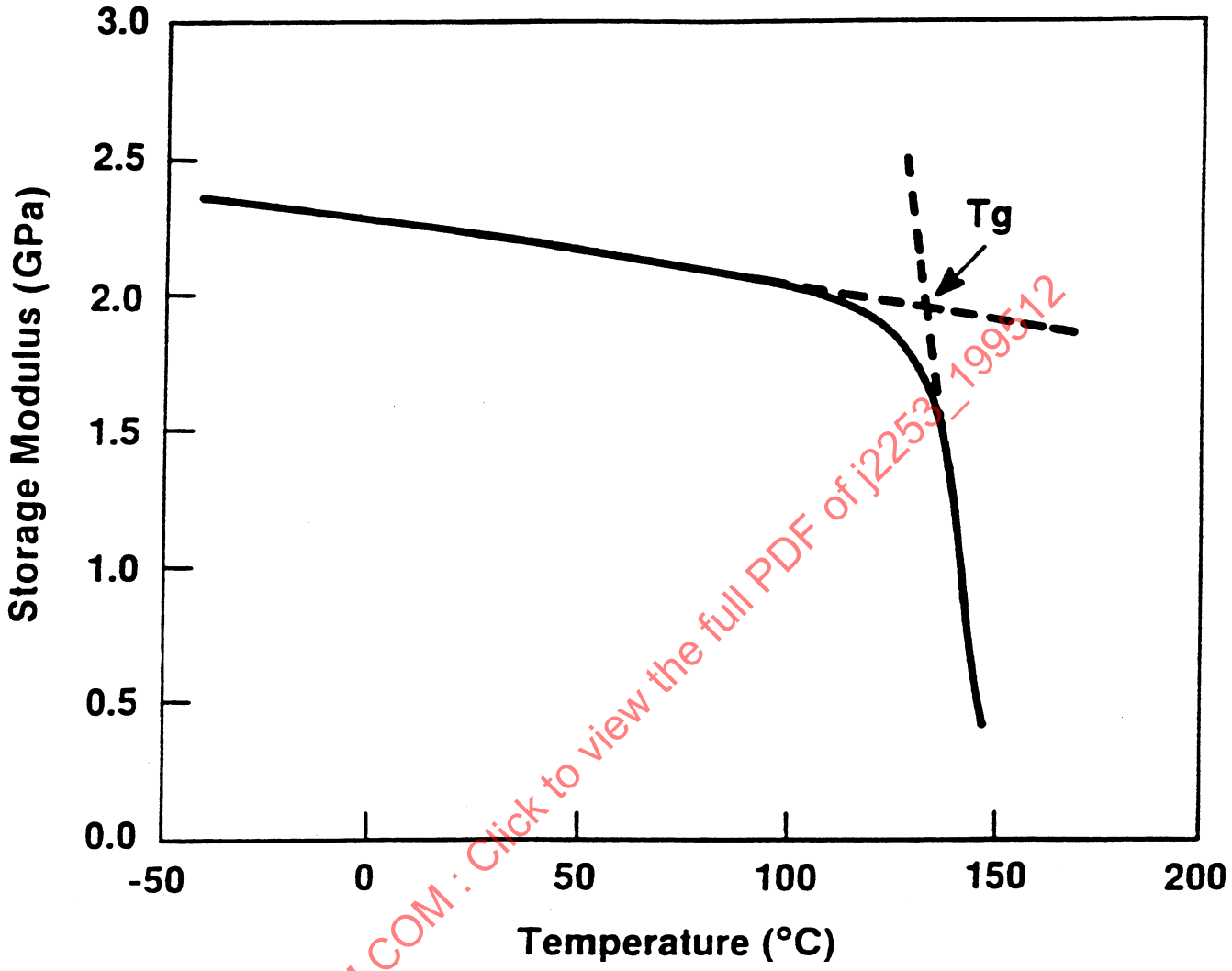


FIGURE 2—STORAGE MODULUS DIAGRAM

10.3 Test Specimen

10.3.1 SPECIMEN DIMENSIONS—The test specimen shall be of constant cross-section and the specimen size is 215 mm x 25 mm x 3.2 mm for random fiber composites and 215 mm x 12.5 mm x 3.2 mm for 0 degree continuous fiber composites. Dimensional variation of specimen width shall be limited to ±0.15 mm. Measure samples to nearest 0.025 mm.

10.3.2 SPECIMEN PREPARATION—Test specimen preparation procedures described in Section 7 shall be followed to ensure good quality samples.

10.3.3 SPECIMEN TABBING—Tabbing of specimens is not required unless unacceptable failures, as defined in 10.4.3, are encountered.

10.4 Procedure

10.4.1 SETUP—Measure the width and thickness of the flat specimens with a suitable micrometer to the nearest 0.025 mm at a minimum of three points along its length. Calculate and record the cross-sectional area based on the average width and thickness measurements. Place the specimen in the grips with a 115 mm separation between the ends of the gripping surfaces. Attach the extensometer or connect the strain gage and record load-extension curve of the specimen. The speed of testing shall be the relative motion of the grips or test fixtures during the test. The standard speed of testing shall be 5 mm/min (0.2 in/min).

10.4.2 REPLICATES—Twelve specimens from each of six panels shall be tested in the directions, temperatures, and locations indicated in Figure 1.

10.4.3 ACCEPTABLE FAILURES—Specimens failing closer than 12.5 mm to the grip shall be discarded. If a significant number of at-the-grip failures is encountered, tabs as defined in ASTM D 3039 shall be applied. Most composites containing 0 degree continuous fibers will require tabbing.

10.5 Calculations—Determine the tensile strength, chord modulus, Poisson's ratio, and percent strain at failure using the standard procedures. The chord modulus shall be calculated using the 0.05% and 0.25% strain and corresponding stress values. Poisson's ratio shall be calculated using the 0.05% and 0.25% longitudinal strain and corresponding transverse strain values. The area under the stress-strain curve up to the point of failure (maximum stress) shall be determined and reported as the tensile energy to failure in units of MJ/m^3. If the energy-to-failure is not reported for a material, the customer will approximate this number as one-half the product of the stress at failure multiplied by the strain at failure. This approximation may result in an underestimation of the energy-at-failure.

10.6 Report—The report shall include the following:

a. Individual tensile strength values, average value, and standard deviation
b. Tensile (chord) moduli, average value, and standard deviation
c. Tensile strains to failure, average value, and standard deviation
d. Poisson's ratio, average value, and standard deviation
e. Tensile energies to failure, average value, and standard deviation
f. A representative example of the stress/strain or load/extension curve

RECORD IN SDRP AND PROVIDE CURVE.

10.7 Resin Tensile Properties—Determine the tensile strength, modulus, and strain to failure for the neat, cured resin in accordance with ASTM D 638. RECORD ON SDRP.

11. Compression Testing

11.1 General Description—Compression testing shall be conducted according to ASTM D 3410, Procedure B (IITRI method), with the exceptions and/or provisions cited herein. Mechanical tests shall include compressive strength at -40 °C, 23 °C, and 120 °C. Modulus, strain to failure, and energy to failure at these temperatures are optional. These tests shall be conducted on each of the labeled specimens in the numbers and directions indicated in Figure 1.

NOTE—If a material cannot be tested at 120 °C because it is too close to the resin Tg or exceeds the resin Tg, contact the customer to discuss an appropriate lower temperature.

11.2 Compression Test Fixture—Test fixture dimensions shall correspond to those found in ASTM D 3410, Procedure B for specimens 12.5 mm wide.

11.3 Test Specimen

11.3.1 SPECIMEN DIMENSIONS—The test specimen shall be 12.5 mm wide. All other necessary specimen dimensions are called out in ASTM D 3410, Procedure B for specimens 12.5 mm wide.

11.3.2 SPECIMEN PREPARATION—Test specimen preparation procedures described in Section 7 shall be followed to ensure good quality samples.

11.3.3 SPECIMEN TABBING—Untabbed specimens are permissible if failures occur within the center area of the sample and away from the edge of the grip. If required, specimen tabs as specified in ASTM D 3410 shall be applied prior to any environmental conditioning. However, specimen tabs are not required to be beveled as specified in ASTM D 3410. Tabs shall be applied to the specimens prior to final width dimension machining.

11.4 Procedure

11.4.1 SETUP—Measure the width and thickness of the compression specimens in the gage area to the nearest 0.025 mm. Calculate and record the cross-sectional area of the specimen. Particular care should be taken to properly align the specimen in the test fixture. Specimen shall be tested using a constant crosshead rate of 5 mm/min (0.2 in/min).

11.4.2 REPLICATES—Twelve specimens from each six panels shall be tested in the directions, temperatures, and locations indicated in Figure 1.

11.4.3 STRAIN MEASUREMENT—If performed, strain measurement may be taken by use of strain gages or extensometer. Any transducer used shall not in any way damage the surface of the specimen prior to or during the test.

11.4.4 CHORD MODULUS—When measured, modulus shall be collected using the chord modulus method, and shall be calculated using the 0.05 and 0.25% strain and corresponding stress values.

11.5 Calculations—Determine the compressive strength as well as the chord modulus and percent strain at failure when measured using standard procedures. The area under the stress-strain curve up to the point of failure (maximum stress) shall be determined and reported as the tensile energy to failure in units of MJ/m3. If the energy-to-failure is not reported for a material, the customer will approximate this number as one-half the product of the stress at failure multiplied by the strain at failure. This approximation may result in an underestimation of the energy-at-failure.

11.6 Report—The report shall include the following:

a. Individual compressive strengths, average value, and standard deviation
b. Compressive (chord) moduli, average value, and standard deviation (optional)
c. Compressive strains to failure, average value, and standard deviation (optional)
d. Compressive energies to failure, average value, and standard deviation (optional)
e. A representative example of the stress/strain or load/displacement curve (optional)

RECORD IN SDRP AND PROVIDE CURVE.

12. Shear Testing

12.1 General Description—Shear testing shall be conducted according to ASTM D 5379 (Iosipescu method) with the exceptions and/or provisions cited herein. Mechanical properties determined shall include: shear strength, modulus, and strain to failure at -40 °C, 23 °C, and 120 °C. These tests shall be conducted on each of the labeled specimens in the numbers and directions indicated in Figure 1.

NOTE—If a material cannot be tested at 120 °C because it is too close to the resin Tg or exceeds the resin Tg, contact the customer to discuss an appropriate lower temperature.

12.2 Shear Test Fixture—The test fixture dimensions shall correspond to those found in ASTM D 5379.

12.3 Test Specimen

12.3.1 SPECIMEN DIMENSIONS—Specimens shall nominally be 75 mm long, 20 mm wide, and 3.2 mm thick. Load bearing edges should be ground flat and parallel to within 0.05 mm using an abrasive wheel operating on a precision surface grinder as described in Section 7.

12.3.2 SPECIMEN PREPARATION—The prescribed notch angles and root radii should be ground in the specimens using diamond abrasive tooling on a precision surface grinder. Care must be taken to avoid delaminating specimens during notch grinding. Stacking and clamping specimens in the tool grinder vise have been found to be effective. The strain is to be measured using a strain gage rosette (for example, Micro - Measurements EA-06-062TV-350 or N2A series gages). Special care shall be taken in the mounting and alignment of the gages in order to avoid erroneous data collection. Appropriate gage excitation voltages shall also be used, and a sufficiently low voltage applied to prevent excessive resistive heating of the test sample. For elevated temperature gaging, refer to the strain gage manufacturer's literature for proper adhesive.

12.3.3 SPECIMEN TABBING—Untabbed specimens are permissible providing the specimens exhibit appropriate failure modes as defined in ASTM D 5379. The tabs shall be bonded to the specimen per the adhesive manufacturer's instructions prior to final machining and conditioning. The adhesive used shall be commercially available and capable of withstanding the load levels and temperatures of the test. Most random fiber composites will require tabbing.

12.4 Procedure

12.4.1 DIMENSIONS—Measure the thickness of the specimen to within 0.025 mm at three points. Determine the minimum distance between the notch tips. Calculate and record the cross-sectional area.

12.4.2 MOUNTING—Mount the specimen in the test fixture using a lift-up alignment tool to index on the lower specimen notch. Tighten the wedge clamps to hold the specimen firmly in place. These clamps need only be "finger tight." The purpose of the wedges is to prevent the specimen from rotating during a test. Excessive tightening of the wedge clamps is not necessary or desirable.

12.4.3 LOADING—The fixture is loaded in compression until the specimen fails. The loading rate shall be no greater than 5 mm/min (0.2 in/min).

12.4.4 REPLICATES—Twelve specimens from each of six panels shall be tested in the directions, temperatures, and locations indicated in Figure 1.

12.5 Calculation

12.5.1 SHEAR STRENGTH—Shear strength is calculated by dividing the applied load by the specimen cross-sectional area between the notches as shown in Equation 1:

$$\tau_{12} = P/wt \qquad \text{(Eq. 1)}$$

where:

τ_{12}= Shear strength
P = Applied load
w = Distance between the notches
t = Specimen thickness

Ultimate shear strength is not necessarily calculated from the maximum force attained during loading. During and after actual shear failure, the reinforcing fibers in a composite material may reorient, subsequently bearing some portion of the applied force in a tensile mode. This reorientation is more likely to occur in composites with matrix materials which are very nonlinear in shear, such as thermoplastic composites. The point at which this happens can usually be determined from a load (stress) versus displacement plot. The point at which the stress-displacement plot abruptly changes slope is the point at which shear failure occurred. Test results must thus be carefully examined.

NOTE—On the 0 degree unidirectional specimens a horizontal crack consistently develops at the notch root causing a small drop in the load-deflection curve. In determining shear strength for the 0 degree unidirectional specimen, this failure should not be taken as the shear failure of the specimen.

12.5.2 SHEAR MODULUS—Shear modulus is determined using the shear stress-strain curve. The shear strain is determined by Equation 2:

$$\gamma_{12} = \left|\varepsilon_{45} - \varepsilon_{-45}\right| \quad \text{(Eq. 2)}$$

where:

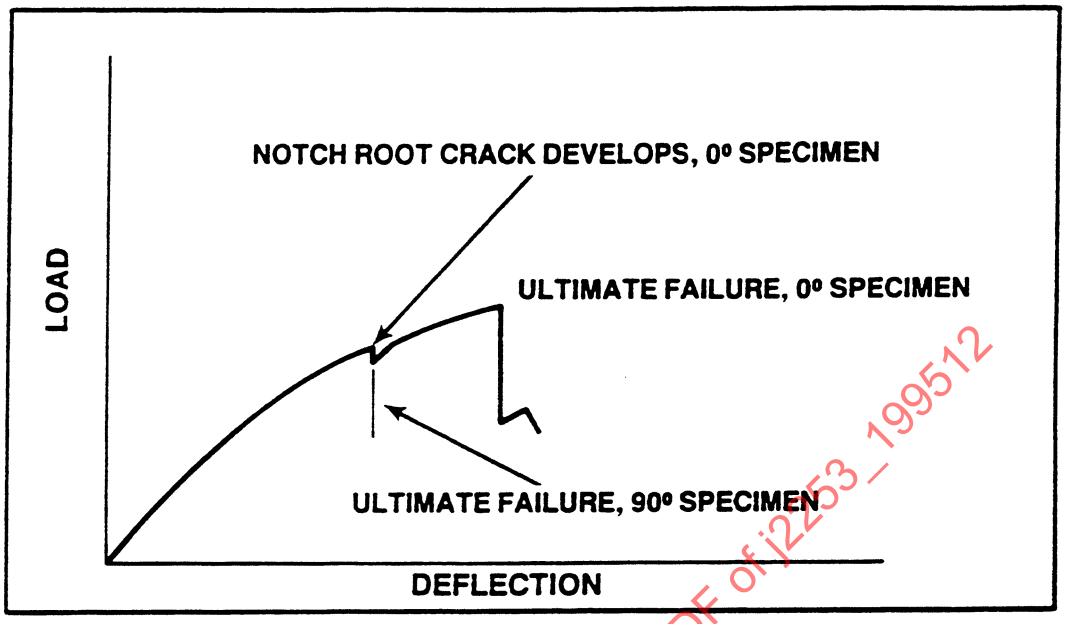
γ_{12} is the total shear strain
ε_{45} and ε_{-45} are the strains measured by each gage

Shear modulus is then determined by Equation 3:

$$G_{12} = \tau_{12}/\gamma_{12} \quad \text{(Eq. 3)}$$

The shear modulus shall be defined as a chord modulus using the 0.05 and 0.25% strain (γ_{12}) levels.

12.5.3 ASSESSING FAILURE MODES—The failure mode should be assessed for each failed test specimen to determine the validity of the failure mode. Failure should be through the test section. There should be no failures along the loaded portions of the specimen. Any failure which does not meet these conditions constitutes grounds for discounting the strength data measured by the test and additional tests shall be run. Acceptable and unacceptable failure modes are depicted in ASTM D 5379. Figure 3 presents typical load/deflection plots for several types of specimens.



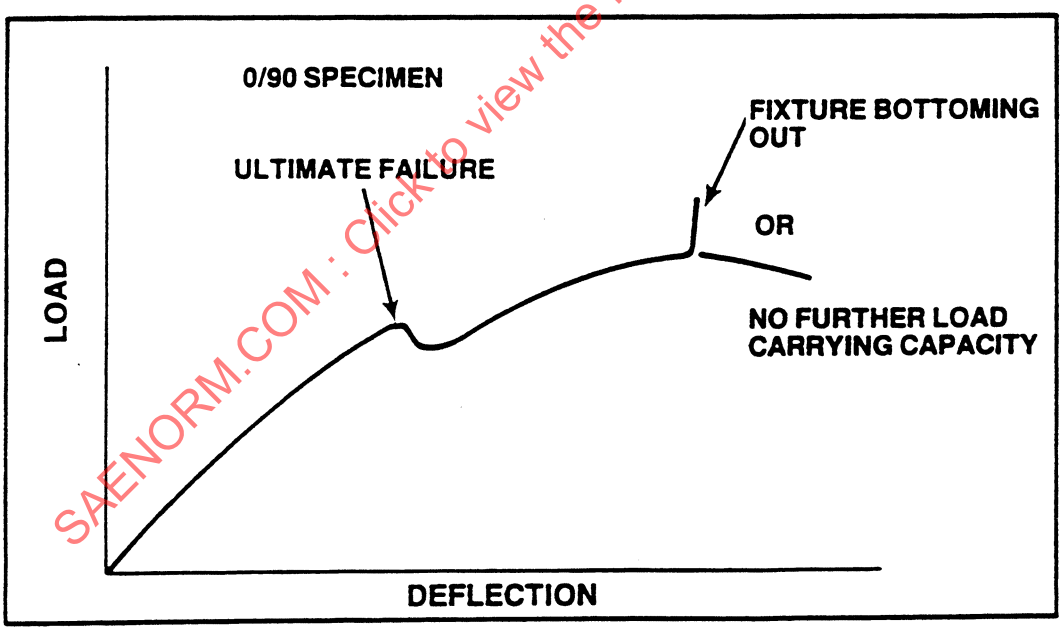


FIGURE 3—TYPICAL SHEAR LOAD-DEFLECTION CURVES

12.6 Report—The report shall include the following:

a. Individual shear strengths, average value, and standard deviation
b. Shear (chord) moduli, average value, and standard deviation
c. A representative example of the stress/strain or load/extension curve

RECORD IN SDRP AND PROVIDE CURVE.

13. Statistical Analysis Methods

13.1 Mean Calculation—The arithmetic mean for a given set of data shall be calculated as follows in Equation 4:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad \text{(Eq. 4)}$$

where:

$\bar{x}$ = Arithmetic mean
x_i = Value of a single observation
n = Number of observations

13.2 Standard Deviation Calculation—The standard deviation for a given set of data shall be calculated as follows in Equation 5:

$$S = \sqrt{\frac{\left(\sum_{i=1}^{n} x_i^2 - n\bar{x}^2\right)}{(n-1)}} \quad \text{(Eq. 5)}$$

where:

S = Standard deviation
$\bar{x}$ = Arithmetic mean
x_i = Value of a single observation
n = Number of observations

14. Constituent Content Conversions

14.1 Weight Percent to Volume Percent—The volume percent of a constituent (fiber, resin, or filler) in the composite is calculated from the weight percent of the constituent as follows in Equation 6:

$$V_i = \frac{W_i \cdot \rho_c}{\rho_i} \quad \text{(Eq. 6)}$$

where:

V_i = Volume percent constituent
W_i = Weight percent constituent
ρ_i = Constituent specific gravity
ρ_c = Composite specific gravity

14.2 Volume Percent to Weight Percent—The volume percent of a constituent in the composite is converted to the weight percent fiber as follows in Equation 7:

(Eq. 7)

$$W_i = \frac{V_i \cdot \rho_i}{\rho_c}$$

14.3 Specific Gravity Estimation—Prior to fabrication of the composite, its specific gravity may be estimated by Equation 8:

$$\frac{100}{\rho_c} = \frac{W_F}{\rho_F} + \frac{W_R}{\rho_R} + \frac{W_f}{\rho_f} + V_V \qquad \text{(Eq. 8)}$$

where:

W_F = Weight percent fiber
W_R = Weight percent resin
W_f = Weight percent filler
ρ_F = Fiber specific gravity
ρ_R = Resin specific gravity
ρ_f = Filler specific gravity
V_v = Volume percent voids

15. Material Characterization Summary—A materials characterization includes composite fabrication, specimen preparation, specimen testing, and data reporting as follows:

a. Mold flat sheet panels (610 mm x 610 mm x 3.2 mm) in accordance with specifications.
b. Cut specimens from six panels per specified layout (Figure 1).
c. Assure that all panels meet thickness and fiber content standards and measure specific gravity. If any panel does not meet the standard, replace it with one that does.
d. Measure dynamic mechanical properties and assure acceptable material performance at 120 °C.
e. Determine coefficient of linear thermal expansion and measure mechanical properties (tensile, compression, shear) at -40 °C, 23 °C, 120 °C (Figure 4).
f. Enter constituent material descriptions, resin properties, molding information, panel dimensions, fiber content measurements, and test results into the computerized Supplemental Data Reporting Package (SDRP, Appendix B).
g. Send copy of the completed SDRP and requested graphs to the customer.

PROPERTY	MANUAL SECTION	TOTAL SPECIMENS REQUIRED
RESIN PROPERTIES		
TENSILE TESTS TENSILE STRENGTH TENSILE MODULUS TENSILE STRAIN TO FAILURE	ASTM D 638	5
THERMOPLASTIC RESIN PROPERTIES		
CRYSTALLINITY	8.7	6
MOLECULAR WEIGHT	8.8	6
COMPOSITE PROPERTIES		
DIMENSIONAL TESTS PANEL THICKNESS	8.6	N/A
PHYSICAL PROPERTIES TEST		30
SPECIFIC GRAVITY	8.2	
RESIN CONTENT	8.3	
FILLER CONTENT	8.4	
FIBER CONTENT	8.5	
THERMAL TESTS		
DMA TESTS[1]	9.2	6
CLTE 0°, 90°	9.3	12
TENSILE TESTS TENSILE STRENGTH 0°, 90° TENSILE MODULUS 0°, 90° POISSON'S RATIO 0°, 90° STRAIN TO FAILURE 0°, 90° ENERGY TO FAILURE 0°, 90°	10	72[2]
COMPRESSION TESTS[3] COMPRESSION STRENGTH 0°, 90° COMPRESSION MODULUS 0°, 90° STRAIN TO FAILURE 0°, 90° ENERGY TO FAILURE 0°, 90°	11	72[2]
SHEAR TESTS SHEAR STRENGTH 0°, 90° SHEAR MODULUS 0°, 90°	12	72[2]

FIGURE 4—CHARACTERIZATION TEST MATRIX—TEST MATRIX—PLANAR ISOTROPIC OR ORTHOTROPIC COMPOSITES—MINIMUM REQUIREMENT

PREPARED BY THE SAE COMPOSITES COMMITTEE

APPENDIX A

APPENDIX A
SUPPLEMENTAL DATA REPORTING PACKAGE (SDRP)

Organization Supplying Data _____ Date_____

Composite Designation_____

CONSTITUENT MATERIALS

Fiber

Fiber Material Type _____
Fiber Product Form _____
Nominal Volume Fraction in Composite (%) _____
Specific Gravity _____
Manufacturer _____
Trade Name_____
Product Code_____
Lot Number _____
Chopped Fiber Length (mm) _____
Roving/Yarn Yield (m/kg)_____
Bundle Size/Splits _____
Filament Diameter (microns) _____
Chemical Size Description_____
Chemical Size Amount (wt%) _____
Binder Description _____
Binder Amount (wt%)_____

Mat/Fabric

Product Form_____
Manufacturer _____
Trade Name_____
Product Code_____
Lot Number _____
Stitching Material _____
Stitching Material Amount (wt%) _____
Stitch Designation _____
Area Weight (g/m^2) _____

Resin

Resin Type _____
Nominal Volume Fraction in Composite (%) _____
Specific Gravity (Cured) _____
Manufacturer _____
Trade Name_____
Product Code_____
Lot Number _____
Viscosity (cp) _____
Resin Composition _____
_____

FIGURE A1—CONSTITUENT MATERIALS/PROCESS DATA SHEET

Resin

Neat Polymer Glass Transition Temp. (°C) _____
Neat Polymer Mechanical Properties:
Tensile Strength (MPa) _____
Tensile Modulus (GPa) _____
Tensile Elongation (%) _____

Filler

Filler Type _____
Nominal Volume Fraction in Composite (%) _____
Specific Gravity _____
Manufacturer _____
Trade Name _____
Product Code _____
Lot Number _____
Particle Size _____
Surface Treatment _____

Cure System

Catalyst/Initiator(s) Concentration and Type:
Type _____
Concentration (%) _____
Supplier _____
Trade Name _____
Lot Number _____

Promoter(s) Concentration and Type:
Type _____
Concentration (%) _____
Supplier _____
Name _____
Lot Number _____

Accelerator:
Type _____
Concentration (%) _____
Supplier _____
Trade Name _____
Lot Number _____

Inhibitor:
Type _____
Concentration (%) _____
Supplier _____
Trade Name _____
Lot Number _____

FIGURE A1—CONSTITUENT MATERIALS/PROCESS DATA SHEET (CONTINUED)

Additional Constituents (each)

Material Type _____
Material Function _____
Nominal Volume Fraction in Composite (%) _____
Specific Gravity _____
Manufacturer _____
Trade Name _____
Product Code _____
Lot Number _____
Relevant Information _____

PROCESS

General

Molding Date _____
Molding Process _____
Mold Composition _____

Molding Detail

Mold Temperature (°C) _____
Mold Pressure (MPa) _____
Vacuum (Bars) _____
Fill Time/Mold Closure Time (sec) _____
Cure Time (sec) _____

Liquid Molding

Preform Construction _____
Number of Layers _____
Binder Type _____
Binder Conc. (wt%) _____
Preform Processing:
- Procedure _____
- Temperature (°C) _____
- Time (sec) _____
- Pressure (KPa) _____

Resin A/B Mix Ratio _____
Resin Injection Rate (Kg/min) _____
Resin Injection Pressure (MPa) _____
Resin Temperatures (°C)
- A Side _____
- B Side _____

Thermoplastic Composite

Resin Molecular Weight _____
Resin Crystallinity _____
Preheat Time (sec) _____
Preheat Temperature (°C) _____
Number of Plies _____
Mold Coverage (%) _____

FIGURE A1—CONSTITUENT MATERIALS/PROCESS DATA SHEET (CONTINUED)

SMC

Maturation Temperature (°C) _____
Maturation Time (hours) _____
Paste Viscosity at Molding (KPa·sec) _____
Number of Plies _____
Mold Coverage (%) _____

Postcure

Postcure temperature (°C) _____
Postcure Time (min) _____
Additional Parameters _____
_____

FIGURE A1—CONSTITUENT MATERIALS/PROCESS DATA SHEET (CONTINUED)

Supplier _____ Date _____

Composite Designation _____

Fiber Content (% Vol) _____ Specific Gravity _____ Tg (°C) _____
Resin Content (% Vol) _____
Filler Content (% Vol) _____

0° DIRECTION PROPERTIES

Thermal

CLTE (1/°C x 10^{-6}) Ranges: A _____ B _____ C _____

MECHANICAL

		−40 °C		23 °C		120 °C*	
Tensile		AVG	STD DEV	AVG	STD DEV	AVG	STD DEV
STRENGTH	(MPa)						
MODULUS	(GPa)						
POISSON'S RATIO							
FAILURE STRAIN	(%)						
FAILURE ENERGY	(MJ/m^3)						
Compressive							
STRENGTH	(MPa)						
MODULUS	(GPa)						
FAILURE STRAIN	(%)						
FAILURE ENERGY	(MJ/m^3)						
Shear							
STRENGTH	(MPa)						
MODULUS	(GPa)						

*See 10.1 for alternative temperature testing.

FIGURE A2—MATERIAL PROPERTIES—0° DIRECTION SUMMARY SHEET

Supplier _____ Date _____

Composite Designation _____

Fiber Content (% Vol) _____ Specific Gravity _____ Tg (°C) _____
Resin Content (% Vol) _____
Filler Content (% Vol) _____

90° DIRECTION PROPERTIES

Thermal

CLTE (1/°C x 10^{-6}) Ranges: A _____ B _____ C _____

MECHANICAL

Tensile		–40 °C AVG	–40 °C STD DEV	23 °C AVG	23 °C STD DEV	120 °C AVG	120 °C STD DEV
STRENGTH	(MPa)						
MODULUS	(GPa)						
POISSON'S RATIO							
FAILURE STRAIN	(%)						
FAILURE ENERGY	(MJ/m^3)						
Compressive							
STRENGTH	(MPa)						
MODULUS	(GPa)						
FAILURE STRAIN	(%)						
FAILURE ENERGY	(MJ/m^3)						
Shear							
STRENGTH	(MPa)						
MODULUS	(GPa)						

FIGURE A3—MATERIAL PROPERTIES—90° DIRECTION SUMMARY SHEET

Supplier _____ Date _____

Composite Designation _____

QA DATA							
		PLAQUE NUMBER					
SAMPLE	TEST	1	2	3	4	5	6
QA 1	FIBER % VOL						
	RESIN % VOL						
	FILLER % VOL						
	Sp. Gr.						
QA 2	FIBER % VOL						
	RESIN % VOL						
	FILLER % VOL						
	Sp. Gr.						
QA 3	FIBER % VOL						
	RESIN % VOL						
	FILLER % VOL						
	Sp. Gr.						
QA 4	FIBER % VOL						
	RESIN % VOL						
	FILLER % VOL						
	Sp. Gr.						
QA 5	FIBER % VOL						
	RESIN % VOL						
	FILLER % VOL						
	Sp. Gr.						

THERMOPLASTIC DATA						
	PLAQUE NUMBER					
TEST	1	2	3	4	5	6
CRYSTALLINITY %						
MOLECULAR WT X 10^5						

FIGURE A4—QA PROPERTIES DATA

THERMAL EXPANSION				UNITS = (1/°C x 10–6)			DMA UNITS = °C
SAMPLE NUMBER	CLTE1			CLTE 2			
TEMP. RANGE	A	B	C	A	B	C	Tg
PLAQUE 1							
PLAQUE 2							
PLAQUE 3							
PLAQUE 4							
PLAQUE 5							
PLAQUE 6							

FIGURE A5—THERMAL PROPERTIES DATA

Supplier _____ Date _____

Composite Designation _____

THERMAL EXPANSION				UNITS = (1/°C x 10–6)			DMA UNITS = °C
SAMPLE NUMBER	CLTE1			CLTE 2			
TEMP. RANGE	A	B	C	A	B	C	Tg
PLAQUE 1							
PLAQUE 2							
PLAQUE 3							
PLAQUE 4							
PLAQUE 5							
PLAQUE 6							

FIGURE A6—PANEL THICKNESS DATA

Supplier _____ Date _____

Composite Designation _____

0° TENSILE STRENGTH						UNITS = MPa
SAMPLE #1	T1	T2	T3	T4	T5	T6
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

90° TENSILE STRENGTH						UNITS = MPa
SAMPLE #1	T7	T8	T9	T10	T11	T12
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

FIGURE A7—MECHANICAL PROPERTIES DATA SHEET—TENSILE STRENGTH

Supplier _____ Date _____

Composite Designation _____

0° TENSILE MODULUS						UNITS = GPa
SAMPLE #1	T1	T2	T3	T4	T5	T6
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

90° TENSILE MODULUS						UNITS = GPa
SAMPLE #1	T7	T8	T9	T10	T11	T12
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

FIGURE A8—MECHANICAL PROPERTIES DATA SHEET—TENSILE MODULUS

Supplier _____ Date _____

Composite Designation _____

0° POISSON'S RATIO						
SAMPLE #1	T1	T2	T3	T4	T5	T6
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

90° POISSON'S RATIO						
SAMPLE #1	T7	T8	T9	T10	T11	T12
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

FIGURE A9—MECHANICAL PROPERTIES DATA SHEET—POISSON'S RATIO

Supplier _____ Date _____

Composite Designation _____

0° TENSILE STRAIN TO FAILURE						UNITS = %
SAMPLE #1	T1	T2	T3	T4	T5	T6
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

90° TENSILE STRAIN TO FAILURE						UNITS = %
SAMPLE #1	T7	T8	T9	T10	T11	T12
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

FIGURE A10—MECHANICAL PROPERTIES DATA SHEET—TENSILE STRAIN TO FAILURE

Supplier _____ Date _____

Composite Designation _____

0° TENSILE ENERGY TO FAILURE						UNITS = MJ/m^3
SAMPLE #1	T1	T2	T3	T4	T5	T6
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

90° TENSILE ENERGY TO FAILURE						UNITS = MJ/m^3
SAMPLE #1	T7	T8	T9	T10	T11	T12
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

FIGURE A11—MECHANICAL PROPERTIES DATA SHEET—TENSILE ENERGY TO FAILURE

Supplier _____ Date _____

Composite Designation _____

0° COMPRESSIVE STRENGTH						UNITS = MPa
SAMPLE #1	C1	C2	C3	C4	C5	C6
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

90° COMPRESSIVE STRENGTH						UNITS = MPa
SAMPLE #1	C7	C8	C9	C10	C11	C12
PLAQUE 1						
PLAQUE 2						
PLAQUE 3						
PLAQUE 4						
PLAQUE 5						
PLAQUE 6						

FIGURE A12—MECHANICAL PROPERTIES DATA SHEET—COMPRESSIVE STRENGTH