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Standard Test Method for Tensile Properties of Glass Fiber Strands, Yarns, and Rovings Used in Reinforced Plastics[1]

This standard is issued under the fixed designation D 2343; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the determination of the comparative tensile properties of glass fiber strands, yarns, and rovings in the form of straight standard test specimens when tested under defined conditions of pretreatment, temperature, humidity, and tension testing machine speed. This test method is applicable to continuous filament, glass fiber materials that have been coated with a resin compatible sizing.

NOTE 1—There is no known ISO equivalent to this test method.

NOTE 2—This test method was originally developed as a quality control test for glass fiber. It should not be used to develop composites design data. Consult Test Method D 638, Test Method D 3039/D 3039M, or the materials specification for development of composite design properties.

1.2 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

NOTE 3—Prime consideration should be given to the use of a polymeric binder that produces specimens that yield the highest consistent values for the glass fiber material under test. Tensile properties may vary with specimen preparation, resin impregnation system, and speed and environment of testing. Consequently, where precise comparative results are desired, these factors must be carefully controlled.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 618 Practice for Conditioning Plastics and Electrical Insulating Materials for Testing[2]

D 638 Test Method for Tensile Properties of Plastics[2]

D 3039/D3039M Test Method for Tensile Properties of Fiber-Resin Composites[3]

E 4 Practices for Force Verification of Testing Machines[4]

E 6 Terminology Relating to Methods of Mechanical Testing[4]

3. Terminology

3.1 *Definitions:*

3.1.1 Definitions of terms and symbols relating to this test method appear in Terminology E 6 and the Appendix to Test Method D 638.

4. Summary of Test Method

4.1 This test method consists of impregnating glass fiber strands, yarns, or rovings with a suitable polymeric binder material and loading the resulting test specimens to failure in a tension testing machine having a constant-rate-ofcrosshead movement. The cross sectional area is determined from skeins of glass fiber taken before and after each set of test specimens. After impregnation and curing, the specimens are tested in accordance with the procedure outlined in 4.1.1.

4.1.1 *Procedure*—The test specimen is cut to a specified length and tested using rubber-faced grips, 240 grit sandpaper, fine emery cloth, or combination thereof.

5. Significance and Use

5.1 Tensile properties determined by this test method are of value for identifying and characterizing materials for control and specification purposes as well as for providing data for research and development studies.

5.2 This test method is intended for use in testing resin-compatible sized glass fiber materials that have been designed specifically for use with certain generic types of plastics. The use of a resin impregnant that is compatible with the reinforcement material under test produces results that are most representative of the actual strength that is available in the material when used as intended in an end item. Premature reinforcement failure may occur if the elongation of the resin system is less than that of the reinforcement being tested. Misleading results

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Changes incorporated since the last revision of this test method are designed to improve reproducibility by giving more specific instructions on the sample preparation procedures.

[2] *Annual Book of ASTM Standards*, Vol 08.01.

[3] *Annual Book of ASTM Standards*, Vol 15.03.

[4] *Annual Book of ASTM Standards*, Vol 03.01.

may be obtained when glass fiber materials are tested dry or when a noncompatible resin impregnant is used.

5.3 This test method is useful for testing pretreated specimens for which comparative results are desired. The reproducibility of test results is good when precise control is maintained over all test conditions. Values obtained by this test method may be affected by gage length, gripping system, testing speed, and the resin impregnation ratio of the specimen.

6. Apparatus

6.1 *Impregnation Apparatus*—An example of an acceptable impregnation apparatus for strands is shown in Fig. 1, and for rovings and yarns in Fig. 2. Minor modifications to the apparatus are acceptable providing consistent samples are produced. The apparatus shall consist essentially of the following:

6.1.1 *Free Wheeling Spindle*—A freely turning spindle with a horizontal axis for holding the yarn spool or roving ball. A spindle is not required for testing strands because the material is pulled over the end from the outside or the inside of the forming cake.

6.1.2 *Guide Eye and Pulley*—A ceramic guide eye, 25 mm (1.0 in.) in diameter, and a freewheeling pulley, 20 mm (0.8 in.) minimum groove diameter, to guide the material as illustrated in Fig. 3.

6.1.3 *Impregnation Tank*, as illustrated in Fig. 3 and Fig. 4, consisting of a container and a static spreader bar assembly having at least three bars, each a minimum of 8 mm (5⁄16 in.) diameter, made of a corrosion-resistant material.

6.1.4 *Winding Fixture*—A typical winding fixture for glass fiber strands and yarns is shown in Fig. 5, and for rovings in Fig. 6.

6.2 *Cutting Gage*—A typical cutting gage is shown in Fig. 7. This tool eliminates the need for measuring the specimens manually.

6.3 *Tension Testing Machine*—A testing machine having a constant-rate-of-crosshead movement and comprising essentially the following shall be available:

6.3.1 *Stationary Member*, carrying one grip.

6.3.2 *Movable Member*, carrying a second grip.

6.3.3 *Grips*—Grips for holding the test specimen between the fixed and the movable member shall be of the self-aligning type (that is, they shall be attached to the fixed and movable members in such a manner that they will move freely into alignment as soon as any load is applied). The long axis of the test specimens will then coincide with the direction of the applied pull through the center line of the grip assembly.

NOTE 4—Air-actuated grips have been found advantageous and are recommended for use in this test method.

6.3.4 *Jaws*—A set of removable jaws to match the required grips shall be used for clamping the test specimens. One of the faces of the jaws should be adjustable to compensate for thickness of the specimen ends, so that the tension force may be lined up with the center of the jaw. Rubber-faced jaws, 25 by 102 mm (1.0 by 4.0 in.), shall be used for gripping specimens. If slippage of the test specimens is observed, 240 grit sandpaper strips may be used to improve gripping. The sandpaper should be replaced when it has lost its grittiness, or after every 30 to 50 breaks.

6.3.5 *Drive Mechanism*—A drive mechanism capable of imparting a uniform controllable speed to the movable member of the apparatus.

6.3.6 *Load Indicator*—A suitable load-indicating mechanism capable of showing the total tensile load carried by the test specimen when held by the grips shall be used. This mechanism shall be essentially free of inertial lag at the specified rate of testing and shall indicate the load with an accuracy of at least ±1 % of the indicated load value. The accuracy of the testing machine shall be verifiable in accordance with Practices E 4.

6.3.7 *Deflection-Measuring Device and Recorder*—A suitable instrument for measuring deflection (extensometer) and a suitable mechanism for recording this deflection shall be provided. It is desirable that this instrument and recorder

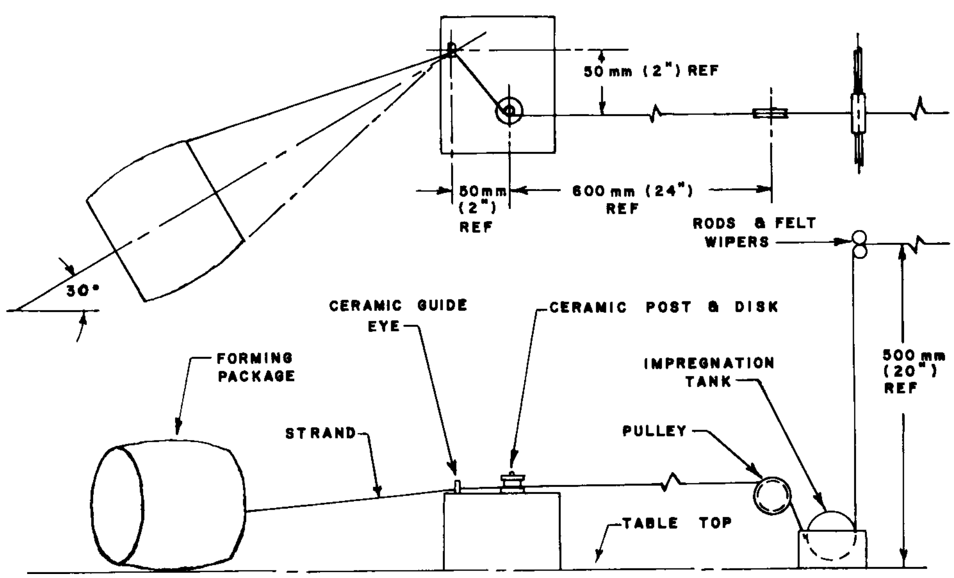


FIG. 1 Typical Impregnating Apparatus for Strands

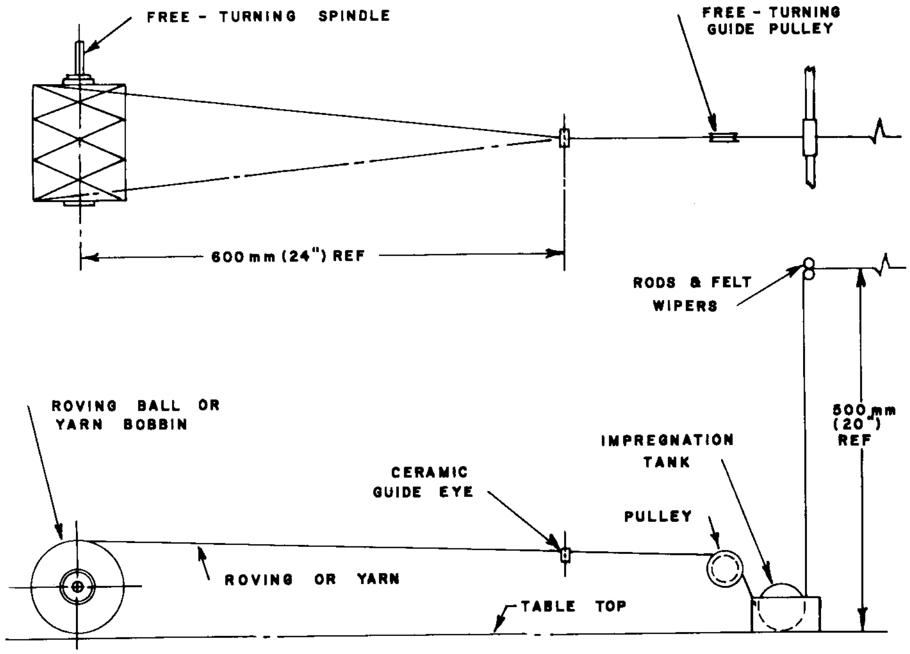


FIG. 2 Typical Impregnating Apparatus for Rovings and Yarns

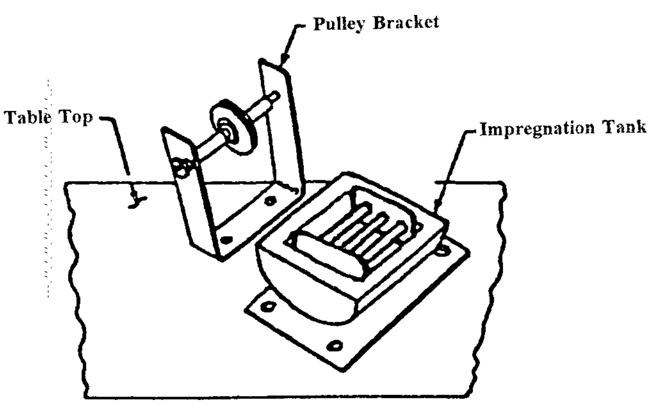


FIG. 3 Guide Pulley and Impregnation Tank

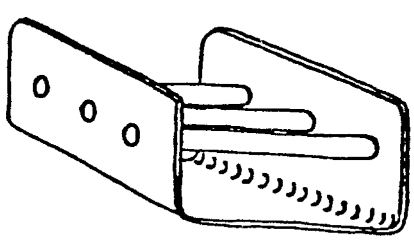


FIG. 4 Static Breaker Bar

automatically record this deflection as a function of the load on the test specimen.

6.4 *Balance, Analytical.*

7. Test Specimens

7.1 Test specimens shall consist of straight lengths of impregnated glass fiber strands, yarns, or roving. The lengths shall be 356 mm (14 in.) ± 3.2 mm (⅛ in.).

7.2 *Effective Gage Length*—The distance between the tabs or the distance between the rubber faced jaws shall be 254± 1 mm (10.0 ± 0.04 in.).

7.3 *Number of Specimens*—At least five tension test specimens shall be tested for each ball or spool of glass fiber material under test.

8. Conditioning

8.1 *Strands, Yarns, and Rovings Conditioning*—The glass fiber from which test specimens are to be prepared shall be kept in a room or enclosed space maintained at 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity in accordance with Procedure A of Practice D 618, except that 24 h shall be the minimum conditioning time.

8.2 *Test Specimen Conditioning*—The specimens shall be conditioned and tested in a room or enclosed space maintained at atmospheric conditions of 23 ± 2°C (73.4 ± 3.6°F) and 50 ± 5 % relative humidity in accordance with Procedure A of Practice D 618, except that 3 h shall be the minimum conditioning time.

9. Speed of Testing

9.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during test. Rate of motion of the driven grip or fixture when the machine is running idle may be used if it can be shown that the resulting speed of testing is within the limits of variation allowed.

9.2 The standard speed of testing for tensile strength and for apparent modulus of elasticity shall be 12.7 ± 0.3 mm (0.50± 0.01 in.)/min.

10. Impregnation Procedure

10.1 Set up the impregnating apparatus in accordance with Fig. 1 or Fig. 2.

10.2 Cover the ends of the winding fixture using 0.025 mm (0.001 in.) nominal thickness, heat-resistant plastic film, aluminum foil, or equivalent parting film.

10.3 Prepare a sufficient quantity of an impregnant suitable for impregnating the material under test. Pour the impregnating

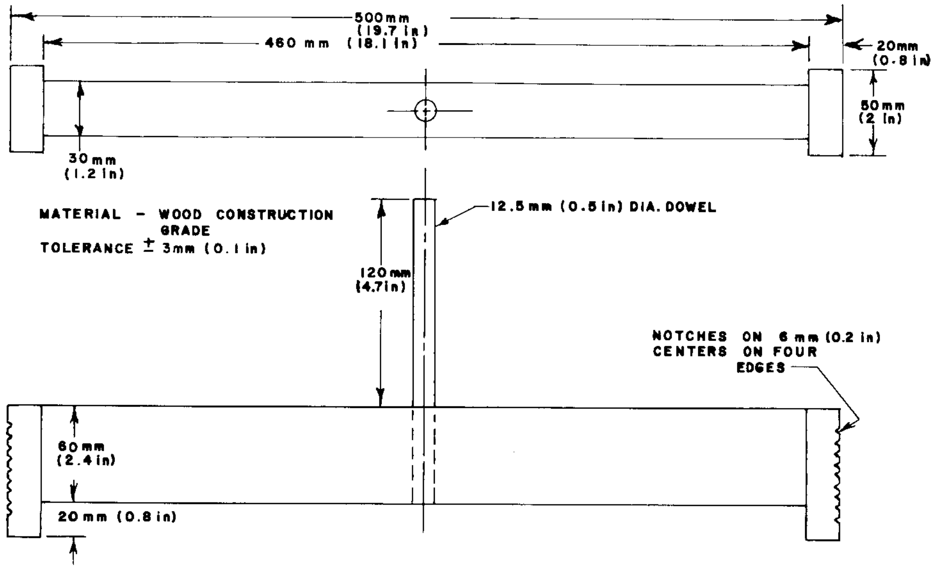


FIG. 5 Typical Winding Fixture for Strands and Yarns

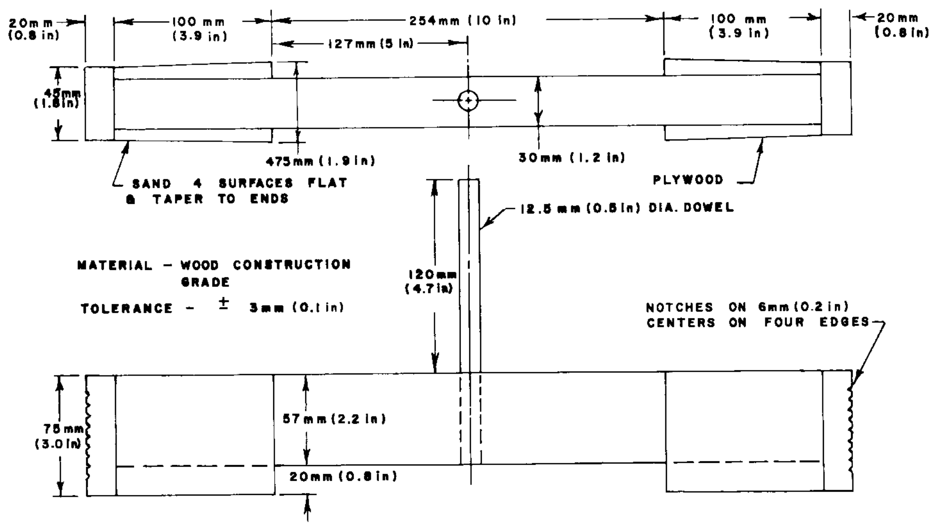


FIG. 6 Typical Winding Fixture for Rovings

mixture into the tank so that the level is about 10 mm (0.39 in.) above the static breaker bars (see Fig. 3 and Fig. 4).

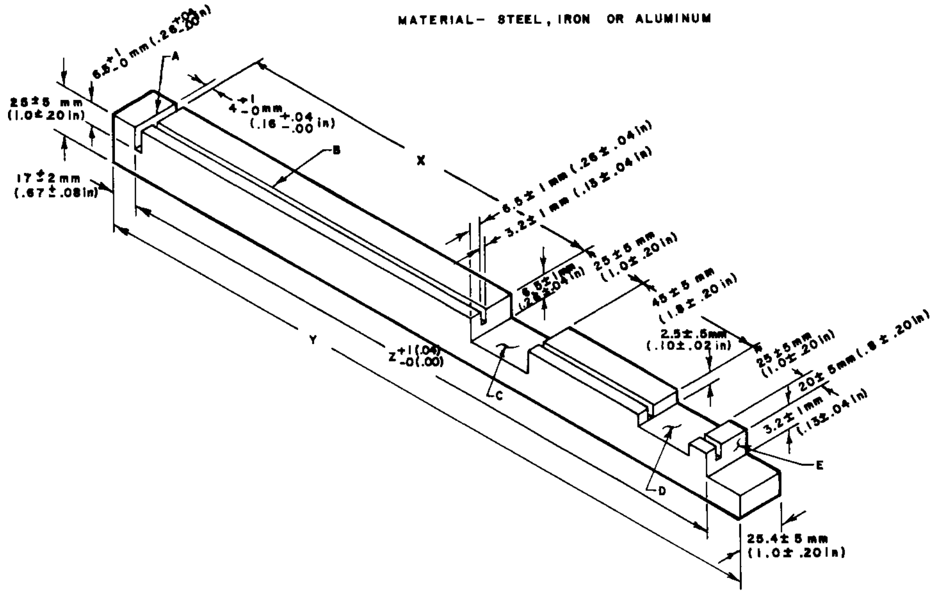
10.4 Immediately prior to threading the material through the impregnation apparatus, cut a 1000 ± 1-mm (40 ± 0.04-in.) skein of the material under test. Repeat the procedure immediately after winding one set of specimens. Place the two skeins in a muffle furnace maintained at a temperature that will give complete burnoff. Remove the two skeins from the furnace and place in a desiccator for a minimum of 15 min. Weigh the two skeins to the nearest 0.001 g and record as Weight *X*.

10.5 Select a stripper die of the proper diameter by using the calculations in 13.2 and 13.3.

10.6 Thread the glass fiber material through the impregnating apparatus in an "under, over, under" path through the static spreader bars. Firmly attach the end of the glass fiber to the winding fixture with heat-resistant masking tape. Drape the material on the winding fixture. Rotate the fixture either manually or motorized at a rate not exceeding 8 m/min (26 ft/min) (which is equivalent to approximately 7 r/min for the winding fixture described in this test method—see Fig. 5).

10.6.1 Maintain an impregnant-to-glass weight ratio satisfactory for the preparation of the test specimens (see Note 5). Generally, an impregnant weight equivalent to 40 ± 10 % of the total weight is satisfactory. If the impregnant-to-glass ratio is excessively high or low, erratic test results will be obtained. Hence, when directly comparable results are desired, all specimens should have similar impregnant-to-glass ratios.

10.6.2 After the required number of specimens are wound, hold the winding tension on the material and use heat-resistant masking tape to attach the material to the winding fixture. Cut the material after attachment has been made. Optionally, a flat tongue depressor or metal spatula may be used to flatten the end 100 mm (3.9 in.) of the glass strands. This flattening of the gripped portion of the strands allows better clamping of the specimens while minimizing crushing in the grip jaws. When a solvent-diluted impregnant is used, allow the loaded winding fixture to stand horizontally for at least 15 min so that the



Procedure	*X*	*Y*	*Z*
A	23.5	39.6	35.4
B	33.5	49.6	45.4

A Backstop Groove
B Groove for Specimen
C Pickout Groove
D Hold Down Groove
E Cutting Surface

FIG. 7 Typical Cutting Gage

solvent can evaporate. If a nonsolvent impregnant is used, allow the fixture to stand on end for at least 15 min so that excess impregnant will drain.

10.6.3 Place the loaded winding fixture in a horizontal position in an air-circulating oven for the required length of time and at the required temperature. After curing, cool to room temperature and remove the specimens from the winding fixture.

10.7 Using a typical specimen cutting gage (see Fig. 7), cut the specimens to the required length. During all handling, exercise care to prevent damage to the specimens.

10.8 Select specimens for the test on the basis of their uniformity and freedom from cuts, nicks, or other visible imperfections. Discard any unacceptable specimens. Weigh each specimen selected to the nearest 0.001 g and record as Weight *Y*.

NOTE 5—A thorough wetting of the glass fiber is essential to obtaining acceptable specimens. It is important that the specimens be examined visually to ensure that good wet-out of the fibers by the resin has occurred. A note regarding the wet-out is required in the report.

11. Testing Procedure

11.1 Set the speed of the testing machine at 12.7 mm ± 0.3 mm (0.50 ± 0.01 in.)/min.

11.2 Adjust the load scale range so that it shall be adequate for the estimated breaking load of the specimen under test.

11.3 Set the jaws at the effective gage length of 254 ± 1 mm (10.0 ± 0.04 in.) apart. Place the specimen in the jaws, taking care to ensure alignment of the specimen axis on the grips with an imaginary line joining the points of the attachments of the grips to the machine. If mechanical grips are used, tighten the jaws evenly and firmly to the extent necessary to prevent slippage of the specimen during the test, but not to the point where the specimen is crushed.

11.4 Zero the machine. If modulus is being determined, set up the deflection measuring device (extensometer) and start the recorder. Load the test specimen to failure. Record the ultimate breaking load.

12. Retests

12.1 Specimens that break or shatter at some obvious fortuitous flaw, or outside the gage length of the specimen (jaw breaks), shall be discarded and retests made, unless such flaws constitute a variable under study.

13. Calculation

13.1 *Resin Content*—Calculate the resin content as follows:

$$\text{resin content, weight \%} = (Y/L_2 - X/L_1)/(Y/L_2) \times 100 \quad (1)$$

where:
Y = cured specimen weight,
L_2 = length of cured specimen,
X = two skeins weight after burnoff, and
L_1 = total of two skeins length.

13.2 *Cross Sectional Area*—Calculate the cross sectional area of the specimen to three significant figures, as follows:

$$A_o = X/L_1 P \quad (2)$$

where:
A_o = cross sectional area,
X = two skeins weight after burnoff,
L_1 = total of two skeins length, and
P = density of glass.

13.3 *Required Stripper Die Size*—Calculate the stripper die diameter (SDD) required to produce an impregnated strand with a desired 40 ± 10 weight % resin content (see Note 6) as follows:

$$SDD = \sqrt{[(A_O \div V_G)\cdot 4] \div \pi} \quad (3)$$

where:
A_O = cross sectional area, in.^{2}, and
V_G = desired glass volume, %.

NOTE 6—To convert from weight % to volume % proceed as follows: Divide the weight % of both the glass and resin each by their respective specific gravities, then divide each result in turn by the sum of the quotients, for example, to convert glass weight % to volume % the following applies:

$$\text{volume \% glass} = (W_G/S_G)/[(W_G/S_G) + (W_R/S_R)] \quad (4)$$

where:
W_G = weight % of glass (60 ± 10 %),
W_R = weight % of resin (40 ± 10 %),
S_G = specific gravity of glass, and
S_R = specific gravity of resin.

13.4 *Tensile Strength*—Calculate the tensile strength by dividing the ultimate breaking load by the average cross sectional area of the two skeins. Report the results to three significant figures.

13.5 *Tensile Modulus of Elasticity*—Obtain the tensile modulus of elasticity by extending the initial linear portion of the load strain curve and dividing the difference in stress corresponding to a certain section of this straight line by the related difference in strain. Report the results to three significant figures (see Note 7).

NOTE 7—For the correct method of drawing the tangent to the load strain curve, see the definitions in the Appendix to Test Method D 638.

14. Report

14.1 Report the following information:

14.1.1 Complete identification of the glass material tested, including type, source, and manufacturer's lot number, and other pertinent information,

14.1.2 Impregnating system, including the name of the manufacturer, resin formulation, elongation, and cure cycle,

14.1.3 Method of preparing test specimen, including static spreader bar description (for example, number of bars, spacing, etc.), stripper die diameter, and pulling speed,

14.1.4 Number of specimens tested,

14.1.5 Specimen gage length,

14.1.6 Speed of testing,

14.1.7 Breaking load,

14.1.8 Cross-sectional area of glass roving,

14.1.9 Tensile strength of each specimen, average value, and standard deviation,

14.1.10 Tensile modulus of elasticity (if measured),

14.1.11 Density of glass,

14.1.12 Resin content,

14.1.13 Conditioning procedure used,

14.1.14 Atmospheric conditions in the test room (temperature and relative humidity),

14.1.15 Date of test, and

14.1.16 Condition of wet-out (good, marginal, poor) of samples.

15. Keywords

15.1 glass fibers; impregnated glass strands; reinforced plastics; rovings; tensile strength; yarns

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