



# Standard Test Method for In-Plane Shear Strength of Pultruded Glass-Reinforced Plastic Rod<sup>1</sup>

This standard is issued under the fixed designation D 3914; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This test method covers the determination of the in-plane shear strength of pultruded, glass-fiber reinforced, thermosetting plastic rod of diameters ranging from 19 to 32 mm ( $\frac{3}{4}$  to  $1\frac{1}{4}$ in.).

1.2 The values stated in SI units are to be regarded as the standard.

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.* Specific precautionary statements are given in Note 2 and Note 3.

NOTE 1—There is no similar or equivalent ISO standard.

## 2. Referenced Documents

### 2.1 ASTM Standards:

D 618 Practice for Conditioning Plastics for Testing<sup>2</sup>

D 695 Test Method for Compressive Properties of Rigid Plastics<sup>2</sup>

E 4 Practices for Force Verification of Testing Machines<sup>3</sup>

## 3. Terminology

### 3.1 Definition:

3.1.1 *in-plane shear strength*—the shear strength at maximum load in which the plane of fracture is centrally located along the longitudinal axis of the specimen between two diametrically opposed notches machined halfway through its diameter.

## 4. Summary of Test Method

4.1 In-plane shear strength, as determined by this test method, is measured by applying a compressive load to notched cylindrical specimens of the type shown in Fig. 1. Loading of the specimen is accomplished with a subpress, or

compression tool, such as those shown in Fig. 1 and Fig. 2 of Test Method D 695. Failure of the specimen occurs in *shear* between two centrally located notches, diametrically opposed and machined halfway through its diameter at a fixed distance apart. The notches are accurately machined in the specimen with maximum reproducibility by means of a special notching jig (Fig. 2a and Fig. 2b) designed specifically for this purpose.

## 5. Significance and Use

5.1 Shear tests of various kinds are widely used in the reinforced plastics industry to assess the strength of the reinforcement-to-resin bond in polyester-, vinyl ester-, and epoxy-resin composites. In addition to their importance for the generation of data for research and development, quality control, and specification purposes, such tests are of fundamental value to the fibrous reinforcement industry, since they can be used to determine the potential of new sizing systems for the surface treatment of glass fibers.

5.2 The in-plane shear strength of pultruded cylindrical composites is an important property from an engineering standpoint, since pultruded rod, as such, is used in many structural applications.

## 6. Apparatus

6.1 *Testing Machine*—Any suitable testing machine capable of control of constant-rate-of-crosshead movement and comprising essentially the following:

6.1.1 *Drive Mechanism*—A drive mechanism for imparting to the movable member a uniform, controlled velocity with respect to the stationary member, as required in 10.3.

6.1.2 *Load Indicator*—A load-indicating mechanism capable of showing the total compressive load carried by the test specimen. The mechanism shall be essentially free of inertial lag at the specified rate of testing and shall indicate the load with an accuracy of  $\pm 1\%$  of the maximum indicated value of the test (load). The accuracy of the testing machine shall be verified at least once a year in accordance with Practices E 4.

6.1.3 *Notching Jig*—A notching jig of the type shown in Fig. 2a and Fig. 2b, or the equivalent, for notching the test specimens.

6.1.4 *Compression Tool*—A compression tool for applying the load to the test specimen, such as those shown in Fig. 1 and Fig. 2 of Test Method D 695.

<sup>1</sup> This test method is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.18 on Reinforced Thermosetting Plastics.

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<sup>2</sup> *Annual Book of ASTM Standards*, Vol 08.01.

<sup>3</sup> *Annual Book of ASTM Standards*, Vols 03.01 and 04.02.

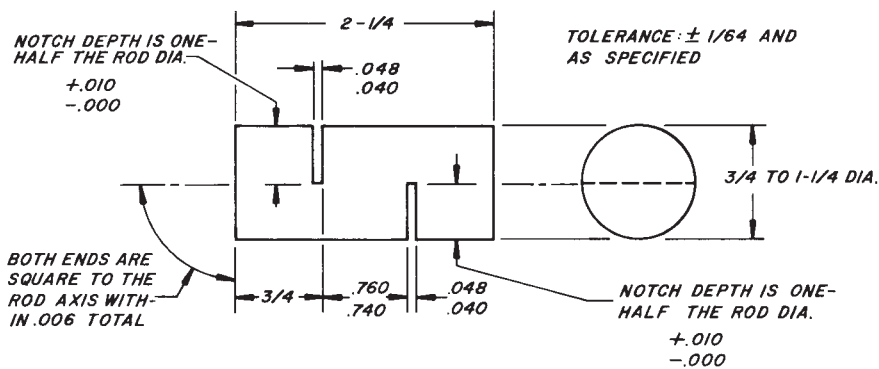
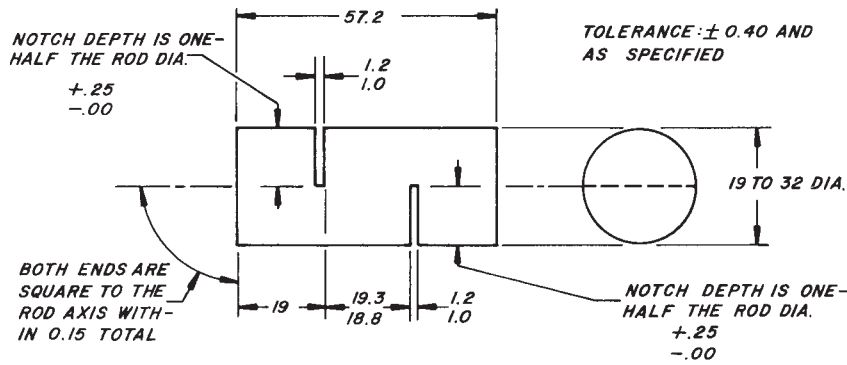


FIG. 1 Notched Rod In-Plane Shear Specimen; Dimensions: Top, mm; Bottom, in.

6.1.5 *Micrometers*—Suitable micrometers, reading to 0.025 mm or 0.001 in., for measuring the diameter of the specimen, as well as the depth of, and distance between, the notches.

## 7. Test Specimens

7.1 *Configuration*—Test specimens shall be carefully machined from the rod sample of interest and shall conform to the shape and dimensions given in Fig. 1. The ends of the specimen shall be machined flat and parallel to prevent point loading upon application of the compressive load.

7.2 *Preparation*—After machining the specimen to proper length, insert it in the notching jig, flush it with one face of the jig, and tighten the cap screws of the jig to secure it in place. Push the assembly (jig and specimen) into a diamond grit cutoff wheel (or equivalent blade) after setting the blade to give

the proper depth of notch. This arrangement is shown in Fig. 3. Guidance of the jig during specimen notching is by means of sliding contact with the fence of the table saw as the jig is pushed along the table to a stop. After machining one notch, turn the tool over and repeat the procedure to provide a second notch in the specimen diametrically opposed to the first and at a fixed, defined distance (Fig. 1) from it.

NOTE 2—**Caution:** When fabricating composite specimens by machining operations, a fine dust consisting of particles of fibers or the matrix material, or both, may be formed. These fine dusts can be a health or safety hazard, or both. Adequate protection should be afforded operating personnel and equipment. This may require adequate ventilation or dust collecting facilities, or both, at a minimum.

7.3 *Number*—A minimum of five specimens shall be tested.

<b>52TEI164</b>		REV
<b>NOTCHING JIG, IN-PLANE SHEAR</b>		
NEXT ASSEM		
DATE	9-16-77	BY
TOLERANCE; $\pm 0.25\text{mm}$ , $\pm 1/2^\circ$ AND AS SPECIFIED		
MATERIAL; ALUMINUM 2024-T351 AND NOTED		
FINISH;		
REFERENCE		REV
SPECIMEN 52TEA1193		

1. CHAMFER OUTSIDE CORNERS  $0.8 \times 45^\circ$
2. THE TWO  $45^\circ \pm 1/4^\circ$  SURFACES OF THE PRISMATIC HOLE ARE USED FOR GAGING AND MUST BE WITHIN THE SPECIFIED TOLERANCE
3. THE SIDES ARE SQUARE TO THE TOP AND BOTTOM WITHIN  $\pm .10$
4. DIMENSIONS ARE IN MILLIMETRES AND SURFACE FINISH IS IN MICROMETRES

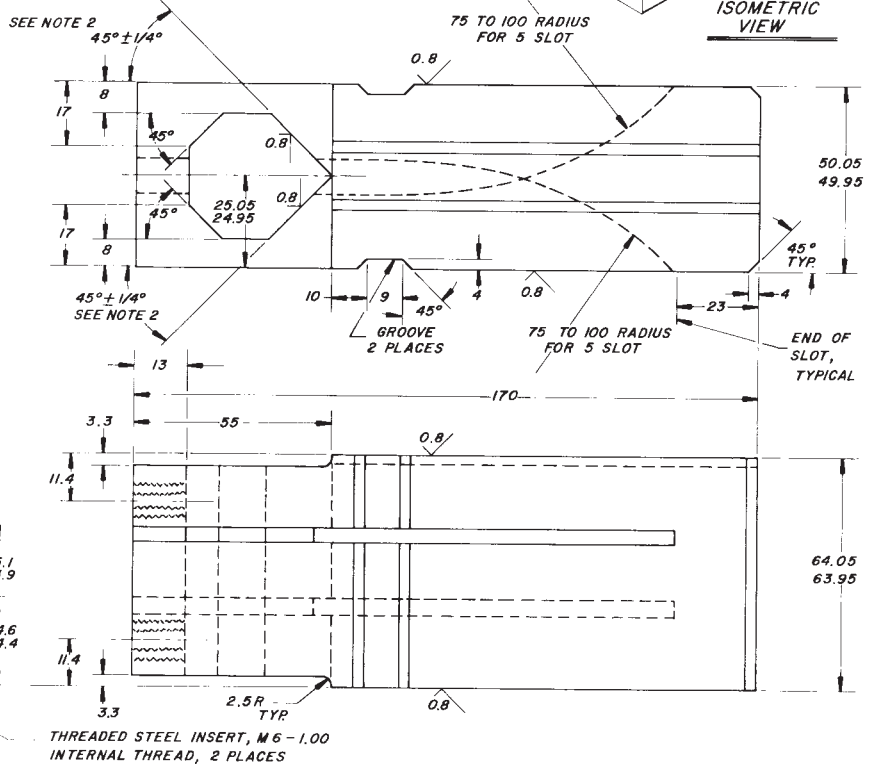
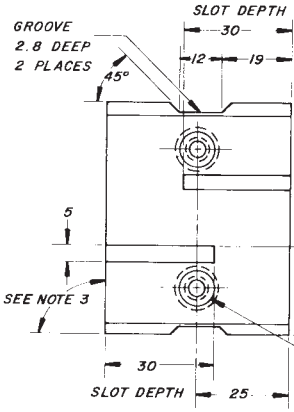
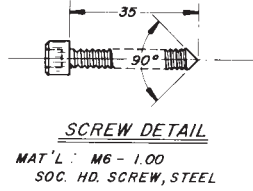
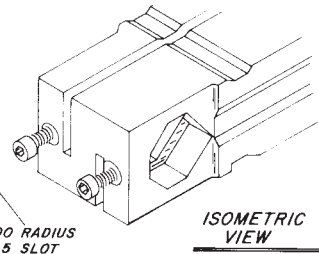


FIG. 2A Details of Specimen Notching Jig for In-Plane Shear Test, Dimensioned in mm

<b>52TELI63</b>		REV
<b>NOTCHING JIG, IN-PLANE SHEAR</b>		
NEXT ASSEM.		
DATE	7-21-77	BY
TOLERANCE: $\pm 1/64"$ $\pm 1^\circ$ AND AS SPECIFIED		
MATERIAL: ALUMINUM 2024 - T 351 AND NOTED		
FINISH:		
REFERENCE:	REV	
SPECIMEN 52TEA1193		

1. CHAMFER OUTSIDE CORNERS  $1/32 \times 45^\circ$
2. THE TWO  $45^\circ \pm 1/4^\circ$  SURFACES OF THE PRISMATIC HOLE ARE USED FOR GAGING AND MUST BE WITHIN THE SPECIFIED TOLERANCE
3. THE SIDES ARE SQUARE TO THE TOP AND BOTTOM WITHIN  $\pm 0.04$
4. DIMENSIONS ARE IN INCHES AND SURFACE FINISH IS IN MICROINCHES

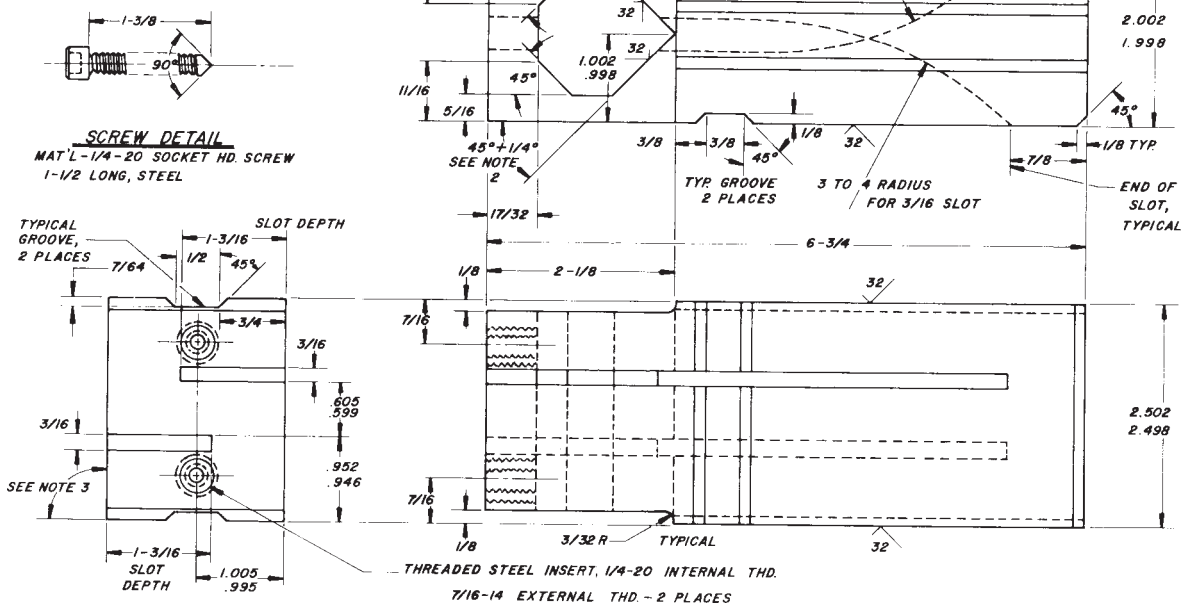
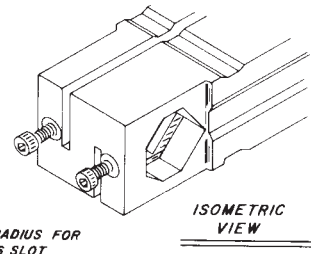


FIG. 2B Details of Specimen Notching Jig for In-Plane Shear Test Dimensioned in Inches

**8. Conditioning**

8.1 *Conditioning*—Condition the test specimens at  $23 \pm 2^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and  $50 \pm 5\%$  relative humidity for not less than 40 h prior to test in accordance with Procedure A of Practice D 618, for those tests where conditioning is required. In cases of disagreement, the tolerances shall be  $\pm 1^\circ\text{C}$  ( $\pm 1.8^\circ\text{F}$ ) and  $\pm 2\%$  relative humidity.

8.2 *Test Conditions*—Conduct tests in the standard laboratory atmosphere of  $23 \pm 2^\circ\text{C}$  ( $73.4 \pm 3.6^\circ\text{F}$ ) and  $50 \pm 5\%$  relative humidity, unless otherwise specified. In cases of disagreement, the tolerances shall be  $\pm 1^\circ\text{C}$  ( $\pm 1.8^\circ\text{F}$ ) and  $\pm 2\%$  relative humidity.

**9. Speed of Testing**

9.1 Speed of testing shall be the relative rate of motion of the grips or test fixtures during the 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 shall be  $1.3 \pm 0.3\text{ mm}$  ( $0.050 \pm 0.010\text{ in.}$ )/min.

**10. Procedure**

- 10.1 Measure the diameter of the specimen between the notches to the nearest 0.025 mm or 0.001 in.
- 10.2 Center the specimen in the compression tool of 6.1.4 and mount the tool between the loading heads of the testing machine.
- 10.3 Set the speed control at 1.3 mm/min (0.050 in./min) and start the machine.
- 10.4 Record the maximum load carried by the specimen during the test (usually, this will be the load at the moment of rupture).

NOTE 3—**Caution:** When testing composite materials, it is possible to store considerable energy in the test specimen which can be released with considerable force on rupture. This can release small high velocity particles and dust consisting of fractured fibers and matrix materials. The particles and fine dust can potentially be a health or safety hazard, or both. Adequate protection should be afforded operating personnel, bystanders, and the equipment. This may require shielding or dust collection facilities, or both, at a minimum.

10.5 Determine the length of the failed (sheared) area to the nearest 0.025 mm or 0.001 in. by measurement of this surface with respect to either half of the ruptured specimen. This

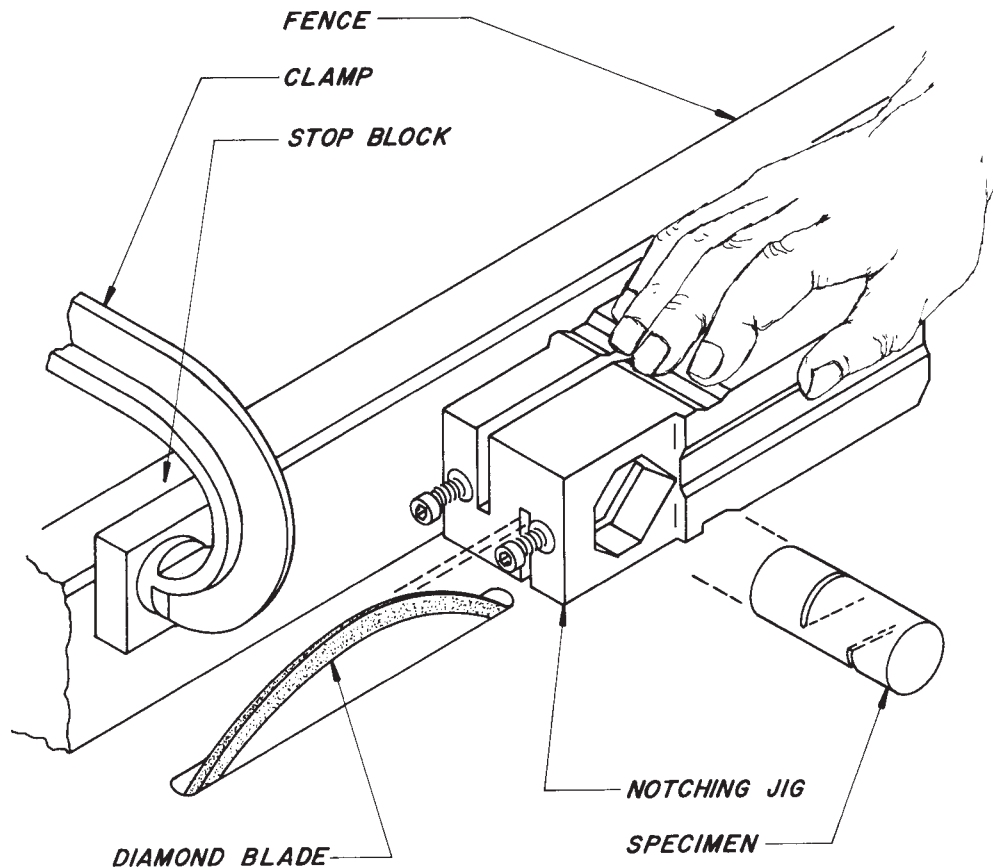


FIG. 3 Arrangement for Machining Notches in Pultruded Rod Specimens. Notching Jig Accommodates Rods Ranging in Diameter from 19 mm (3/4 in.) to 32 mm (1 1/4 in.)

technique affords the most accurate determination of the length of the sheared plane defined by the separation of the notches machined in the specimen.

NOTE 4—The width of the notches and the distance between them may vary somewhat from the dimensions indicated in Fig. 1, depending upon the actual thickness of the circular saw blade used to machine the notches and the particular notching jig used. However, round-robin tests of rods of various diameters, employing different notching tools and saw blades of thickness up to 3.2 mm (1/8 in.), have shown little, if any, influence on the test results due to variation of the notches attributed to these factors. A particularly attractive feature of the notching jig shown in Fig. 2a and Fig. 2b is its ability to accommodate rods ranging in diameter from 19 to 32 mm (3/4 to 1 1/4 in.).

## 11. Calculations

11.1 *In-Plane Shear Strength*—Calculate the in-plane shear strength by dividing the maximum shear load carried by the specimen during the test by the product of the specimen's diameter (see 10.1) and the length of the failed area as determined in 10.5. Express the result in megapascals or pounds-force per square inch and report it to three significant figures.

## 12. Report

12.1 The report shall include the following:

12.1.1 Complete identification of the material tested, including type, source, manufacturer's code number, form, principal dimensions, previous history, etc.,

12.1.2 Method of preparing test specimens,

12.1.3 Conditioning procedure used,

12.1.4 Atmospheric conditions in test room,

12.1.5 Number of specimens tested,

12.1.6 A brief description of the type of testing machine used, and the date on which it was last verified (see 6.1.2) and by whom,

12.1.7 In-plane shear strength, average value, and standard deviation, and

12.1.8 Date of test.

## 13. Precision and Bias <sup>4</sup>

13.1 *Repeatability*—Testing in a single laboratory of a sample of pultruded laminate resulted in a within-laboratory coefficient of variation of 5.9%. The within-laboratory critical interval ( $c_r$ ) between two test results is 16.58% ( $2.8 \times V_r$ ). Two results obtained within one laboratory on the same material shall be judged not equivalent if they differ by more than the critical interval ( $c_r$ ). Attempts to develop a full precision and bias statement for this test method have not been successful. For this reason, data on precision and bias cannot be given. Because this test method does not contain a round robin based numerical precision and bias statement, it shall not be used as

<sup>4</sup> Round-robin data for this test method may be obtained from ASTM Headquarters. Request RR:D-20-1083.

a referee method in case of dispute. Anyone wishing to participate in the development of precision and bias data should contact the Chairman, Subcommittee D20.18 (Section 20.18.02), ASTM, 100 Barr Harbor Drive, West Conshohocken, PA 19428.

NOTE 5—An attempt to run a round robin in 2001 resulted in insufficient laboratories to develop a bias between laboratory precision statements. Only three laboratories were available for participation when a minimum of six is required.

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