



Designation: D4502 – 92 (Reapproved 2019)

## Standard Test Method for Heat and Moisture Resistance of Wood-Adhesive Joints<sup>1</sup>

This standard is issued under the fixed designation D4502; 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 The purpose of this test method is to estimate the resistance of adhesive-bonded joints to thermal and hydrolytic degradation.

1.2 This test method is primarily for wood-to-wood joints but may be applied to joints of wood to other materials.

1.3 The effects of chemicals such as fire retardants, preservatives, and extractives in the wood upon joint degradation resistance can be estimated.

1.4 This test method does not account for the effects of stress, the other principal degrading factor, nor does it account for cyclic or variable temperature or moisture levels.

1.5 The values stated in SI units are to be regarded as standard. The values given in parentheses after SI units are provided for information only and are not considered standard.

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

### 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

D897 Test Method for Tensile Properties of Adhesive Bonds

D905 Test Method for Strength Properties of Adhesive Bonds in Shear by Compression Loading

D907 Terminology of Adhesives

D2304 Test Method for Thermal Endurance of Rigid Electrical Insulating Materials

D2307 Test Method for Thermal Endurance of Film-Insulated Round Magnet Wire

D2339 Test Method for Strength Properties of Adhesives in Two-Ply Wood Construction in Shear by Tension Loading

2.2 *IEEE Standard:*

IEEE No. 1 General Principles for Temperature Limits in the Rating of Electrical Equipment<sup>3</sup>

### 3. Terminology

3.1 *Definitions*

3.1.1 For definitions of terms used in this test method, refer to Terminology D907.

3.2 *shear strength, n*—in an adhesive joint, the maximum average stress when a force is applied parallel to the joint.

3.2.1 *Discussion*—In most adhesive test methods, the shear strength is actually the maximum average stress at failure of the specimen, not necessarily the true maximum stress in the material.

### 4. Summary of Test Method

4.1 The degradation of adhesive joints is a physicochemical process. The speed of degradation is related to the levels of temperature, moisture (and other chemicals), and physical stress to which the joint is exposed. This test method is based on the principles of chemical kinetics and uses the Arrhenius temperature dependence relationship to estimate the long-term effects of heat and moisture at the service temperature.

4.2 Specimens whose unaged properties have been estimated by control tests are subjected to an accelerated thermal or hydrolytic aging environment in groups. Aging is accelerated by using elevated temperature. Periodically, a group of specimens is removed from the aging environment and tested. The estimated property after aging and the time of aging are recorded. After several groups have been tested in this manner, the rate of property loss in the aging environment can be estimated. This basic experiment is repeated at several other elevated temperatures, and the rates of property loss at those

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from Institute of Electrical and Electronics Engineers, Inc. (IEEE), 445 Hoes Ln., P.O. Box 1331, Piscataway, NJ 08854-1331, <http://www.ieee.org>.

temperatures estimated. The rate of property loss relationship to temperature is estimated. This relationship can be extrapolated to lower service temperatures for estimating service life.

4.3 This test method employs a smaller version of the Test Method **D905** block shear specimen, but other shear strength or tensile strength specimens may also be used.

## 5. Significance and Use

5.1 This test method can serve as a useful tool for durability assessment and service life forecasting.

5.1.1 This test method can be used to measure the effects of heat and moisture and the effect of their interaction on adhesives and bonded joints. Knowledge of these effects is useful to an adhesive formulator or manufacturer. Moist heat aging is particularly useful for determining the effects of acidic adhesive systems on the hydrolysis of wood adherends.

5.1.2 This test method provides a means of comparing the rate of degradation of an unknown adhesive-adherend combination to the rate of degradation of a known combination in thermal or hydrolytic aging environments. Such a comparison can be useful to adhesive manufacturers for introducing a new product to the market and for helping designers selecting adhesives.

5.1.3 This test method does not duplicate any natural service environment, but it does provide a means of estimating the service life of joints in similar environments. Service-life estimates are useful to designers of bonded structures or structures using bonded products.

5.2 Service-life estimates rely on the assumption that the chemical degradation mechanism is the same at the elevated aging temperatures as at the service temperature. However, this may not be true in every case. This possibility, together with the variability in specimen preparation, in the aging exposures, and in the strength measurements, require that caution be used in accepting the estimate of service life.

## 6. Apparatus

6.1 *Aging Ovens*—Ovens are required that are capable of control within  $\pm 2\%$  of specified exposure temperature throughout the chamber for extended periods of time ( $\pm 0.5^\circ\text{C}$  control is desirable).<sup>4</sup> The ovens must be capable of operating at temperatures from 60 to 175°C. The oven must have an internal capacity for up to 100 specimens well-spaced and supported on racks to allow free air flow.

6.2 *Environmental Chambers*—Chambers for moist-heat aging must be capable of  $\pm 0.5^\circ\text{C}$  temperature and 0.5 % relative humidity control uniformly throughout the chamber. The chamber must be capable of operating at temperatures from 60 to 90°C and relative humidity from 60 to 80 %. The chamber must have the capacity for up to 100 specimens well-spaced and supported on racks to allow free air flow.

6.3 *Moist Aging Jars*—Heat-resistant glass jars are required to expose specimens to constant relative humidity and tem-

perature over saturated salt solutions. Wide-neck canning jars with volumes of 3½ L (1 gal), rubber gaskets, and clamp lids have proven satisfactory at temperatures of 100°C (212°F) and below. The jars must have a platform inside (without legs) to support specimens above the saturated salt solution. A 6 mm (¼ in.) diameter bead of silicone sealant around the inside surface of the jar and about 5 cm (2 in.) above the bottom provides a ledge to support the platform. The platform must be perforated to permit free-flow of water vapor. It may be cut from any material that is resistant to corrosion, heat, and moisture. Perforated high-density hardboard has proven satisfactory. The platform must be cut in half to pass through the neck of the jar. An aging jar with platform is shown in **Fig. 1**. The jars must be placed in an aging oven, such as described in **5.1**, to achieve the required temperature.

6.4 *Water Baths*—Constant-level water baths capable of control to within 0.5°C of the desired temperature are required. The baths must be able to contain 100 specimens.

6.5 *Testing Machine*—The testing machine shall have a capacity of not less than 3000 kg (6210 lbf) in compression. The machine shall be capable of maintaining a uniform rate of loading such that the load may be applied with a continuous motion of the movable head to the maximum load at a rate of  $10.0 \pm 5$  mm/min (0.40 in./min) with a permissible variation of  $\pm 0.5\%$ .

6.6 *Shearing Tool*—A shearing tool similar to the tool pictured in Test Method **D905** is satisfactory. The tool must have a self-aligning seat to ensure uniform lateral distribution of the load.

## 7. Materials

7.1 *Adhesive to Be Tested:*

7.2 *Joints*—Wood for wood-to-wood joints or joints of wood to metal or plastic shall be free of defects such as knots, cracks, short-grain and sharp-grain deviations, or any discolorations or soft spots indicative of decay. Generally, a high-density uniform-textured wood is desirable so that the maximum stress will be placed on the adhesive joint during testing. The standard shall be hard maple (*Acer saccharum* or *Acer nigrum*) having a minimum specific gravity of 0.65 (based on oven-dry weight and volume). Other species may be used where evaluation of the adhesive's performance in contact with that species is a specific requirement.

7.3 *Saturated Salt Solutions*—A constant relative humidity at a given temperature can be maintained in sealed aging jars by a saturated aqueous solution in contact with an excess of the solid phase of a specific salt. Tables are available that show relative humidities at given temperatures for many salts.<sup>5</sup> Sodium chloride is recommended. A saturated solution of sodium chloride will produce a relative humidity of 73 to 76 % over the temperature range from 40 to 100°C. This translates to wood moisture content in the approximate range from 9 to 13 %.

<sup>4</sup> Millett, M. A., Western, L. J., and Booth, J. J., "Accelerated Aging of Cellulosic Materials: Design and Application of a Heating Chamber," TAPPI, Vol 50, No. 11, 1967, pp. 74A–80A.

<sup>5</sup> Dean, J. A., ed., *Lange's Handbook of Chemistry*, 12th ed., McGraw-Hill Book Co., Inc., 1978.

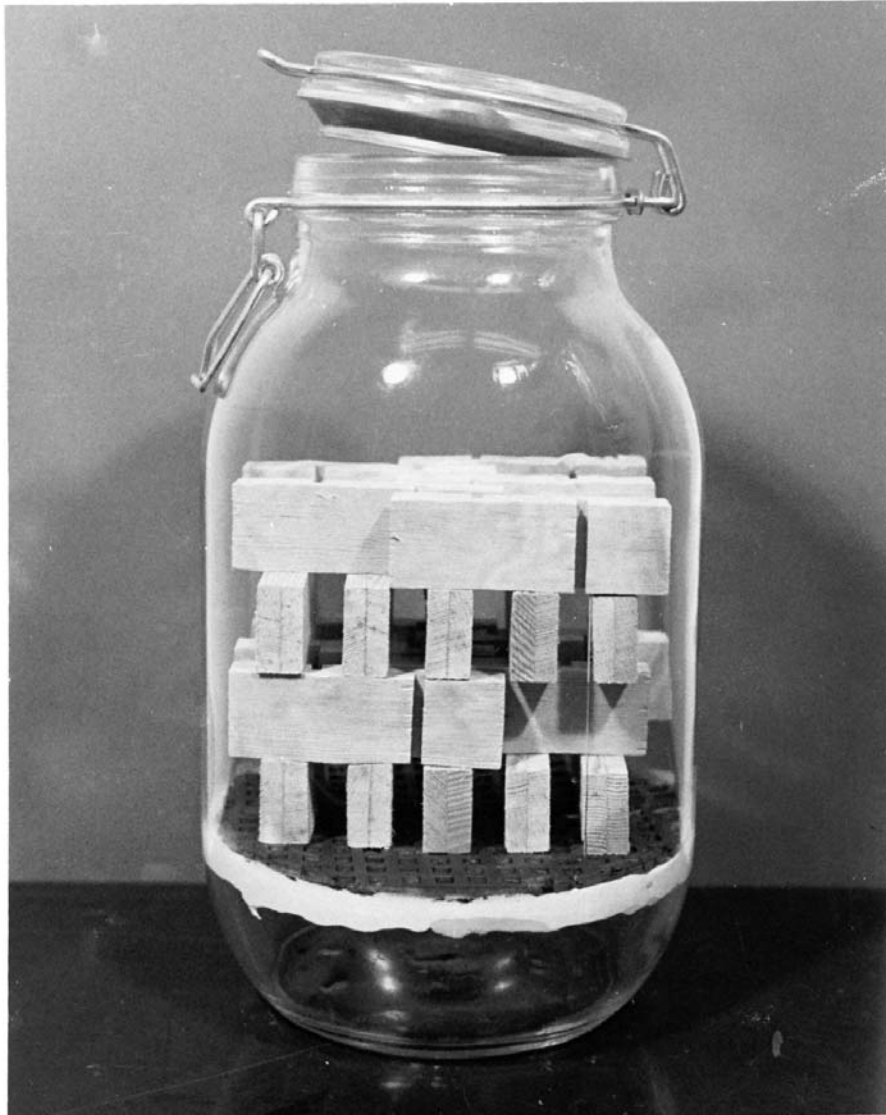


FIG. 1 Moist Aging Jar with a Shelf for Aging Specimens Over a Saturated Salt Solution

## 8. Test Specimens

8.1 A modified block shear specimen (Fig. 2) is suggested. The specimen is similar to the specimen of Test Method D905, but its smaller size allows more specimens to fit in the aging chambers. Other specimens such as used in Test Method D897 or Test Method D2339 are also satisfactory. If a type from Test Method D2339 is selected, then use 6.5 mm (¼ in.) lumber for each lamina, and increase the specimen length to 130 mm (5.1 in.) while maintaining the 25.4 mm (1 in.) overlap. Other bonded joints or products may also be tested if a suitable specimen can be devised.

8.2 Condition the wood at  $23 \pm 2^\circ\text{C}$  ( $73.4 + 3.6^\circ\text{F}$ ) and relative humidity of either 30 or 65 %, or other conditions, depending on the adhesive manufacturer's requirement.

8.3 Prepare modified shear block specimens as described in Test Method D905 with the following exceptions:

8.3.1 Cut rough 25.4 mm (1 in.) lumber into 127 or 63 by 305 mm (5 or 2½ by 12 in.) billets as required by Section 9. Saw each billet in half through the thickness using a bandsaw. Joint the surface of each half that is to be bonded and plane to 8 mm (5/16 in.) thickness. (Note 1) Bond the billets as described in Test Method D905.

NOTE 1—If during strength testing specimens fail in compression parallel to the grain at the ends, the laminae thickness should be increased from 8 mm (5/16 in.) to 9.5 mm (3/8 in.) or greater, as necessary.

8.3.2 After bonding, trim one edge and one end of each panel. Then cut two rows of five specimens each from the 63 by 305 mm (2½ by 12 in.) panels, as shown in Fig. 3, or four rows of five specimens each from the 127 by 305 mm (5 by 12 in.) panels.

NOTE 2—The adhesive should be thoroughly cured by hot pressing, oven heating, high-frequency heating, or whatever method is appropriate.