Designation: D 4688 – 99

Standard Test Method for Evaluating Structural Adhesives for Finger Jointing Lumber [1]

This standard is issued under the fixed designation D 4688; 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 is designed to evaluate adhesives for finger jointing lumber used in the manufacture of structural glued laminated timber. It tests the tensile strength of joints under the following treatments; dry with no treatment, wet after one vacuum-pressure soak treatment, and wet after cyclic boil-dry treatment.

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

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 907 Terminology of Adhesives[2]

D 2559 Specification for Adhesives for Structural Laminated Wood Products for Use Under Exterior (Wet Use) Exposure Conditions[2]

3. Terminology

3.1 *Definitions*—Many terms in this test method are defined in Terminology D 907.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *billet*, *n*—a piece cut from a vertical finger joint assembly as an intermediate step in making specimens.

3.2.2 *finger joint assembly*, *n*—a short portion of two boards joined at their ends by a finger joint obtained from a finger joint production line for testing, frequently referred to as an *assembly.*

3.2.3 *sample*, *n*—a group of finger joint assemblies obtained from a finger joint production line for statistical purposes.

3.2.3.1 *Discussion*—In the laminating industry the term *sample* is used for an individual finger joint assembly.

3.2.4 *specimen*, *n*—an individual strip, ¼ by 1⅜ (approximately) by 12 in. (6.4 by 35 by 305 mm), cut from a finger joint assembly for the tension test described in this test method.

4. Significance and Use

4.1 This test method is specifically designed to measure the performance of adhesives in finger joints manufactured under production line conditions.

4.2 The results of the test method may be used to certify an adhesive as suitable for finger jointing lumber under production-line conditions where the intended end use of the finger jointed lumber will be in a structural glued laminated timber. When the test results are to be used for certification of an adhesive for this purpose, use a standard wood species and a standard finger profile. Standard species may be found in Table 1 of Specification D 2559. Two standard finger profiles commonly used in the manufacture of structural glued laminated timber industry are shown in Fig. 1.[3]

4.3 This test method is not intended for quality control as the test assemblies are selected for their absence of defects usually found in run-of-the-mill lumber and finger joints.

5. Apparatus

5.1 *Test Machine*, capable of applying a calibrated tensile force up to 23 kN (5000 lbf), equipped with Templin (wedge-action) grips with grip area of 38 by 75 mm (1½ by 3 in.).

5.2 *Vacuum Pressure Vessel*, capable of drawing and holding a vacuum of at least 635 mm (25 in.) of mercury (sea level) for 30 min, holding a pressure of 620 ± 35 kPa (75 ± 2 psi) for 30 min, and capacity to ensure that all of the specimens are at least 51 mm (2 in.) below the water level during the complete vacuum-pressure cycle.

5.3 *Tank for Boiling*, capacity such that all specimens are at least 51 mm (2 in.) below the water level for the duration of the boil cycles.

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[1] This test method is under the jurisdiction of ASTM Committee D-14 on Adhesives and is the direct responsibility of Subcommittee D14.30 on Wood Adhesives.

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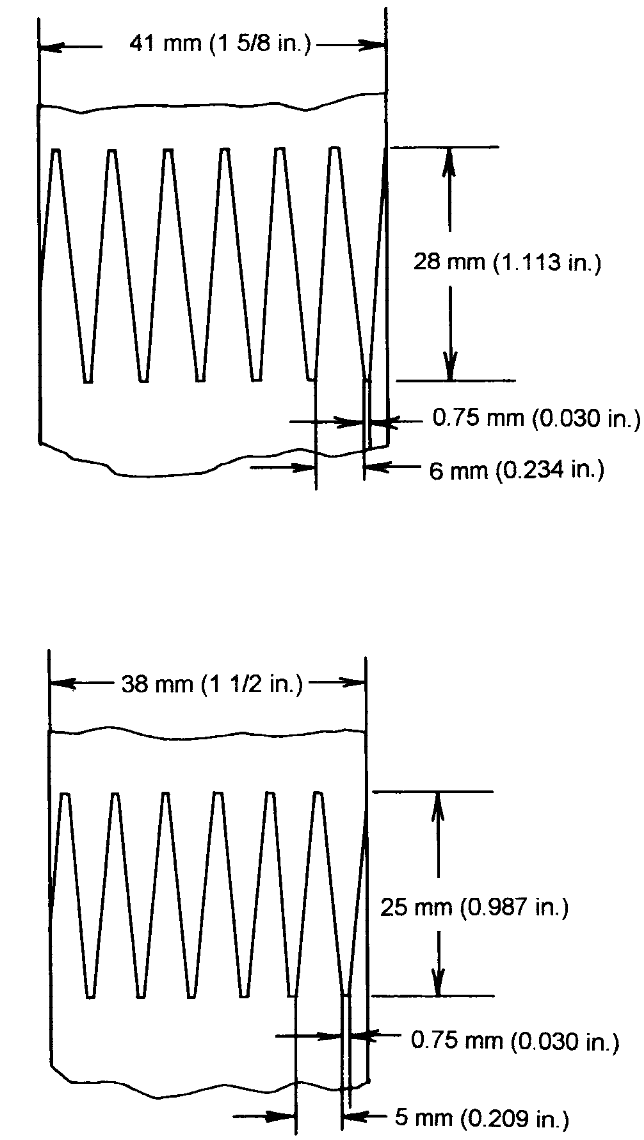
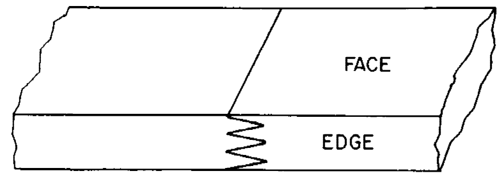
[2] *Annual Book of ASTM Standards*, Vol 15.06.

[3] American Institute of Timber Construction, 7012 S. Revere Parkway, Suite 140, Englewood, CO 80112.

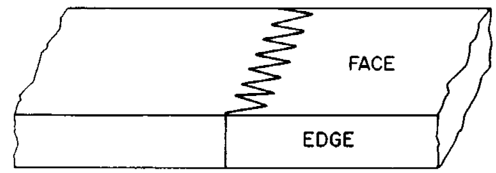


NOTE 1—Recommended by American Institute of Timber Construction.[3]

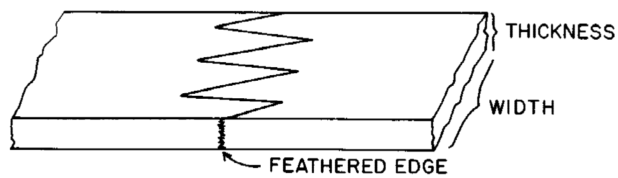
FIG. 1 Standard Joint Profiles for Certification Tests



(a) Horizontal Joint



(b) Vertical Joint



(c) Test Specimen

FIG. 2 Finger Joint Assembly and Specimen Descriptions

5.4 *Oven*, capable of operating continuously for 20 h at 63 ± 2°C (145 ± 5°F) with sufficient air circulation to lower the moisture content of the group of specimens to 8 % within 20 h.

5.4.1 *Timer*, to shut the oven off automatically is desirable.

6. Specimen Preparation

6.1 Obtain a sample consisting of either 20 horizontal or vertical finger joint assemblies from a finger joint production line. The boards must be nominal 2 by 4-in. or 2 by 6-in. Reject any assembly with obvious defects in the lumber or joint.

6.2 *Horizontal Joint* (Fig. 2(*a*)):

6.2.1 Joint one face of each assembly until the finger on the surface is feathered as shown in Fig. 2(*c*).

6.2.2 Joint one edge of the assembly for end cutting and ripping at a later stage.

6.2.3 Plane the second face of the assembly until the finger on the surface is feathered maintaining 35-mm (1⅜ -in.) assembly thickness or nearly so.

NOTE 1—It is more important to feather the finger than to maintain the 35-mm (1⅜ -in.) thickness.

6.2.4 Cut the assembly to a 305-mm (12-in.) length with the finger jointed area at the center.

6.2.5 Rip individual specimens 6.4-mm (¼ -in.) thick (Fig. 1) from the assembly starting with the jointed edge of the assembly (see 6.2.2) against the saw guide. A thin hollow-ground rip saw blade is preferred but the important criteria is the straightness of the cut. Check cut specimens for uniform thickness throughout. Thickness shall not vary by more than 0.5 mm (0.02 in.). Number the specimens in order from one side of the assembly to the other.

6.3 *Vertical Joint* (Fig. 2(*b*)):

6.3.1 Joint one edge of the finger joint assembly.

6.3.2 Joint one face of the finger joint assembly.

6.3.3 With the jointed edge against the saw guide, rip billets 40 mm (1$\frac{9}{16}$ in.) wide from the assembly.

NOTE 2—The 40-mm (1$\frac{9}{16}$ -in.) dimension is not critical but this dimension must be enough to allow feathering the fingers in following steps.

6.3.4 Joint and plane the sides of each billet so the exposed sides of the fingers are feathered as described in 6.2.1 and 6.2.3.

6.3.5 Rip four individual specimens of 6.4-mm (¼ -in.) thickness from each billet of the assembly as in 6.2.5. Number the specimens in order from one side of the assembly to the other. Use the same order for each assembly.

6.4 Inspect specimens for defects. Assemblies yielding specimens that have obvious strength-reducing characteristics such as: low visual density, knots, steep slope of grain, compression wood, compression failures, decay, pitch pockets, or stress risers due to errors in specimen preparation, may be rejected. If specimens with questionable strength characteristics are tested they shall be identified by appropriate notes on the report form prior to exposure and testing.

6.5 Condition all specimens to equilibrium moisture content (EMC) at 23 ± 2°C (73 ± 4°F) and 50 to 65 ± 5 % relative humidity. Monitor the weight periodically to determine when equilibrium is reached.

6.6 Weigh all specimens to the nearest 0.01 g and record the weight. Measure the width and thickness of the specimens to the nearest 0.25 mm (0.010 in.) and record the measurements.

6.7 Randomly assign two specimens from each of the 20 finger joint assemblies in the sample to each test (that is, dry, soak, and boil). (Note this requires only six specimens from each assembly, the other specimens are extra.) Fig. 3 shows the source and distribution of the specimens.

7. Procedure

7.1 *Dry Test* (No Treatment):

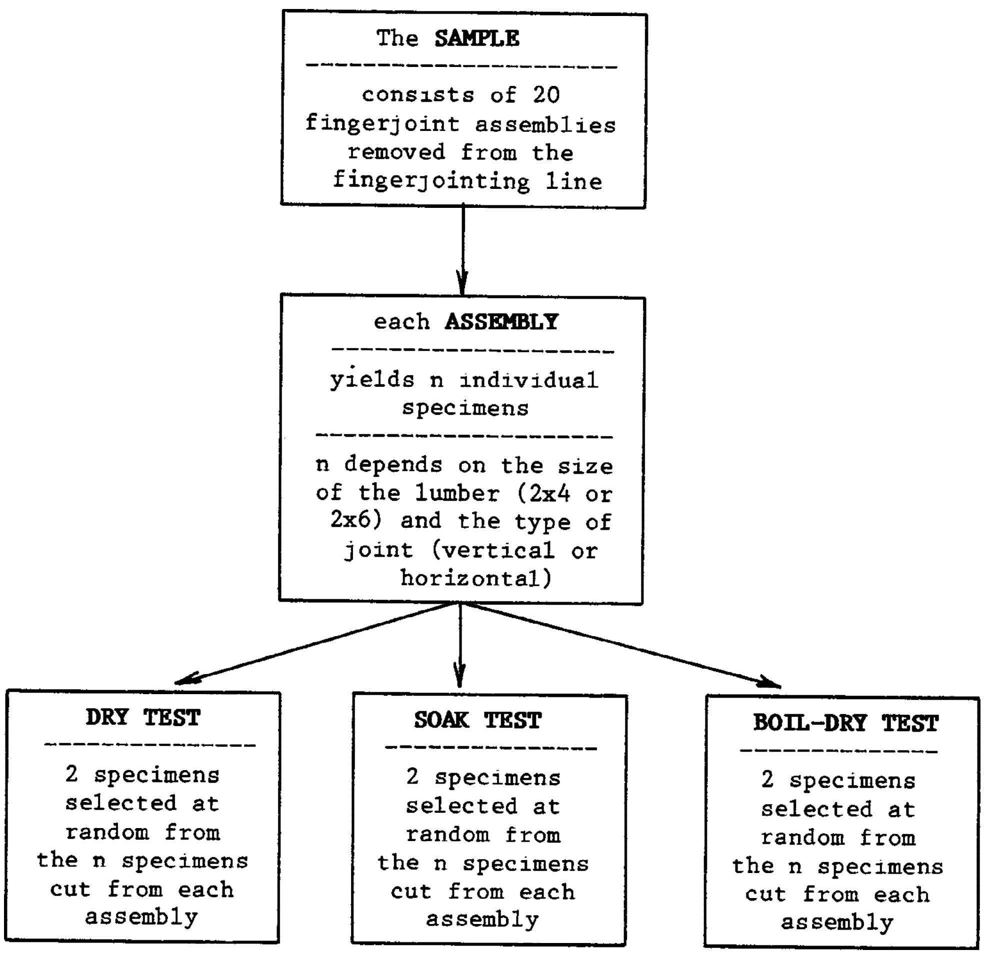
7.1.1 As described in 6.7, assign 40 specimens to this test. Test each specimen to failure by loading at a rate of 5 mm/min (0.20 in./min). Maintain a space of 210 ± 6 mm (6 ± 0.25 in.) between the ends of the jaws of the grips. Record the load at failure.

NOTE 3—Be very careful to align the specimen with the principal axis of the test grip. Failure to do this will increase the variability of the results. Markings or spacers on the grips, or some other device is recommended to ensure proper front-to-rear alignment, and a plumb bob or other device is recommended to ensure the vertical alignment.

7.1.2 Determine the failure mode using the criteria given in Annex A1 independent of any knowledge of the strength test result.

7.2 *Cold Water Vacuum-Pressure Soak Test*:

7.2.1 As described in 6.7, assign 40 specimens to this test. Place all 40 specimens in a vacuum-pressure vessel with spacers between them so that water has free access to all surfaces. Fill the vessel with tap water at 18.5 to 27.5°C (65 to 80°F) so that all specimens are at least 51 mm (2 in.) below the surface of the water. After filling, seal the vessel and draw a vacuum of at least 635 mm (25 in.) of mercury (sea level). Hold the vacuum for 30 min, then release the vacuum and apply pressure of 620 ± 35 kPa (75 ± 2 psi). Hold this pressure for 2 h, then release. Remove the specimens from the



NOTE 1—Thus: 20 assemblies × 2 specimens/assembly = 40 specimens/test.

FIG. 3 Flowchart of the Source and Allocation of Individual Test Specimens

pressure vessel and place them submerged in water at room temperature until tested.

7.2.2 Wipe the surface of each specimen with a dry cotton cloth or paper towel and test wet as described in 7.1.1. Record the load at failure.

7.2.3 After the specimens have dried, determine the failure mode as described in 7.1.2. Record the failure mode.

7.3 *Cyclic Boil Test*:

7.3.1 As described in 6.7, assign 40 specimens to this test. Place all 40 specimens in the boil tank with spacers so that water has free access to all surfaces. Fill with water such that the specimens are at least 51 mm (2 in.) below the water level. Boil specimens for 4 h, then dry them in an oven at 63 ± 2°C (145 ± 5°F) with sufficient air circulation to lower the moisture content to 8 % (ovendry basis) in no more than 20 h.

NOTE 4—The rate of air circulation, the size of the load of specimens in the oven, and the spacing of the specimens greatly affect drying time and the steepness of the moisture gradient in the specimen. Variation of these factors strongly affects the repeatability of the test method. If repeatability (within-laboratory variability) or reproducibility (between laboratories) is important, the drying variables must be maintained as constant as possible from one series of tests to the next. If this is not possible, the drying should be conducted so that the specimens reach 8 % moisture content within the same drying period in every test. One way to do this is to monitor the weight of the specimens and adjust the oven vents so the specimens reach the target 8 % moisture in 15 to 20 h. As an aid in following moisture content, the weight of specimens at 8 % moisture content is about 96 % of their weight at 12 % moisture content. The drying time required can be established with some of the extra specimens cut from the 20 assemblies.

7.3.2 Repeat the boil-dry cycle five more times; except during the final cycle do not dry the specimens. Cool the specimens to room temperature submerged in water and keep them there until they are tested.

7.3.3 Test wet in tension as described in 7.2.2. Record the load at failure.

7.3.4 After the specimens have dried, determine the failure mode as described in 7.1.2. Record the failure mode.

NOTE 5—Nonmandatory guidelines for joint performance follow:

Mode 1	—	An unacceptable failure.
Modes 2 and 3	—	Unconditionally acceptable failure.
Modes 4, 5, and 6	—	Conditionally acceptable failure if strength is acceptable.

8. Calculation of Results

8.1 Calculate the tensile stress at failure in megapascals (pounds-force per square inch) as the load at failure in newtons (pounds-force) divided by the cross-sectional area of the specimen expressed to the nearest mm^2 (0.01 in.^2).

8.2 Estimate the 25th, 50th, and 75th percentiles for the group of specimens in the following manner:

8.2.1 Arrange the specimens in order of increasing strength.

8.2.2 Estimate the 25th percentile as the average of the 10th and 11th lowest strength values.

8.2.3 Estimate the 50th percentile as the average of the 20th and 21st values.

8.2.4 Estimate the 75th percentile as the average of the 30th and 31st strength values.

8.3 Determine the upper and lower adjacent values (see definition below) for the group of specimens. Determine the outliers (test values outside the range expressed by the upper and lower adjacent values).

25th percentile = $Q1$	=	the value below which 25 % of the observations fall.
50th percentile = $Q2$	=	the value below which 50 % of the observations fall.
75th percentile = $Q3$	=	the value below which 75 % of the observations fall.
Upper adjacent value	=	the largest observation equal to or less than the quantity $Q3 + 1.5(Q3 - Q1)$.
Lower adjacent value	=	the smallest observation greater than or equal to the quantity $Q1 - 1.5(Q3 - Q1)$.
Outliers	=	observations greater than the upper adjacent value or less than the lower adjacent value.

8.4 Calculate the mean and standard deviation. Specimens exhibiting failure mode 6 may be excluded from the calculation. Include specimens with failure modes 1, 2, 3, 4, and 5 in the calculation unless the strength value is an outlier or the wood is of poor quality (such as compression wood, etc.).

9. Report

9.1 Include the following general information in the report:

9.1.1 Complete identification of the adhesive tested including type, source, manufacturers' code numbers, form, and any other pertinent information,

9.1.2 Adhesive application and bonding conditions used to prepare the finger jointed boards,

9.1.3 Conditioning procedure used before testing,

9.1.4 Temperature and relative humidity of the test room,

9.1.5 Number of finger joint assemblies represented in the test, and

9.1.6 Number of specimens per assembly tested in each test (dry, soaked, and boiled),

9.2 Include the following statistical information in the report:

9.2.1 The range of test values,

9.2.2 The 25th, 50th, and 75th percentile values,

9.2.3 The upper and lower adjacent values,

9.2.4 Outliers identified by finger joint assembly and specimen number,

9.2.5 Failure mode 6 specimens identified by finger joint assembly and specimen number,

9.2.6 Specimens with defects of material or bonding discovered after testing identified by finger joint assembly and specimen number,

9.2.7 The mean and standard deviation, and

9.2.8 The statistical mode (most frequent value) of the observed failure modes.

10. Precision and Bias

10.1 A measure of the precision of this test method covering all possible types of finger joints has not been determined. It is unlikely that a precision statement could be determined to cover all possible cases because many factors that affect precision, such as wood species, finger geometry, cutting tool sharpness, the adhesive, and the bonding conditions, are not specified by these test methods. The precision of this test method for a given sample may be compared to any previous test using the parameters listed in 8.2. The precision of this test method for a given sample may also be compared to the precision determined in a series of tests conducted by four laboratories during the development of this test method. A summary of these results, including the sources of variation, is given in Appendix X1. However, it must be remembered that factors beyond the control of this test method affect precision.

10.2 This test method has no bias because the tensile strength of finger joints is defined only in terms of this test method.

11. Keywords

11.1 billet; failure mode; finger joint; horizontal joint; structural joint; vertical joint

ANNEX

(Mandatory Information)

A1. FAILURE MODE CLASSIFICATION OF TESTED SPECIMENS

A1.1 The types of failure that occur in finger jointed specimens due to tension loading may be roughly classified

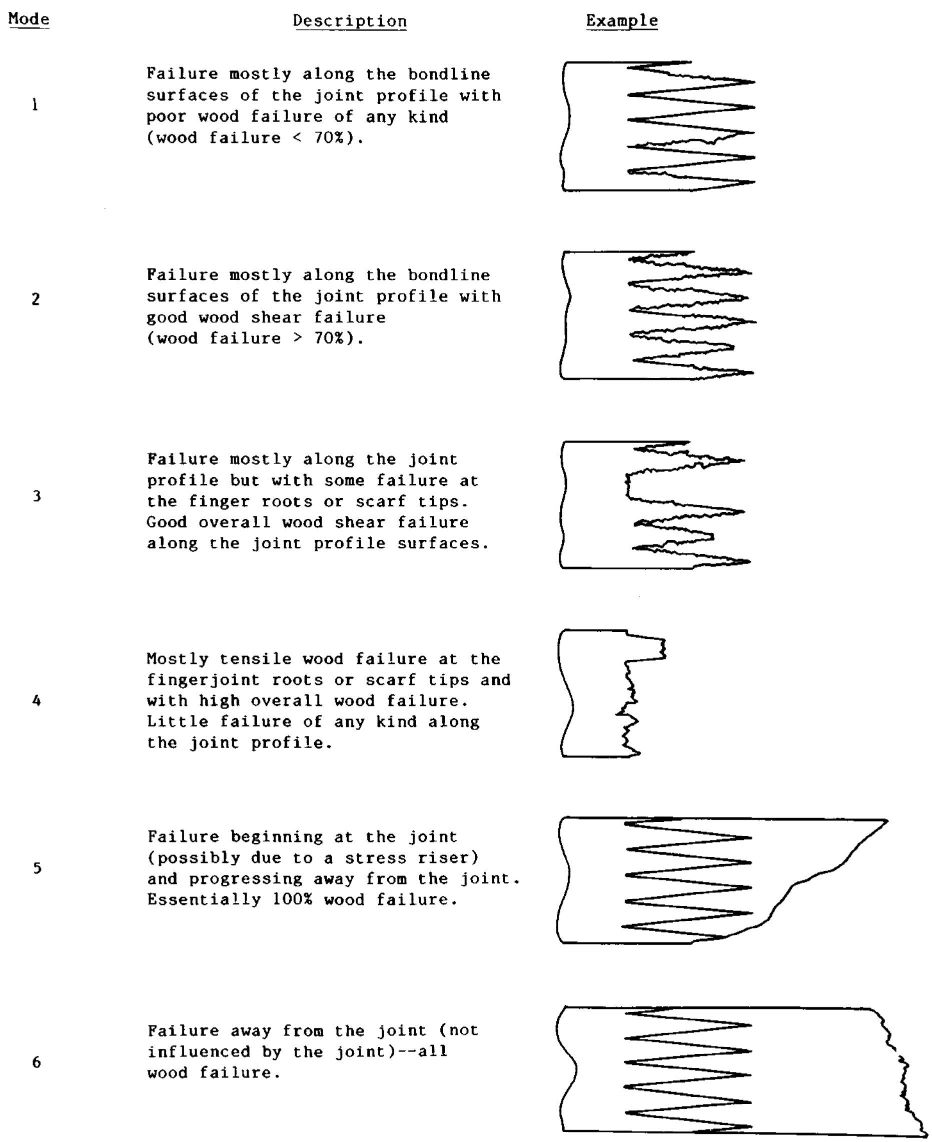


FIG. A1.1 Failure Mode Criteria

into six modes. Determine the failure mode of each specimen based on the written and graphical description given in Fig. A1.1.

A1.2 Failure modes 1 and 2 require the evaluator to make a distinction between less than 70 % wood failure and more than 70 % wood failure. This is often a difficult quantity to judge from an oblique angle. In difficult cases it is suggested that the fingers be cut off at their roots so that the failed surfaces of the finger can be viewed directly.

APPENDIX

(Nonmandatory Information)

X1. PRECISION AND SOURCES OF VARIABILITY

X1.1 A round-robin study was conducted during the development of the dry, soak, and cyclic boil tests. The study was based on 75 finger jointed assemblies obtained in a single run from a commercial laminating plant. The jointed assemblies were made with L1 or better laminating grade Douglas fir lumber.[4] The joints were of the horizontal type (Fig. 1), and they were bonded with melamine-urea adhesive. After bonding the assemblies were sent to one laboratory where they were cut into individual specimens. After cutting each assembly was inspected specimen-by-specimen for defects. The 60 best assemblies were selected for actual testing. Each specimen was marked, allocated to one of five participating laboratories, and assigned to a test and trial. Finally the specimens were preconditioned to 12 % EMC before they were sent to the other testing laboratories. All the preparation was done at one laboratory to minimize specimen preparation as a source of variability. Each laboratory conducted three trials of each test using three groups of specimens. No two trials were conducted on the same day. (See Table X1.1.)

TABLE X1.1 Round-Robin Study

Item	Number
Finger joint assemblies	60
Specimens per assembly	15
Total specimens	900
Laboratories	4[A]
Tests	3[B]
Trials per test	3
Specimens within trials	20
Specimens per assembly per trial	1

[A] One of the original five laboratories dropped out.
[B] Dry, soak, and boil.

X1.2 *Results:*

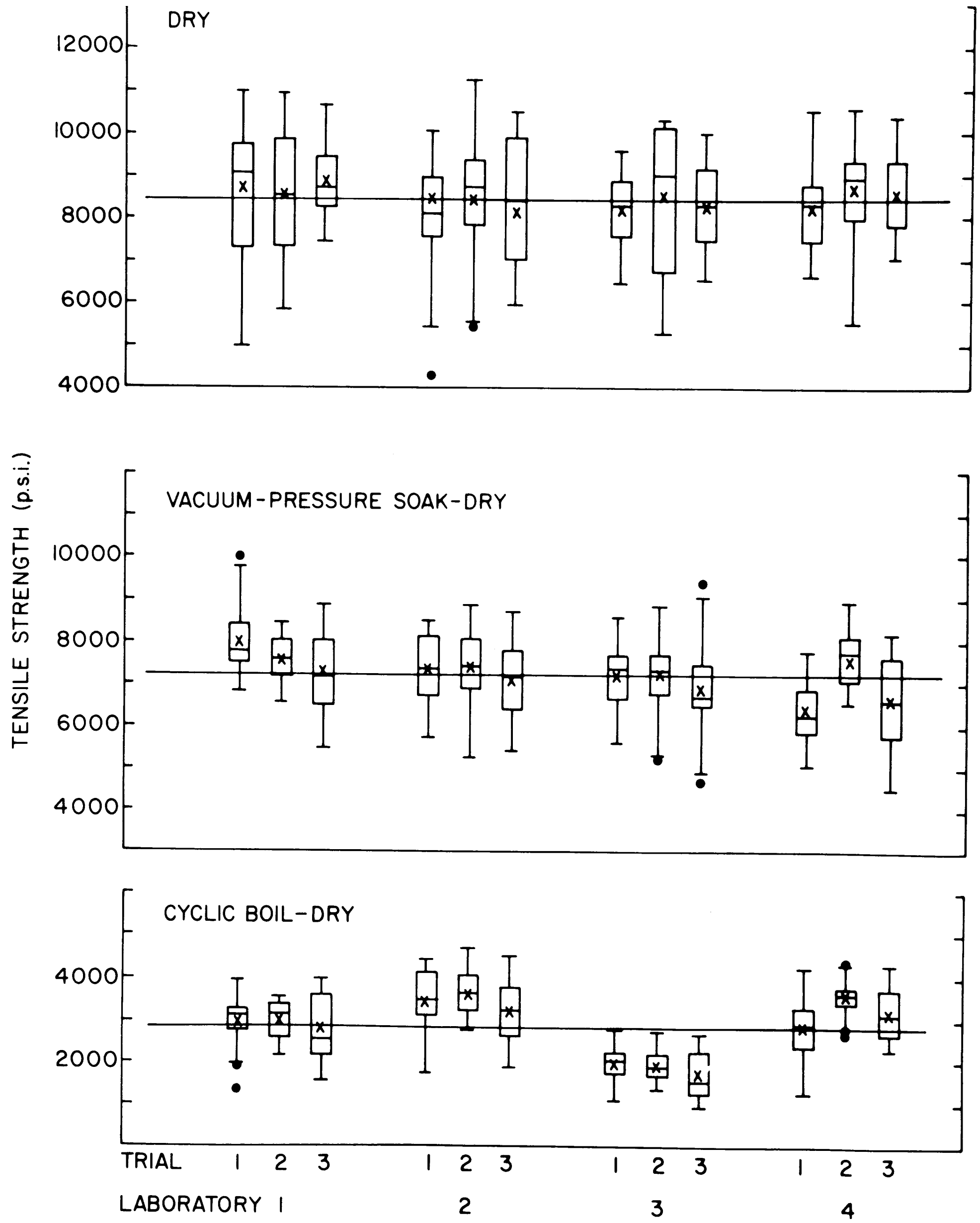
X1.2.1 The results are summarized in Fig. X1.1 with the major breakdown by test. Within a test the results are organized by laboratory and group. The data is represented in the form of Tukey box plots.[5] The horizontal line segment enclosed in the box is the 50th percentile. The horizontal line segments at the top and bottom of the box are the 75th and 25th percentile values, respectively. The horizontal line segments at the ends of the lines extending from the ends of the box are the "adjacent values." Dots above or below the adjacent values are outliers. The *X* inside the box is the mean. The horizontal line extending across all the groups and all the laboratories is the grand mean for the test.

X1.2.2 The dry and soak tests were repeatable and reproducible. An analysis of the variance revealed that differences between individual finger joint assemblies accounted for most of the strength variation observed in the dry and soak tests. There were few significant differences between trials of a given test conducted by a given laboratory (repeatability) and none of these differences were of practical significance. Furthermore, differences in equipment or procedure used at the different laboratories did not account for practical differences between the laboratory's results (reproducibility).

X1.2.3 The cyclic boil test was not reproducible. Differences between individual finger joint assemblies were also an important source of variation in the cyclic boil test. Some differences between trials for a given laboratory were significant, but not of practical importance and the boil test was repeatable within a given laboratory where the same equipment and procedure were used from trial to trial. On the other hand, the differences between laboratories were statistically and practically significant. Repetition apparently multiplies the effects of differences in drying ovens, oven loading, and other drying conditions between the laboratories. These between-laboratory differences accounted for more than half the variation of strength in the boil test.

[4] Standard grading rules for West Coast lumber No. 16. Available from West Coast Lumber Inspection Bureau, P.O. Box 23145, 6980 Varnes Road, Portland, OR 97223.

[5] Cleveland, W. S., and R. McGill, "Graphical Perception and Graphical Methods for Analyzing Scientific Data," *Science*, 229: 828–833, 1985.



NOTE 1—Results obtained by four laboratories conducting three separate trials of the dry, soak, and cyclic boil tests.

FIG. X1.1 Tukey Box Plots