SIGNIFICANCE OF MECHANICAL WOOD-JOINT TESTS
FOR THE SELECTION OF WOODWORKING GLUES

Information Reviewed and Reaffirmed

May 1952

No. R1111

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
FOREST PRODUCTS LABORATORY
Madison 5, Wisconsin

In Cooperation with the University of Wisconsin
THE SIGNIFICANCE OF MECHANICAL WOOD JOINT TESTS
FOR THE SELECTION OF WOODWORKING GLUES*

By

T. R. TRUAX, Wood Technologist
F. L. BROWNE, Chemist
and
DON BROUSE, Assistant Engineer

Abstract

The testing of glued wood joints is well adapted to the laboratory study of such problems as the usefulness of new adhesives or new treatments of old ones, the technic of gluing operations, the gluing characteristics of different woods, and the causes of weak joints in specific woodworking operations. Wood joint tests are not suitable for the grading of animal glues for woodworking because in practice more direct evidence of the physical properties of the glue is afforded by the viscosity and jelly strength tests. Strong joints may be made with any animal glue suitable for woodworking, but different gluing conditions must be used according to the grade of the glue. If wood joint tests are made with glues of different grades under a uniform set of gluing conditions, the grade of glue that will give the best results will be the glue best adapted to the particular gluing conditions and fair deductions regarding the intrinsic "strength" of the glues cannot be drawn. Wood joint tests are used to some extent for selecting casein and vegetable glues because no better grading system has been worked out and because such glues yield strong joints under a comparatively wide range of gluing conditions. An unfavorable joint test indicates that the glue is not reliable under the particular gluing conditions tried; it does not prove the glue to be lacking intrinsically in "strength" or "adhesiveness."

Introduction

When a well designed and well glued wood joint is torn apart, except where one or both of the joined surfaces are end grain wood, the wood splinters over all or a large part of the joint area. Accordingly, a sample wood joint that breaks by splintering of the wood has been considered by many woodworkers as a reasonable proof of satisfactory gluing. Technologists,

*Published in Industrial and Engineering Chemistry, January, 1929.
however, have revealed that wood failure alone is not a satisfactory criterion of good gluing and have therefore designed numerous special types of wood joints suitable for testing in machines that indicate the load under which failure takes place.

It has been generally assumed that woodworking glues possess an intrinsic property known as "strength" or "adhesiveness" which is significant of their value for making strong wood joints and that a suitable technique for measuring this property should provide a better standard of grading glues for woodworking purposes than tests of viscosity and jelly strength. Wood joint tests therefore suggest themselves as a direct method for measuring this supposedly characteristic property of glues. Thus, Sauer\textsuperscript{2} would grade glues in accordance with a wood joint test and the viscosity of a standard solution. The British Engineering Standards Association\textsuperscript{2} specifies that animal glues for airplane propellers pass a certain wood joint test with a breaking stress of 1,100 pounds per square inch or more. The specifications of the U. S. Navy and Army\textsuperscript{2} for animal glue formerly included the requirement that test joints withstand an average load of 2,400 pounds per square inch before breaking with no specimen breaking below 2,200 pounds per square inch. However, this joint test has been abandoned and the present Federal Specifications\textsuperscript{2} do not include joint tests for animal glue.

The attempt to grade glues on the basis of wood joint tests presents a dilemma. If, on the one hand, the test specimens are well designed and depend upon side grain gluing, well made joints fail very largely by splintering of the wood even though a very strong wood and a comparatively low grade animal glue be chosen. Under such circumstances the strength of the wood rather than that of the glue seems to be measured. If, on the other hand, the test specimens are poorly designed and especially if they depend upon end grain gluing, the failure is almost certain to take place entirely in the glue line.

\textsuperscript{1}National Association of Glue Manufacturers, Ind. Eng. Chem., 16, 310, 1924.
\textsuperscript{3}First Report of the (British) Adhesives Research Committee, 1922, p. 19.
but the stress producing failure may be materially less than that required
to break good joints in end grain gluing. Furthermore, the woodworker
objects to an end grain joint as it is unreliable.

Rudeloff,6 using a test specimen of red beech with end grain gluing and
carefully applying a load in tension uniformly over the joint area, obtained
1,630 pounds per square inch for his strongest joint and considered values
exceeding about 1,000 pounds per square inch representative of strong joints;
variations of individual tests from the average ranged from 16 to 123 percent.
Hoppl7 and Gill8 avoided the dilemma presented by wood joint tests by break-
ing specimens of the dried glue jelly in tension, but the preparation of the
specimens was a long and tedious task. Bateman and Towne2 showed that the
strength of such glue specimens varies enormously with the relative humidity
of the air. Other workers10 have found it more convenient to impregnate
such materials as filter paper with glue and measure the increase in strength,
a procedure open to much criticism.

McBain and his coworkers overcome both experimental difficulty and mechanical
objection by preparing thin films of the adhesives for measurement of their
strengths in tension. However, the results of such direct observations of
the mechanical properties of glues present the following facts which are
contrary to the theory that glues possess an inherent "strength" indicative
of the strength of the wood joints that can be made with them: (1) Animal
glues of the wide range in grades employed for woodworking do not differ
observably in the strength so measured, though they may vary in a property
called by McBain and Lee "deformability." (2) A high grade animal glue
remains practically unchanged in strength after keeping a solution of it at
140° F. (60° C.) for a month (a treatment that degrades it enormously). (3)
Although animal glue of the woodworking grades is much stronger than wood.

6Rudeloff, Kitt. Materialprüfungsamt Berlin-Lichterfelde West, 1918, No. 1
   and 2. See also reference 8.
   1900; Neumann, Kolloid-Z. 33, 356, 1923; Bockhold and Neumann, Z. angew.
   Chem., 37, 534, 1924; Horst, Z. angew., Chem., 37, 225, 1924; See also
   Reference 8.
11McBain and Hopkins, 2nd Report of the (British) Adhesives Research Com-
joints made from it, there are glues which when tested alone by the method
of thin films in tension give lower strength values than wood joints made
from them.\textsuperscript{12}

Influence of Gluing Technique on the Strength of Wood Joints

Previous workers have not fully recognized that the strength of a wood joint
depends upon the care in making it and have assumed that an arbitrary set
of gluing conditions can be adopted in accordance with which the test joints
may be prepared, regardless of the nature of the glue to be tested or the
use for which it is intended. The fallacies of such a procedure are that
some glues give strong joints only when gluing conditions prevail that differ
materially from those necessary to make strong joints with other glues, and
that the woodworker cannot arrange the same gluing conditions in all of his
operations. For example, in gluing plywood panels a relatively long assembly
time elapses between spreading the glue on the wood of the first panel and
applying pressure to the bundle of panels in the press. In edge gluing
lumber cores, however, pressure is usually applied to the joint within less
than a minute after spreading the glue. The woodworker using animal glue
must buy a very different grade for the two operations if he is to obtain
joints strong enough to withstand the maximum stresses that the wood itself
can sustain.

The several factors, kind of glue, grade of glue, temperature of room,
temperature of wood, temperature of glue, quantity of glue spread, time of
assembly, and pressure applied, may be termed collectively the gluing con-
ditions. These factors govern the strength of wood joints and have been
described elsewhere.\textsuperscript{13} It will, therefore, suffice to illustrate with typical
results, the joint strength values and types of failure obtained with common
woodworking glues under different gluing conditions. Two animal glues, one
of high grade and one of comparatively low grade, were chosen because most
of the published discussions of glue joint tests have been upon such glues.
Animal glues, moreover, are more sensitive than casein or vegetable (starch)
glues to changes in the gluing conditions and there is a recognized system
of grading them independently of the making of wood joints.

Glue A was purchased to match the "standard animal glue" used during the
World War as the basis for comparison by the U. S. Government inspectors in
certifying animal glues for airplane propellor manufacture. The viscosity
of Glue A as determined by the standard test procedure of the National
Association of Glue Manufacturers\textsuperscript{1} was 108 millipoises and its jelly strength

\textsuperscript{12}Browne and Brouse, Ind. Eng. Chem., 21, 80, 1929.

Mfr. & artisan, May 1924.
303 grams. Glue B was made by the same manufacturer that made Glue A and had a viscosity of 65 millipoises and a jelly strength of 190 grams. It represents a moderately low grade of woodworking glue. To prepare them for use, the dry glues were soaked in cold water until thoroughly softened, melted at 140° F. (60° C.), and spread at that temperature on the wood with a mechanical glue spreader. The proportion by weight of water to dry glue was for Glue A, 2.25 to 1, and for Glue B, 1.95 to 1. These ratios gave glue mixtures of approximately equal viscosity at 140° F.

The wood used in side grain gluing was sugar maple (Acer saccharum). Details of the gluing conditions are given in Table 1, together with the results of the tests.

Photographs of representative fractured test specimens are shown in Figure 1. Good, chilled, dried, and starved types of glued joints are illustrated, all four of which have been observed in commercial woodworking operations.

Good joints are characterized by high average strength and by the occurrence of the fracture, at least in part, in the wood rather than in the glue line. (See Figure 1.) Each test specimen characterized in Table 1 as "good" failed in the wood at least in part, indicating that there is little or no advantage in strength to be gained by using a "stronger" glue. In good joints the difference between the average and the minimum breaking loads observed in the specimens tested is usually less than it is in the chilled, dried, or starved joints.

Chilled joints are obtained when the glue congeals, but does not dry, during the time of assembly to such an extent that the pressure applied proves insufficient to establish adequate contact between glue and wood and to cause the glue to flow into a uniform film. Chilled joints usually have a thick layer of glue which may either shatter or pull away cleanly from one surface when the joint fails. (See Figure 1.) They are more likely to be obtained in practice with a high grade than with a low grade glue. A cold glue room and cold wood, a long time of assembly, and a low pressure favor chilled joints. Of the faulty gluing conditions, that causing chilled joints is most easily overcome because the pressure may be increased, the wood preheated, the time of assembly shortened, or glue may be placed on both surfaces to be joined instead of one only. Only hot glues are subject to chilled joints.

Dried joints are obtained when the glue loses enough moisture during the time of assembly through evaporation or through absorption by the wood to harden appreciably. The fractured test specimens (see Figure 1) exhibit characteristic glossy areas where contact between glue film and wood was not established. A warm glue room, warm wood, and a long time of assembly cause dried joints. All common woodworking glues are subject to dried joints.

Starved joints are caused by the glue penetrating excessively into the wood or by excessive "squeeze out" of the glue when pressure is applied and contrary to a common belief they are favored by a too generous rather than a
too stingy spread of glue. The broken pieces of a starved joint show little or no glue between the joined surfaces (see Figure 1) and microscopic observation of a cross section through the joint reveals deep penetration of the glue into the wood. Warm wood, a heavy spread of glue, a short time of assembly, and a high pressure produce starved joints. They are more likely to be obtained with a low than with a high grade glue. Hot glues are more subject to starved joints than glues that are used cold because the latter usually are less mobile.

It may be noticed in Table 1 that somewhat different gluing conditions were chosen for Glue A than for Glue B. This was necessary because the range of gluing conditions in which joints of any of the four types is obtained varies with the grade of glue. The woodworker is concerned with knowing which grade of animal glue can be trusted to give good joints under the gluing conditions attainable in his particular operations. With the woodworking glues in common use, faulty joints are far more likely to result from maladjustment of glue grade to gluing conditions than from inadequate adhesive power inherent in the glue itself.

Since several of the factors entering into the gluing conditions are interdependent and compensatory, the woodworker has a certain latitude in adjusting them to meet the requirements of various operations without the necessity of changing to a glue of different grade. Changing the water ratio for a given glue has somewhat the same effect as changing the grade. Table 2 shows a few of the many possible gluing conditions that give good joints with sugar maple using Glue A.

Glue Grade and Joint Strength

Proposals to determine the intrinsic strength or adhesiveness of animal glues by means of wood joint tests usually set forth a standardized routine of gluing conditions to be followed with all of the glues tested, except that some of them permit adjusting the proportion of water so that the glue mixture will have about the same viscosity at the temperature of application. Table 1 shows that such procedure is fundamentally unsound unless the chosen routine of gluing is definitely related to the particular manufacturing conditions for which a glue is being selected, for no one set of gluing conditions will produce joints that are representative of best practice with glues of every grade.

---

Thus we find:

<table>
<thead>
<tr>
<th>Under gluing conditions: designated in Table 1</th>
<th>Glue A</th>
<th>Glue B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average</td>
<td>Average</td>
</tr>
<tr>
<td>joint failure</td>
<td>Wood</td>
<td>Wood</td>
</tr>
<tr>
<td>strength</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lbs. per sq. in.</td>
<td>Percent</td>
<td>Lbs. per sq. in.</td>
</tr>
<tr>
<td>I</td>
<td>3,950</td>
<td>2,950</td>
</tr>
<tr>
<td></td>
<td>55</td>
<td>75</td>
</tr>
<tr>
<td>II</td>
<td>2,500</td>
<td>3,100</td>
</tr>
<tr>
<td></td>
<td>27</td>
<td>84</td>
</tr>
</tbody>
</table>

Under one set of conditions Glue A seems "stronger," under the other Glue B. Neither glue appears to best advantage when applied in accordance with the best practice for the other. With Glue A chilled joints resulted under conditions II, which gave the best results with Glue B. With Glue B the joints made under conditions I, though classified as good, bordered on the starved condition.

If the two glues are compared when each one is used under its most favorable conditions, the chemist, noting the higher average load at failure, is likely to conclude that Glue A is "stronger." The craftsman, looking at the fractured test specimens and observing the greater amount of wood failure, would favor Glue B. The differences appearing in the table for these particular tests are due mostly to variation in the strength of the maple blocks because the wood failure in both cases is high enough to indicate that the strength of the wood rather than that of the glue joint governed the load at which failure took place. In support of this interpretation the results of other tests may be cited. Eight pairs of maple blocks were glued with Glue A under eight different good gluing conditions; 10 test specimens from each joint -- 80 specimens in all -- gave an average load at failure of 3,300 pounds per square inch with 62 percent wood failure and a minimum load of 2,035 pounds per square inch. Another series of eight joints was made with a glue of still lower grade than Glue B, the viscosity of which was 142 millipoises and the jelly strength 150 grams; the 80 test specimens gave an average load at failure of 3,500 pounds per square inch with 47 percent wood failure and a minimum load of 1,927 pounds per square inch.

What Wood Joint Tests Tell

From these considerations it is clear that wood joint tests in side grain gluing are not suitable for the routine grading and evaluation of animal glues for woodworking. When used under suitable gluing conditions, all of
the grades of glue used in woodworking give joints whose load at failure depends chiefly upon the strength of the wood joined. By testing each glue under a range of different gluing conditions wide enough to establish the zone of conditions within which it will give good joints, it would be possible to group animal glues in classes corresponding roughly to the grading on the basis of jelly strength and viscosity as now employed. But such an arduous task is one for the research, not for the control laboratory. Viscosity and jelly strength, which are quickly and fairly easily measured with precision, give essentially the same information. Viscosity tells the woodworker how much water to add to get the right amount of the glue on the wood at the least cost. Jelly strength, insofar as it is proportional to the chilling point, indicates how long it will take to reach the right consistency for pressing under the conditions prevailing and how long it will remain in that favorable condition. The two properties together serve admirably for checking successive shipments of glue for uniformity and for comparing competing brands to insure economy in purchasing.

On the other hand, the wood joint test is essential in the glue research laboratory for studying such problems as the practical usefulness of newly proposed adhesives, the influence of new treatments upon or additions to established glues, the gluing characteristics of different woods, the technique of gluing operations, and for examining glued wood products for their reliability or for the location of the causes of manufacturing difficulties. Direct measurements of the strength of solid specimens of glues may not, in the present state of knowledge, be substituted for the wood joint test because it has not yet been shown that the "strength" of a glue so measured bears any essential relation to the strength of wood joints made with it, nor do they appear to have a close relation to the viscosity or jelly strength of the glues themselves.11

Wood joint tests were adopted15 as the foundation of specifications for casein glues. Most attempts to test vegetable glues also rely upon wood joint tests. Some representative results with these glues are given in Table 3 and Figure 2. At present wood joint tests seem necessary for these types of glues because knowledge of their significant physical and chemical characteristics is not yet sufficient to permit the adoption of more refined testing methods. Fortunately, casein and vegetable glues are much less sensitive to changes in gluing conditions than animal glues and good joints are obtained with them through a fairly wide range in conditions. There is no danger of obtaining chilled joints with cold glues and starved joints are comparatively rare. Dried joints, however, are often encountered.

When making test wood joints with any glue it is well to bear in mind that, while a favorable outcome proves the glue capable of making good joints, an

---

unfavorable test does not prove the contrary. Before the glue can be re-
jected as inherently weak, it must be tried out under conditions representa-
tive of the range under which it might be practicably employed.

Procedure of the Forest Products Laboratory in

Making Wood Joint Tests

Two types of wood joint tests are made at the Forest Products Laboratory. The test of plywood specimens, designed especially to determine the water resistance of glues, has been described elsewhere.15 The test of lumber joints in side grain gluing is made as follows:

Commercial 1-inch sugar maple (Acer saccharum) lumber is used and wood of average density or higher, straight grained, and free from defects is selected from it. This wood is seasoned thoroughly and stored in a room kept at 30 percent relative humidity and 80°F. (27°C.) until needed. The moisture content is then about 7 percent of the "oven-dry" weight of the wood. Just before gluing, pieces 3/4 by 5 by 12 inches are cut and planed to uniform thickness and smooth, true joint surfaces. The temperature of the gluing laboratory is subject to control within the range of conditions likely to be encountered in practice and a steam-heated chamber is provided for preheating the wood when so desired. The two pieces to be joined are weighed together on a balance, glue applied to one of them with a single roll mechanical glue spreader and the two pieces with the applied glue reweighed to obtain the weight of glue spread. As a rule about 1-1/4 ounces of wet glue is applied per square foot of joint area. The second piece of wood is put in contact with the glue line at once or at the close of the time of assembly according as "open" or "closed" assembly is decided upon. At the end of the allotted time the joint is placed in a screw press under caul boards, a hydraulic pressure gage inserted, and the proper pressure applied. Usually the pressure is 100 or 200 pounds per square inch. If it falls off immediately after application by reason of "squeeze out" of glue, the pressure is readjusted at once.

As a matter of convenience joints are left under pressure for 16 to 24 hours. A few hours would be sufficient. They are then conditioned before test for 7 days in a room at 30 percent humidity at 80°F. and provided with good circulation of air. From each joint, 10 test specimens of the dimensions shown in Figure 3 are cut and torn apart in shear in the machine and shearing tool illustrated. The speed of the machine is such that the shearing blade advances at a rate of 0.0157 inch per minute. Attention is called to the

self-adjusting bearing in the upper jaw of the shearing tool, the purpose of which is to distribute the load uniformly over the upper and lower shoulders of the test specimen, even though they may not be truly parallel to each other. The part $F$ is a semicylindrical-shaped rocker having a flange that fits in a groove of corresponding shape in the upper jaw of the shearing blade. It is free to rotate around the axis of the semicylinder within limits set by means of a pin inserted in the flange of the rocker and sliding in a groove in the shearing blade. There is also an oil hole for lubricating the bearing.

For each specimen tested, notation is made of the breaking load and the estimated percentage of the glue-line area in which the wood splinters. Two or more duplicate joints are usually prepared, each one giving 10 specimens for test. The average and the minimum breaking load and the average percentage of wood failure are generally taken as the final record of the test.

Conclusions

1. The strength and character of failure of test wood joints made with animal glue are greatly influenced by the gluing conditions under which the joints are prepared.

2. The conditions that produce good joints vary with the grade of the animal glue and no one set of gluing conditions gives good joints with all grades of glue.

3. Animal glues of all grades commonly used for woodworking, when applied under conditions suitable for each glue, produce wood joints whose load at failure depends chiefly upon the strength of the wood rather than upon the grade of the glue.

4. It has not yet been shown that animal glues differ among themselves in an intrinsic property of "strength" or "adhesiveness" which is as significant of their value for woodworking purposes as the viscosity and jelly strength tests now constituting the principal bases of grade.

5. Wood joint tests are used in the inspection of casein and vegetable glues because a more refined technique for evaluating them has not yet been developed. Although a favorable wood joint test proves that the glue is capable of making strong joints, an unfavorable test may not prove the contrary.

6. Wood joint tests are well adapted to the research laboratory dealing with problems involving the technique of gluing and to the engineer in checking glue room procedure. The tests should be made in side grain gluing and the nature of the failure as well as the load at which it takes place should be considered.
Table I—Influence of Gluing Conditions on Strength and Type of Failure of Side-Grain Glued Sugar Maple Test Joints Made with Animal Glue of High Grade and Low Grade

<table>
<thead>
<tr>
<th>Glue</th>
<th>Designation</th>
<th>Temp. of room</th>
<th>Glue Conditions</th>
<th>RESULTS OF WOOD-JOINT TESTS</th>
<th>Character of Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>° F.</td>
<td>° F.</td>
<td>Temp.</td>
<td>Time</td>
</tr>
<tr>
<td>A</td>
<td></td>
<td>82</td>
<td>50</td>
<td>120</td>
<td>120</td>
</tr>
<tr>
<td></td>
<td></td>
<td>82</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>87</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>87</td>
<td>20</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>87</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>B</td>
<td></td>
<td>80</td>
<td>80</td>
<td>120</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td></td>
<td>80</td>
<td>120</td>
<td>20</td>
<td>20</td>
</tr>
</tbody>
</table>

a The 120° F. temperature is maintained in a special chamber in the gluing laboratory.
b "Light" means that the glue was applied to the wood in a comparatively thin layer, "heavy," in a comparatively thick layer.
c Time elapsing between application of the glue to the wood and application of pressure to the joint. "Open" assembly means that the two surfaces to be joined were not brought together until end of assembly time. "Closed" that they were brought together at beginning of assembly time.
d Four pairs of maple blocks were glued and 10 test specimens taken from each joint.
e Each broken test specimen was examined visually and an estimate made of the proportion of the total area of the joint in which the failure took place by splintering of the wood rather than in the glue line itself.

Table III—Influence of Gluing Conditions on Strength and Type of Failure of Side-Grain Glued Sugar Maple Test Joints Made with Vegetable Glue and Casein Glue

<table>
<thead>
<tr>
<th>Glue</th>
<th>Temp. of room</th>
<th>Consistency of glue</th>
<th>Glue spread</th>
<th>Time of assembly</th>
<th>Pressure applied</th>
<th>RESULTS OF WOOD-JOINT TESTS</th>
<th>Character of Joint</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>° F.</td>
<td></td>
<td></td>
<td>Min.</td>
<td></td>
<td>Load required to break</td>
<td>Wood failures</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Lbs./sq. in.</td>
<td>Average</td>
</tr>
<tr>
<td>Vegetable</td>
<td>80</td>
<td>Medium</td>
<td>Medium</td>
<td>15 (closed)</td>
<td>200</td>
<td>3200 Lbs./sq. in.</td>
<td>2900 Lbs./sq. in.</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Medium</td>
<td>Medium</td>
<td>35 (open)</td>
<td>200</td>
<td>2300 Lbs./sq. in.</td>
<td>600 Lbs./sq. in.</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Thin</td>
<td>Heavy</td>
<td>1½ (closed)</td>
<td>400</td>
<td>2800 Lbs./sq. in.</td>
<td>1300 Lbs./sq. in.</td>
</tr>
<tr>
<td>Casein</td>
<td>80</td>
<td>Medium</td>
<td>Medium</td>
<td>12 (closed)</td>
<td>250</td>
<td>3200 Lbs./sq. in.</td>
<td>2800 Lbs./sq. in.</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Medium</td>
<td>Medium</td>
<td>21 (open)</td>
<td>200</td>
<td>2750 Lbs./sq. in.</td>
<td>1850 Lbs./sq. in.</td>
</tr>
<tr>
<td></td>
<td>80</td>
<td>Thin</td>
<td>Heavy</td>
<td>1 (closed)</td>
<td>400</td>
<td>2450 Lbs./sq. in.</td>
<td>1350 Lbs./sq. in.</td>
</tr>
</tbody>
</table>

a Depends upon proportion of water with which dry glue is mixed; a thin consistency contains more water than a medium one.
b,c,d,f See corresponding footnotes to Table I.
d Four pairs of maple blocks were glued and 5 test specimens taken from each joint.
Table 2.--Gluing conditions that give good joints with Glue A on sugar maple

| Glue- : Room : Wood : Glue : Time of : Pres- : Load required to break : Wood | Results of joint tests |
| Glue- : Room : Wood : Glue : Time of : Pres- : Load required to break | Failure |
| ratio : ature : : : : | |
| °F. : °F. : Minutes : Pounds per square inch : Percent | |
| 1:2 : 75 : 75 : Medium : 1/2 : 200 : 3,600 : 3,133 : 37 |
| 1:2-1/4 : 70 : 70 : " : 1/2 : 200 : 4,000 : 3,585 : 72 |
| 1:2-1/4 : 90 : 90 : " : 12 : 200 : 3,000 : 2,725 : 73 |

1 Results based upon 10 test specimens cut from one pair of maple blocks glued together.
Figure 1.--Showing the appearance of the fracture in broken test specimens of four types of wood joints made with high grade and with low grade animal glue. (Each group is made up of the two halves of five specimens cut from a single wood joint.)
Figure 2.--Showing the appearance of the fracture in broken test specimens of three types of wood joints made with vegetable and casein glues. (Each group is made up of the two halves of five specimens cut from a single wood joint.)
Figure 3.--Shearing tool, test specimen, and testing machine used for the Forest Products Laboratory's glued wood joint test.