SIGNIFICANCE OF MECHANICAL WOOD-JOINT TESTS

FOR THE SELECTION OF WOODWORKING GLUES

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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,

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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.[1] Wood joint tests therefore suggest themselves as a direct method for measuring this supposedly characteristic property of glues. Thus, Sauer[2] would grade glues in accordance with a wood joint test and the viscosity of a standard solution. The British Engineering Standards Association[3] 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[4] 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[5] 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,

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[1] National Association of Glue Manufacturers, Ind. Eng. Chem., 16, 310, 1924. Alexander, "Glue and Gelatin," Chapter 12, New York, 1923. Bogue, "The Chemistry and Technology of Gelatin and Glue," Chapter 10, New York, 1922.

[2] "Kolloidchemische Technologie," edited by Liesegang, p. 882, Dresden and Leipsig, 1927. Kolloid-Z, 33, 265, 1923.

[3] First Report of the (British) Adhesives Research Committee, 1922, p. 19.

[4] U. S. Army Specification 98-14,000 C, 1923. U. S. Navy, Bureau of Construction and Repair, Specification 11D, 1928.

[5] Federal Specification, C-G-451. "Glue, Animal, Woodworking." May, 1931.

but the stress producing failure may be materially less than that required to break good joints in side 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. Hopp[7] and Gill[8] avoided the dilemma presented by wood joint tests by breaking specimens of the dried glue jelly in tension, but the preparation of the specimens was a long and tedious task. Bateman and Towne[9] showed that the strength of such glue specimens varies enormously with the relative humidity of the air. Other workers[10] 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

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[6]Rudeloff, Mitt. Materialprufungsamt Berlin-Lichterfelde West, 1918, No. 1 and 2. See also reference 8.

[7]Hopp, Ind. Eng. Chem., 12, 356, 1920.

[8]Gill, Ind. Eng. Chem., 7, 102, 1915, and 17, 297, 1925.

[9]Bateman and Towne, Ind. Eng. Chem., 15, 371, 1922.

[10]Hauseman, Ind. Eng. Chem., 9, 359, 1917; Heinemann, Chem. Ztg., 24, 871, 1900; Neumann, Kolloid-Z. 33, 356, 1923; Bechhold and Neumann, Z. angew., Chem., 37, 534, 1924; Horst, Z. angew., Chem., 37, 225, 1924; See also Reference 8.

[11]McBain and Hopkins, 2nd Report of the (British) Adhesives Research Committee, 1926, p. 62; McBain and Hopkins, J. Phys. Chem., 30, 114, 1926; McBain and Lee, J. Soc. Chem. Ind., 46, 321, 1927; McBain and Lee, Ind. Eng. Chem., 19, 1005, 1927.

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.[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 conditions. These factors govern the strength of wood joints and have been described elsewhere.[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[1] was 108 millipoises and its jelly strength

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[12]Browne and Brouse, Ind. Eng. Chem., 21, 80, 1929.

[13]Jones, Proc. Amer. Soc. Testing Materials 23, II, 583, 1923. Truax, Furn. 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[14] 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, <u>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</u>.

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.

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[14] Browne and Truax, Colloid Symposium Monograph, Vol. IV, p. 258, 1926. Weinstein, Ibid, p. 270.

Thus we find:

Under gluing conditions designated in Table 1	Glue A		Glue B	
	Average joint strength	Wood failure	Average joint strength	Wood failure
	Lbs. per sq. in.	Percent	Lbs. per sq. in.	Percent
I	3,950	55	2,950	75
II	2,500	27	3,100	84

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 classed 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 42 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 adopted[15] 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

[15] Federal Specification, C-G-456, Glue; "Casein Type, Water-Resistant." July, 1941.

unfavorable test does not prove the contrary. Before the glue can be rejected as inherently weak, it must be tried out under conditions representative 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.[16] 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 put in position 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

16 Browne and Hrubesky, Ind. Eng. Chem., 19, 215, 1927.

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 P 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

Glue	Gluing Conditions							Results of Wood-Joint Tests				Character of Joint
	Designation	Temp. of room[a]	Preheating of wood: Temp.	Preheating of wood: Time	Glue spread[b]	Time of assembly[c]	Pressure applied	Load required to break: Averaged[d]	Load required to break: Minimum	Wood failure[e]: Averaged[d]	Wood failure[e]: Minimum	
		° F.	° F.	Min.		Min.	Lbs./sq. in.[f]	Lbs./sq. in.	Lbs./sq. in.	Per cent	Per cent	
A	I	82	82	120	Medium	2 (open)	200	3950	3190	55	10	Good
	II	80	80	120	Medium	5 (open)	200	2500	1823	27	0	Chilled
	III	120	120	20	Medium	13 (open)	200	1550	212	13	0	Dried
	IV	87	87	120	Light	9 (open)	100	2750	1138	34	0	Chilled
	V	85	120	20	Heavy	1/2 (closed)	400	2350	1417	5	0	Starved
B	II	80	80	120	Medium	5 (open)	200	3100	2667	84	35	Good
	I	82	82	120	Medium	2 (open)	200	2950	2065	75	5	Good
	III	120	120	20	Medium	13 (open)	200	1700	918	4	0	Dried
	VI	83	83	120	Heavy	13 (open)	50	3200	2333	15	0	Chilled
	VII	83	120	20	Heavy	2 (closed)	400	2250	1317	5	0	Starved

[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.

[f] 14.22 lbs. per sq. in. = 1 kg. per sq. cm.

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

Glue	Gluing Conditions					Results of Wood-Joint Tests				Character of Joint
	Temp. of room	Consistency of glue[a]	Glue spread[b]	Time of assembly[c]	Pressure applied	Load required to break: Averaged[d]	Load required to break: Minimum	Wood failure[e]: Average	Wood failure[e]: Minimum	
	° F.			Min.	Lbs./sq. in.[f]	Lbs./sq. in.	Lbs./sq. in.	Per cent	Per cent	
Vegetable	80	Medium	Medium	15 (closed)	200	3200	2900	99	95	Good
	80	Medium	Medium	35 (open)	200	2300	600	6	0	Dried
	80	Thin	Heavy	1/2 (closed)	400	2300	1300	24	0	Starved
Casein	80	Medium	Medium	12 (closed)	250	3200	2800	88	50	Good
	80	Medium	Medium	15 (open)	200	2750	1850	21	10	Dried
	80	Thin	Heavy	1 (closed)	400	2450	1350	60	5	Starved

[a] Depends upon proportion of water with which dry glue is mixed; a thin consistency contains more water than a medium one.

[b,c,e,f] See corresponding footnotes to Table I.

[d] Four pairs of maple blocks were glued and 5 test specimens taken from each joint.

Z M 30193 F

Table 2.--Gluing conditions that give good joints with Glue A on sugar maple

Gluing conditions						Results of joint tests		
Glue-water ratio	Room temperature	Wood temperature	Glue spread	Time of assembly	Pressure applied	Load required to break: Average	Load required to break: Minimum	Wood failure[1]
	°F.	°F.		Minutes	Pounds per square inch	Pounds per square inch	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	80	80	"	3	200	3,950	3,567	80
1:2-1/4	80	80	"	5	200	3,750	3,478	61
1:2-1/4	90	90	"	12	200	3,000	2,725	73
1:2-1/4	90	90	"	18	200	3,750	3,570	87

[1]Results based upon 10 test specimens cut from one pair of maple blocks glued together.

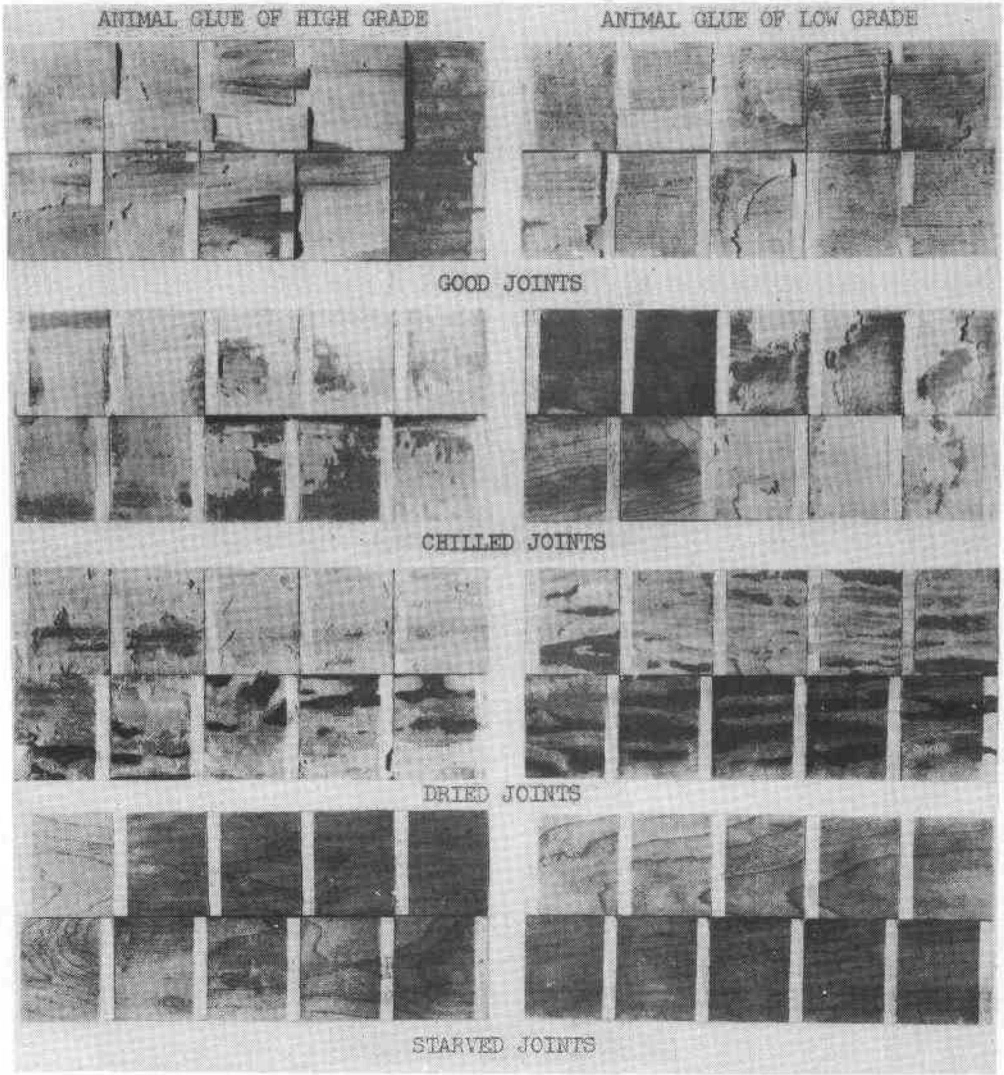


Figure 1.--Showing the appearance of the fracture in broken test specimens of four types of wood joints made with high grade and with low grade animal glue. (Each group is made up of the two halves of five specimens cut from a single wood joint.)

Z M 8630 F

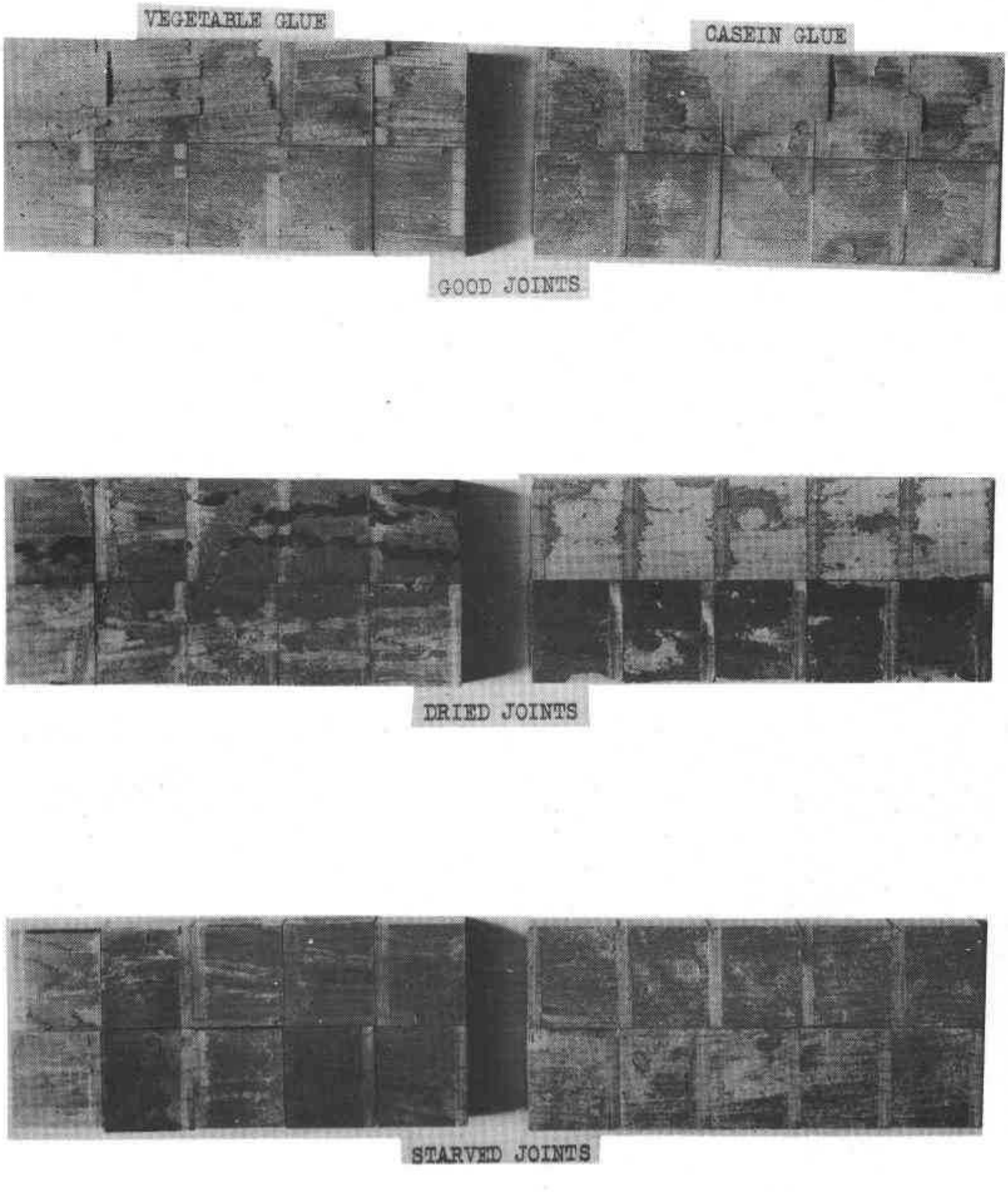
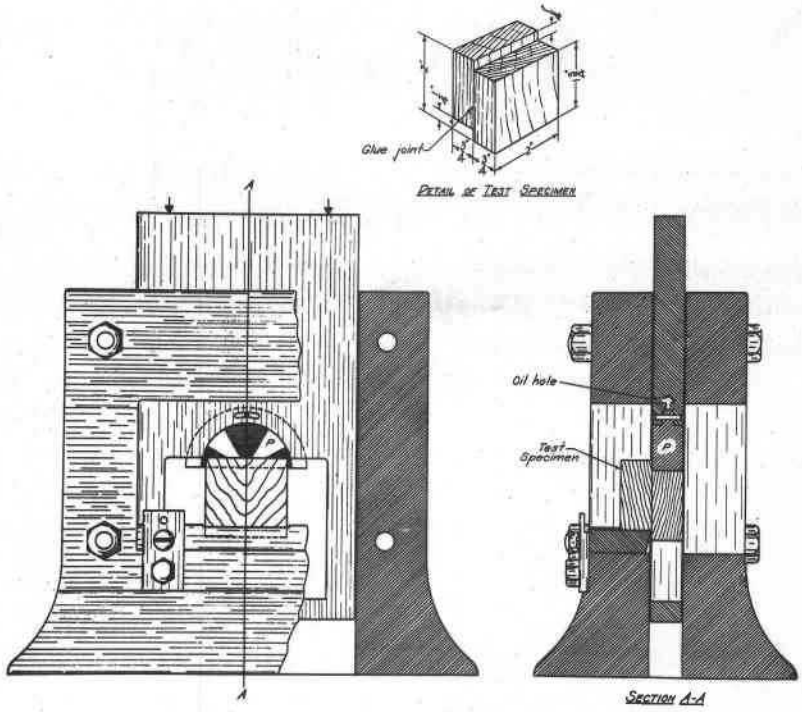


Figure 2.--Showing the appearance of the fracture in broken test specimens of three types of wood joints made with vegetable and casein glues. (Each group is made up of the two halves of five specimens cut from a single wood joint.)

Z M 8727 F



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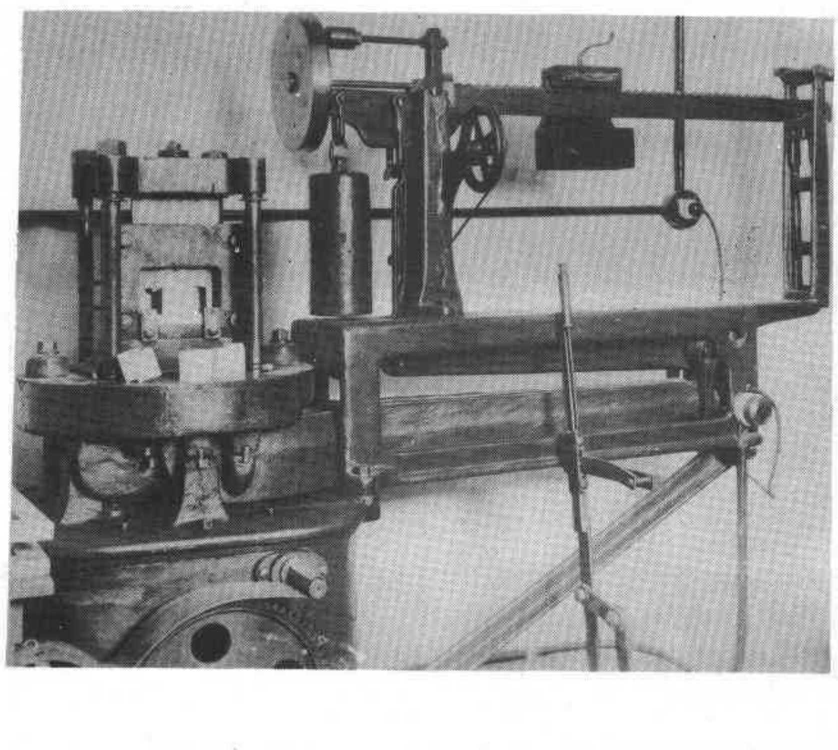

Figure 3.--Shearing tool, test specimen, and testing machine used for the Forest Products Laboratory's glued wood joint test.

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