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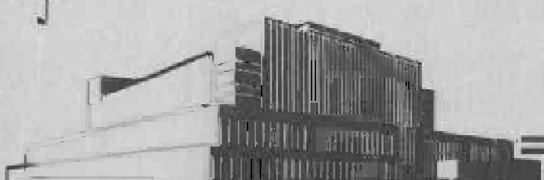
Information Reviewed and Reaffirmed

July 1961

No. 1801



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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

THE EFFECT OF VENEER THICKNESS AND GRAIN DIRECTION ON THE SHEAR STRENGTH OF PLYWOOD[1]

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Summary and Conclusions

This report presents the results of a study to determine the effect of veneer thickness on the shear strength of plywood. Each plywood panel was made from five plies of a single species and thickness of veneer. Three constructions of plywood and four veneer thicknesses were used to make up the various panels.

Veneers making up the plywood were cut from logs of the following species of wood: Douglas-fir, khaya, yellow birch, sweetgum, and yellow-poplar. For each species, except Douglas-fir, the veneers were cut to a thickness of 1/8, 1/16, 1/32, and 1/64 inch. No 1/8-inch veneers were obtained from the Douglas-fir.

A total of 1,658 tests were made for this study. Of this number, 337 panel shear, 522 block shear, and 604 tension shear tests were made on plywood.

[1] This progress report is one of a series prepared and distributed by the Forest Products Laboratory under U. S. Navy, Bureau of Aeronautics No. NBA-PO-NAer 00096 and U. S. Air Force No. USAF-PO-(33-038) 44-2700E. Original report published July 1948.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Fifty-five panel shear and 140 block shear tests were made on solid-wood specimens.

From the analysis of the data of all tests, the following conclusions can be drawn:

1. The shear strength of a plywood panel is greatly influenced by the thickness of the veneers making up the panel. The shear strength of a plywood panel, made from plies of uniform thickness of the same species, can be reasonably approximated by the general formula:

$$F_{swx} = 55\left(\frac{n-1}{t}\right) + \frac{9}{16}F_s, \text{ where } \left(\frac{n-1}{t}\right) \leq 35.$$

This formula is dependent upon the gluing and cutting techniques associated with the veneers. A departure from the methods used herein may yield different values of shear strength.

2. Plywood panels of different construction, but made by the same techniques of the same number, thickness, and species of veneers will have similar shear properties. To obtain these values from test, an apparatus must be used that will subject the panel to a condition of approximately pure shear.

3. The method used in making plywood panel shear tests may greatly affect the results obtained. An apparatus should be used that will apply the loads along the line of the edge of the part of the panel being tested.

4. Checks introduced in cutting the veneer vary with species and veneer thickness. The number of checks appear to be independent of the veneer thickness, but depth of check increases with veneer thickness.

5. The block shear test and the tensile shear test generally give shear strength values higher and lower, respectively, than those obtained from the panel shear test.

Introduction

When plywood panels are used as strength members in a structure, shear stresses may be applied to the edges of the panels as illustrated in figure 1. The strength of plywood when subjected to such stresses is an important mechanical property of the material. It has been assumed that this shear strength is at least equal to the average shear strengths, parallel to the grain, of the various species of wood of which the individual plies, or veneers, are made, with the average being weighted according to the thicknesses of the plies. Experience has shown that this average may be considerably below the actual shear strength determined by test in spite of damage done to the wood during the process of cutting it into veneers. This damage is evidenced by numerous checks on one side of each piece of veneer, leading to the common designations of "loose cut side" and "tight cut side." It is evident that such checks reduce the effective area of each ply by reducing the area of wood subjected to stress and, furthermore, that they introduce zones of stress concentrations that should further decrease the shear strength.

The high shear strength of plywood has been explained in a number of ways: (1) It has been suggested that the checks are filled with glue and that the glue line itself has considerable shear strength. (2) Examination of plywood that has failed in shear shows that some of the plies fail along the grain while others are forced to fail across the grain. The high shear strength of plywood has been attributed to a high shear strength of wood across the grain. (3) It is evident that the grain directions of adjacent plies that are originally perpendicular to each other are no longer so after shear stresses are applied. It has been suggested that the mutual restraint between two such plies may account for the high shear strength of plywood.

The purpose of the experimental work reported here is to provide a method by which the shear strength of plywood may be more accurately estimated and to throw light upon the cause of its high value. A comparison of three methods of determining shear strength is included, and some data upon the change of shear strength of plywood due to a change in moisture content are shown. A summary of the depth and distribution of checks for several of the types of veneers is also incorporated in this report.

The Plan of the Experiment

Choice of Constructions of Plywood to be Tested

Because of the suggested causes of the high shear strength of plywood, it was considered desirable to plan the experiment in such a way that the effect of glue lines between adjacent plies that have mutually perpendicular grain directions, can be separated from the effect of glue lines between adjacent plies that have parallel grain directions. For this reason, three constructions of five-ply plywood were chosen. These constructions could be more readily described if the five plies were consecutively numbered from 1 to 5, starting with one face ply. The constructions chosen were: (A) the grain directions of all plies parallel to each other; (B) the grain directions of plies 1, 2, 4, and 5 parallel to each other, but perpendicular to that of ply 3; and (C) the grain directions of plies 1, 3, and 5 parallel to each other, but perpendicular to those of plies 2 and 4. This last construction is the usual one of plywood.

To make it possible to separate the strengths of the glue lines from that of the wood, four different thicknesses, 1/8, 1/16, 1/32, and 1/64 inch, of plies were employed, with each panel being made of veneers of a single thickness. Thus the ratio of the volume of the glue to that of the wood varied from panel to panel.

Methods of Test

Series A. --Three types of tests were made for purposes of comparison, the panel shear test, the block shear test, and the tension shear test.

Experience with the panel shear test has indicated that a fairly uniform distribution of approximately pure shear is obtained throughout the test section of the specimen. Two different methods of test were employed, illustrated by figures 2 and 3. Method 1 is described in a tentative standard of the American Society for Testing Materials (2).[3] Method 2 is described in a previous report (7). The description of method 1 contains a table of dimensions of the specimens that was followed in the work described herein. In that table yellow birch falls in group I, khaya, sweetgum, and Douglas-fir in group II, and yellow-poplar in group III. The shear panels of 1/8- and 1/16-inch plies were 4 by 4 inches, and the panels of 1/32- and 1/64-inch plies were 2 by 2 inches.

Panel shear specimens were tested in a hydraulic testing machine, at a head speed of 0.005 inch per inch of length of diagonal of the specimen per minute. Extensometers were attached to the specimens as shown in figures 2 and 3, and load-deformation data were obtained for each specimen.

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[3] Figures in parentheses refer to Literature Cited at end of report.

The two methods were used because the hardwood blocks glued to the thinner specimens (made of 1/32- and 1/64-inch veneers) were not sufficiently large to accommodate the apparatus of method 2. It has previously been shown (7) that for conventional five-ply construction of 1/16-inch veneers, with face grain parallel to one of the edges, the values obtained by either method are nearly the same. All tests reported herein employing method 1 were made on panels of 1/32- or 1/64-inch veneers with face grain parallel to one of the edges.

In addition to the shear strength, the panel shear test yields a stress-strain curve from which the shear stress at the proportional limit and the modulus of rigidity may be obtained. It may be assumed that the values obtained for the stress at the proportional limit are reasonably accurate, but experience has shown that the values of the modulus of rigidity may be greater than the true values. This is probably due to the fact that an absolutely pure shear stress is rarely attained, nor is its distribution throughout the specimen perfectly uniform. More accurate values of the modulus of rigidity can be obtained by the use of the plate shear test described elsewhere (6).

The block shear test employed is that designed for measuring the shear strength parallel to the grain of small clear timber specimens and described by the U. S. Department of Agriculture (8) and by the American Society for Testing Materials (1). The specimens (fig. 4) were cut so that the planes of the glued surfaces were perpendicular both to the cross bar and to the knife of the shear tool (fig. 5). A number of identical panels were glued together to make a composite panel about 2 inches thick, from which the specimens were cut. The directions of the face grain of the individual panels were parallel to each other in the composite panel.

The tension shear test employed (fig. 6) is described by the American Society for Testing Materials (2) and no further description is required here.

Series B.--After completion of the tests of series A, a new apparatus became available for testing panel shear specimens. This apparatus was designed for testing panels subjected to combinations of tension and compression, but it is equally applicable to shear tests. It was used for a series of tests for two reasons: (1) The load could be applied along the inner edge of the hardwood block as in method 2, and (2) the apparatus was available in two sizes so that specimens made of thin veneers could be tested in a manner similar to the specimens of thicker veneers. This eliminated any possibility of variation due to change of test method.

The apparatus used in series B (figs. 7, 8, and 9) consists of four pair of machined steel sides glued to thin hardwood blocks. This combination applied the load and rigidly supports the plywood "ears." Three alining pins extending through the sides, blocks, and panel "ear" assure that the axes of each pair of roller pins are in line. The roller pins extend only to the hardwood block and thus eliminate the need for any holes near the inner edge of the block. The centers of the roller pins and rollers are over the midpoint of the inner edge of the hardwood block. The load from the testing machine is transmitted to the rollers, pins, steel plates, and hardwood blocks, which in turn exert shearing force along the inner edge of the blocks.

It should be noted that the purpose of the hardwood blocks is similar to those of series A, but need not be so thick because the heavy steel plates are glued directly to them. Actually, the blocks could be eliminated completely by gluing the plates directly to the specimen, but the method used is preferred because of ease in the fabrication of the specimen.

The specimens were tested in a hydraulic testing machine at a head speed of about one-third that used in series A. This was done to obtain more points for the load-deflection curve. The extensometers were attached as shown in figures 7 and 8.

Measurement of Checks in the Veneers

The checks in the veneers were made visible by a method employing melted paraffin and India ink, described elsewhere (5), and measured by means of a micrometer comparator. Checks less than 0.010 inch deep were not measured for veneers greater than 1/32 inch thick. The depth measured is the perpendicular distance from the face of the veneer to the deepest point of the check.

Description of Materials, Marking, and Matching

Series A

The veneers used for the panels of series A were cut from Douglas-fir, khaya, yellow birch, sweetgum, and yellow-poplar logs. These veneers were cut to four different thicknesses, 1/8, 1/16, 1/32, and 1/64 inch, except the Douglas-fir, for which the 1/8-inch thickness was omitted.

Three flitches were cut from adjacent positions in a large Douglas-fir log, and veneers of one of the three thicknesses sliced from each of the flitches. Thus the veneers of each thickness were reasonably well matched to those of the other two thicknesses. Slicing was done in the radial direction to produce quarter-sliced veneers. The back board from each flitch was used to make specimens of solid wood.

The logs of the other four species were cut into bolts 4-1/2 feet long, and some veneer of each thickness was rotary cut from each bolt. Pieces of solid wood were cut from the annular portion of the log ends corresponding to the location from which the veneers were cut. Solid pieces were cut along the radial and tangential surfaces. In order to make up a specimen for the panel shear test, these pieces were glued together, radial surface to radial surface.

The veneers were conditioned in an atmosphere controlled to a temperature of 72° F. and a relative humidity of 65 percent prior to manufacture of the plywood. The plywood was made by the hot-press method, using a phenolic-resin film glue.

One plywood panel of each of the three constructions was made from the veneers of each species and each thickness. These three panels were so matched that the corresponding plies of each panel came from adjacent positions in the log from which the veneers were cut. Further, the panels of each species were made from veneers cut from the same growth area of the log. The Douglas-fir veneers were made into panels 42 inches square, and the other veneers into panels 24 inches wide and 48 inches long.

Five panel shear specimens and approximately 10 each of block and tension shear specimens were cut from each panel. The panel shear specimens were made of a single piece of plywood, with the exception of those made of 1/64-inch veneers. These were made of two pieces of plywood glued together face to face with face-grain directions parallel. The block shear specimens were glued together in a similar manner to make up a specimen approximately 2 inches thick. The tension shear specimens were made from one piece of plywood.

The specimen number serves to identify the species, number of plies, and veneer thickness, and the number and construction of the panel from which the specimen is cut, as well as to indicate the moisture content. For example, specimen No. YB-516-7C-H1 indicates the following:

YB = yellow birch plywood
516 = five plies of 1/16-inch veneers
7C = number of panel from which the specimen was cut and letter describing its construction (page 3)
H1 = relative moisture content of the specimen ("H" for high, "I" for intermediate, and "L" for low) and the number of the individual specimen

A letter B added to the first group of symbols indicates block shear specimens, and a letter V indicates tension shear specimens. The letters SW added to the second group indicate solid-wood specimens.

The Douglas-fir specimens were divided into three groups. The first group was conditioned in an atmosphere controlled to a temperature of 80° F. and a relative humidity of 80 percent; the second group, to 75° F. and 64 percent; and the third group, to 80° F. and 30 percent. The khaya specimens were divided into two groups. The first was conditioned in an atmosphere controlled to a temperature of 80° F. and a relative humidity of 80 percent; and the second group, to 80° F. and 30 percent. Specimens of the remaining species were conditioned in an atmosphere controlled to a temperature of 80° F. and a relative humidity of 80 percent. The specimens were held in these atmospheres until a condition of substantially constant weight was obtained.

Series B

The veneers used for the panels of series B were rotary cut from two adjacent bolts of a selected yellow birch log. The veneers were cut to four thicknesses, 1/8, 1/16, 1/32, and 1/64 inch, from the same uniform growth-ring area in the heartwood of each bolt.

The veneers were conditioned, matched, and pressed into panels similar to those of series A. The 1/8- and 1/16-inch veneers were made into panels 24 inches wide and 36 inches long, and the 1/32- and 1/64-inch veneers into panels 12 inches wide and 18 inches long. Five panel shear specimens were cut from each panel.

Specimens of this series were conditioned in an atmosphere controlled to a temperature of 75° F. and a relative humidity of 64 percent. The specimens were marked in accordance with the procedure used in series A.

Presentation of Data

Table 1 presents the results of panel shear tests of the yellow birch plywood of series B. The same type of apparatus was used in all these tests. Twelve kinds of plywood were used, in three constructions, for each of which a panel was made from each of the four thicknesses of veneer. Values of (1) proportional limit in shear, (2) shear strength, and (3) shear modulus of elasticity are included in the table.

Tables 2 to 6, inclusive, present the results of panel shear tests of Douglas-fir, khaya, yellow birch, sweetgum, and yellow-poplar wood and plywood of series A. Two methods of test were employed, as described above. Values for panels of 1/32- and 1/64-inch veneers are listed only for Construction C, which had adjacent plies at right angles. Values listed include (1) percent of moisture at test, (2) specific gravity, based on ovendry weight and volume at test, (3) proportional limit in shear, (4) shear strength, and (5) shear modulus of elasticity.

The average panel shear strengths for each group of panels, as listed in tables 1 to 6, inclusive, are plotted in figure 10 against the ratio of number of glue lines divided by thickness of specimen. A total of nine curves and their appropriate formulas are shown in this figure.

Table 7 shows the relation between the observed shear strengths of panels with adjacent plies perpendicular and the values computed by use of equation (2). These values are plotted in figure 11, with the observed shear strengths being plotted as the ordinate versus the computed shear strengths as the abscissa.

Tables 8 to 12, inclusive, present the results of block shear tests of Douglas-fir, khaya, yellow birch, sweetgum, and yellow-poplar wood and plywood. The moisture content at test and the shear strength are tabulated as an average for each group. Similar values obtained from tension shear tests are included in the same tables.

Table 13 offers a comparison of the average observed shear strengths obtained by panel, block, and tension shear tests. Ratios of block shear and tension shear strengths to the comparable panel shear strengths are also shown.

The distribution and number of checks created in the veneer at the time of cutting are shown by the bar graphs of figure 12. The total number of checks in 15 representative inches of veneer are summarized for each species and thickness according to the depth of the individual checks.

Discussion and Analysis of Results

Effect of Method of Test

Previous experience (7) has indicated that there is no appreciable difference between the results obtained for conventional five-ply plywood panels in which the face grain is parallel to one of the edges, by either of the two methods used in the panel shear tests of series A. Exploratory tests, however, showed that this did not hold for all constructions. Method 1, when applied to panels of construction A or B, produced shear strengths that were much less than those of construction C. Method 2 of series A and the method of series B both gave substantially the same values for all three constructions, as is illustrated in figure 10. The data obtained by the use of method 1 of series A for constructions A and B were, therefore, considered to be in error and are not included in this report.

Sufficient data are not available to determine the cause of this error. However, the main difference between the methods that seem to give correct results and the method that gives incorrect results, is in the points of application of the loads. In the method that gives correct results, the loads are applied at the edges of the part of the plywood panel being tested; in the other method, they are applied outside of that part of the panel. It is believed that the latter position of load application introduces bending moments that disturb the distribution of the shear stress in the specimen.

Effect of Plywood Construction

When wood is subjected to pure shear, as in figure 1, it will fail along its weakest plane, which is parallel to the grain. In 0° - 90° plywood, therefore, each ply will first fail along the grain. Consequently, no increase in shear strength by cross lamination of veneers can be expected, and all of the constructions, when tested in pure shear, should produce the same values of shear strength.

It may be seen from figure 10 that the ultimate shear strengths of the plywood panels for each thickness of veneer are comparable, regardless of the type of construction. This is especially evident for the yellow birch panels of series B (fig. 10g). In this series of tests, the conventional plywood, construction C, is slightly stronger than the others for three of the four thicknesses of veneers employed, but the maximum variation is only about 10 percent. Table 1 also shows approximately the same variation of proportional limit in shear, and even less variation of the shear modulus of elasticity. However, the strength of construction A, all plies parallel, usually lies between that of B and C, an indication that this variation is probably not due to the construction, but rather to the matching of the veneers or the method of test.

It is evident from these results that explanations (2) and (3) given in the introduction do not account for the high shear strength of plywood.

Effect of Checks and Veneer Thickness

It would be expected that the checks introduced in cutting the veneer would materially reduce its shear strength because of the reduced shear area and the zone of stress concentration at the inner edge of the check. Figure 12 shows the distribution of these checks as measured from representative veneers. The number of checks appear to be independent of the thickness of veneer. Depth of checks increase with thickness of veneer, and depth of check expressed as a percentage of total thickness of veneer increases with thickness. Checks in sweetgum were appreciably deeper than the other species investigated. The above discussion indicates that plywood panels made of thick veneers would be expected to have a lower shear-strength value than panels made of thin veneers. This is confirmed by the results plotted in figure 10. In general, plywood made of 1/8-inch veneers is lower in shear strength than solid wood. The detrimental effect of the deep checks in sweetgum is apparent in figure 10, where plywood made of 1/8- and 1/16-inch veneers has considerably lower shear strength than the solid wood. It is presumed that if the checks are not too deep, they are completely filled with glue, which may nullify their effect. In addition, the glue will transversely penetrate the wood fibers, and there will be a zone of resin-impregnated wood having higher strength properties than the original veneers. When the thickness of veneer is reduced to twice the distance of penetration of the resin, no further appreciable increase in strength can be expected. The curves of figure 10 were drawn on this assumption. Thus it may be said that, up to a certain thickness of veneer, a decrease in veneer thickness will increase the shear strength of plywood because of the strength added by (1) filling or partially filling of checks with glue, (2) the resin impregnating a greater percent of the veneer thickness, (3) the greater percentage of glue film in the over-all thickness, and (4) the depth of check being a lesser percentage of the thickness of veneers. It is apparent from (1), (2), and (3) above that the amount and type of glue will greatly affect the shear strength of the plywood.

Shear Strength of Plywood

The following formula for the shear strength of plywood is consistent with the ideas presented above:

$$F_{swx} = a\left(\frac{n-1}{t}\right) + b\,F_s \qquad (1)$$

in which:

F_{swx} = shear strength of plywood with the shear stress applied parallel and perpendicular to the direction of the face grain (fig. 1).
a = a constant depending upon the kind of glue used and gluing technique employed.
n = number of plies.
t = thickness of plywood.
b = a constant depending upon the depth of the checks in the veneers.
F_s = shear strength of solid wood of the species used in the plywood.

This formula holds up to some limiting value of F_{swx} or $\left(\frac{n-1}{t}\right)$. The formulas of this type obtained from the test data are shown in figure 10, and are represented by the diagonal straight lines in the graphs of that figure. There is reasonable agreement between the formulas and the data obtained.

If the approximate shear strength of plywood made from one of the species tested for this report were required, it would be well to estimate it by the use of the corresponding equation from figure 10. A formula that applies approximately to all of the species of plywood tested was obtained. This formula is:

$$F_{swx} = 55\left(\frac{n-1}{t}\right) + \frac{9}{16}F_s \qquad (2)$$

in which the value of $\left(\frac{n-1}{t}\right)$ is limited to 35. This formula gives values too low for yellow birch and too high for sweetgum (fig. 11), but it is a reasonable approximation. It must be emphasized, however, that the constants, "a" and "b," are largely dependent upon gluing and cutting methods. The gluing and cutting techniques employed in the fabrication of the test panels are considered to be similar to those used commercially. Any radical departure from these methods, particularly in gluing, may produce panels whose shear strength differs considerably from the values calculated by the formula.

Effect of Moisture Content

It may be noted that the solid-wood-panel shear specimens (tables 2 through 6) have a moisture content considerably higher than the corresponding plywood panel when conditioned in the same atmosphere. The difference between these two moisture contents is probably due to hysteresis in the relation between the moisture content of wood and the relative humidity of the atmosphere, and to a change in the hygroscopic properties of the plywood due to the temperatures employed in its manufacture. Thus, for comparative purposes, it was necessary to correct the shear-strength values for solid wood. The shear strength of the solid-wood panels of series A have been corrected from the values of tables 2 to 6, inclusive, to a value corresponding to the average moisture content of the plywood. This adjustment is made in accordance with table 2-2 of ANC-18 (3). The ultimate shear strength of the yellow birch solid-wood panels of series B has been estimated at 2,060 pounds per square inch. This increase is to correct for the higher specific gravity (0.72) and lower moisture content (9.0 percent), corrected from the tests of the yellow birch solid-wood values of series A. Although it is recognized that the above adjustments are not strictly accurate, they do result in obtaining a value more nearly correct than if no adjustment had been made.

There are not sufficient data obtained from these tests to show the variation of plywood shear strength with changes of moisture content. A previous study (4) at the Forest Products Laboratory tentatively recommended adjusting for moisture content by use of the factors of table 2-2 of ANC-18 applying to modulus of rupture, provided adjustments are limited to moisture contents above 8 percent.

Comparison of Shear Tests

The panel shear test, as stated above, is believed to closely represent a condition of pure shear. Panel, block, and tension shear specimens were made from matched plywood and conditioned to similar moisture contents. The ultimate shear strengths obtained, as tabulated in table 13, will therefore show their comparative values.

The construction of the plywood has a definite effect on the shear strength as determined by the block shear test. In all but three cases, construction A is the weakest and construction C the strongest. This variation in strength is due to the complicated stress distribution in the specimen. Stress concentrations at the edge of the knife used in block shear tests cause failure to take place in the plane in which the knife moves. This plane is parallel to the direction of the grain in all plies of construction A, parallel to the direction of the grain of four-fifths of the plies in construction B, and parallel to the direction of the grain of three-fifths of the plies in construction C. The ratio of block shear strength to panel shear strength is likewise highest for construction C. There is considerable variation in these ratios within and among species, but the block shear strength is generally higher than the panel shear strength, and the ratios are, therefore, generally greater than unity.

The tension shear strengths are more erratic than the block shear strengths, but again the trend indicates that construction C is the strongest. The strength values are less, however, than those from panel shear tests, and the ratios are less than unity.

The block shear test or tension shear test cannot, from these data, be recommended as an accurate indication of the shear strength. The values obtained from the block shear test may be 10 or 20 percent high, and those from the tension shear test 5 to 15 percent low, when compared to the panel-shear-test results.

Table 1.--Shear-strength values for five-ply yellow birch plywood[1] as obtained from panel shear tests, series B

Construction[2]	Number of tests	Panel thickness	Proportional limit in shear	Shear strength	Shear modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
		Inch	P.s.i.	P.s.i.	1,000 p.s.i.
		1/8-inch veneer			
A	5	0.557	723	1,833	125.5
B	5	.562	812	1,701	121.8
C	5	.567	798	1,847	123.6
		1/16-inch veneer			
A	5	.290	907	2,376	144.3
B	5	.291	880	2,249	148.4
C	5	.286	885	2,356	146.5
		1/32-inch veneer			
A	5	.140	1,115	3,146	168.3
B	5	.145	1,031	3,006	156.3
C	5	.139	1,172	3,320	163.0
		1/64-inch veneer (two thicknesses)			
A	5	.145	1,158	4,061	193.8
B	6	.149	1,211	3,908	186.6
C	6	.145	1,145	4,293	189.8

[1] Average specific gravity of wood is 0.72; intermediate moisture content, approximately 9 percent.

[2] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles.

Table 2.--Shear-strength values for Douglas-fir wood and five-ply plywood as obtained from panel shear tests, series A

Construction[1]	Relative moisture content[2]	Number of tests	Panel thickness	Moisture content	Specific gravity	Proportional limit in shear	Shear strength	Shear modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			Inch	Percent		P.s.i.	P.s.i.	1,000 p.s.i.
				1/16-inch veneer				
A	H	5	0.299	11.6	0.499	766	1,430	104.4
	I	4	.297	7.6	.510	1,028	1,590	127.2
	L	5	.302	4.7	.505	1,135	1,550	131.7
B	H	5	.310	12.1	.482	764	1,610	104.4
	I	5	.300	7.8	.513	1,038	1,860	134.5
	L	5	.307	4.6	.508	1,175	1,510	135.8
C	H	5	.305	12.2	.496	693	1,620	111.1
	I	5	.300	7.6	.499	963	1,790	132.4
	L	5	.302	4.6	.527	1,171	1,700	145.1
				1/32-inch veneer				
C	H	5	.167	11.4	.559	1,425	2,130	249.2
	I	5	.159	7.5	.581	1,772	2,560	275.7
	L	5	.150	4.6	.601	2,119	2,340	307.1
				1/64-inch veneer (two thicknesses)				
C	H	5	.124	12.3	.617	1,334	2,780	291.0
	I	5	.135	9.1	.598	2,310	3,010	276.5
	L	5	.133	5.8	.594	2,362	2,920	309.3
				Solid wood				
SW	H	5	.629	15.4	.455	697	1,400	105.2
	I	5	.622	12.2	.517	949	1,840	131.5
	L	5	.613	7.2	.478	501	1,220	156.5

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

[2] H, high; I, intermediate; L, low.

Table 3.--Shear-strength values for khaya wood and five-ply plywood as obtained from panel shear tests, series A

Construction[1]	Relative moisture content[2]	Number of tests	Panel thickness	Moisture content	Specific gravity	Proportional limit in shear	Shear strength	Shear modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
			Inch	Percent		P.s.i.	P.s.i.	1,000 p.s.i.
				1/8-inch veneer				
A	H	5	0.613	12.6	0.427	490	976	59.6
	L	5	.606	6.4	.455	638	1,080	102.6
B	H	5	.621	12.8	.434	510	1,015	74.2
	L	5	.609	6.3	.442	686	1,060	79.8
C	H	5	.616	12.9	.419	494	979	62.5
	L	5	.606	6.0	.443	652	1,131	96.4
				1/16-inch veneer				
A	H	5	.306	12.0	.455	638	1,545	95.2
	L	5	.304	6.2	.444	822	1,543	101.8
B	H	5	.310	12.4	.446	624	1,404	95.4
	L	5	.304	6.4	.453	863	1,490	106.2
C	H	5	.313	12.2	.435	688	1,458	98.7
	L	5	.305	6.4	.461	835	1,608	98.8
				1/32-inch veneer				
C	H	5	.157	12.7	.478	1,235	1,977	173.0
	L	5	.156	5.8	.482	1,839	2,286	198.8
				1/64-inch veneer (two thicknesses)				
C	H	5	.160	12.8	.552	1,539	2,592	207.2
	L	5	.158	7.3	.564	2,127	2,953	272.6
				Solid wood				
SW	H	5	.631	13.6	.414	760	1,551	100.2
	L	5	.628	7.7	.420	837	1,557	138.3

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

[2] H, high; L, low.

Table 4.--Shear-strength values for yellow birch wood and plywood as obtained from panel shear tests, series A

Construction[1]	Number of tests	Panel thickness	Moisture content	Specific gravity	Proportional limit in shear	Shear strength	Shear modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Inch	Percent		P.s.i.	P.s.i.	1,000 p.s.i.
			1/8-inch veneer				
A	4	0.596	12.7	0.635	536	1,797	148.3
B	5	.594	12.4	.639	727	1,764	130.1
C	5	.598	12.7	.631	571	1,769	146.3
			1/16-inch veneer				
A	5	.298	13.4	.671	845	2,125	130.9
B	5	.300	13.5	.662	813	2,104	132.9
C	5	.299	13.6	.659	827	2,083	138.9
			1/32-inch veneer				
C	5	.148	12.5	.704	1,436	3,174	258.1
			1/64-inch veneer (two thicknesses)				
C	5	.153	12.3	.724	1,784	3,570	273.0
			Solid wood				
SW	9	.325	13.0	.640	1,367	1,791	237.2

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

Table 5.--Shear-strength values for sweetgum wood and five-ply plywood as obtained from panel shear tests, series A

Construction[1]	Number of tests	Panel thickness	Moisture content	Specific gravity	Proportional limit in shear	Shear strength	Shear modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Inch	Percent		P.s.i.	P.s.i.	1,000 p.s.i.
			1/8-inch veneer				
A	5	0.577	11.2	0.575	418	1,039	82.7
B	5	.582	11.2	.589	472	1,109	81.6
C	5	.590	11.9	.565	509	1,201	86.6
			1/16-inch veneer				
A	5	.297	12.3	.599	623	1,595	98.9
B	5	.296	12.2	.584	698	1,608	92.2
C	5	.297	12.7	.572	648	1,515	99.0
			1/32-inch veneer				
C	5	.153	12.8	.583	1,222	2,154	152.5
			1/64-inch veneer (two thicknesses)				
C	4	.156	13.2	.621	1,005	2,629	225.1
			Solid wood				
SW	9	.324	16.8	.646	983	1,789	216.9

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

Table 6.--Shear-strength values for yellow-poplar wood and five-ply plywood as obtained from panel shear tests, series A

Construction[1]	Number of tests	Panel thickness	Moisture content	Specific gravity	Proportional limit in shear	Shear strength	Shear modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
		Inch	Percent		P.s.i.	P.s.i.	1,000 p.s.i.
				1/8-inch veneer			
A	5	0.590	10.1	0.432	612	1,110	81.1
B	5	.578	10.3	.432	641	1,131	82.9
C	5	.590	11.3	.419	497	1,092	80.1
				1/16-inch veneer			
A	5	.300	11.0	.465	703	1,530	92.1
B	5	.302	10.6	.466	750	1,524	103.9
C	5	.303	10.9	.464	734	1,578	98.1
				1/32-inch veneer			
C	5	.147	10.3	.523	1,127	2,103	211.6
				1/64-inch veneer (two thicknesses)			
C	5	.147	12.1	.562	1,295	2,270	204.5
				Solid wood			
SW	10	.309	17.4	.356	505	958	121.4

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

Table 7.--Comparison of computed and observed values of shear strength of plywood, tested in panel shear

Species	Moisture content[1]	Number of plies (n)	Thickness (t)	Shear strength of solid wood (F_s)	Plywood shear strength: Theoretical (F_{swx})	Plywood shear strength: Observed ($F_{s\ obs}$)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Percent		Inch	P.s.i.	P.s.i.	P.s.i.
			Series A			
Douglas-fir	11.9	5	0.305	1,490	1,559	1,620
		5	.167		2,158	2,130
		10	.124		2,763	2,780
	7.9	5	.300	1,490	1,569	1,790
		5	.159		2,223	2,560
		10	.135		2,763	3,010
	4.9	5	.302	1,490	1,564	1,700
		5	.150		2,305	2,340
		10	.133		2,763	2,920
Khaya	12.6	5	.616	1,555	1,232	979
		5	.313		1,579	1,458
		5	.157		2,276	1,977
		10	.160		2,800	2,592
	6.4	5	.606	1,555	1,238	1,131
		5	.305		1,596	1,608
		5	.152		2,320	2,286
		10	.158		2,800	2,953
Yellow birch	12.9	5	.598	[2]1,800	1,380	1,769
		5	.299		1,748	2,083
		5	.148		2,497	3,174
		10	.153		2,937	3,570
Sweetgum	12.2	5	.590	[2]2,095	1,552	1,201
		5	.297		1,914	1,515
		5	.153		2,618	2,154
		10	.156		3,103	2,629
Yellow-poplar	10.8	5	.590	[2]1,185	1,040	1,092
		5	.303		1,392	1,578
		5	.147		2,160	2,103
		10	.147		2,591	2,270
			Series B			
Yellow birch	9.0	5	.567	2,060	1,547	1,847
		5	.286		1,929	2,356
		5	.139		2,742	3,320
		10	.145		3,084	4,293

[1] Moisture content of plywood is average as shown in figure 10.

[2] Corrected to moisture content of plywood.

Table 8.--Shear-strength values for Douglas-fir wood and plywood as obtained from block shear test, and for Douglas-fir plywood as obtained from tension shear tests

Construction[1]	Relative moisture content[2]	Block shear: Number of tests	Block shear: Moisture content	Block shear: Shear strength	Tension shear: Number of tests	Tension shear: Moisture content	Tension shear: Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Percent	P.s.i.		Percent	P.s.i.
			1/16-inch veneer and matched solid wood				
A	H	6	12.6	1,356	4	11.8	982
	I	7	7.8	1,515	4	7.4	1,071
	L	7	4.6	1,255	4	5.4	1,242
B	H	6	12.6	1,608	4	11.5	1,221
	I	6	8.2	1,700	3	7.6	1,294
	L	4	4.8	1,469	4	5.1	1,286
C	H	4	12.5	1,646	4	11.2	1,201
	L	4	5.0	1,863	4	5.1	1,380
SW	H	10	15.8	1,253	......	....	....
	I	10	11.4	1,414	......	....	....
	L	10	6.4	1,428	......	....	....
			1/32-inch veneer and matched solid wood				
A	H	7	12.8	1,798	4	11.8	1,418
	I	6	8.0	1,627	5	7.6	1,103
	L	6	4.7	1,564	4	4.7	1,608
B	H	6	12.6	2,028	4	10.9	1,641
	I	5	8.0	2,256	6	7.1	1,577
	L	3	4.7	2,299	4	6.6	1,598
C	H	5	12.3	2,365	4	11.6	1,864
	I	5	8.1	2,759	6	7.4	1,908
	L	5	4.9	2,544	4	5.8	1,756
SW	H	10	16.0	1,386	......	....	....
	I	10	11.9	1,482	......	....	....
	L	10	6.3	1,661	......	....	....

Table 8.--Shear-strength values for Douglas-fir wood and plywood as obtained from block shear test, and for Douglas-fir plywood as obtained from tension shear tests (Continued)

Construction[1]	Relative moisture content[2]	Block shear			Tension shear		
		Number of tests	Moisture content	Shear strength	Number of tests	Moisture content	Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Percent	P.s.i.		Percent	P.s.i.
		1/64-inch veneer and matched solid wood					
A	H	2	12.8	2,091	4	10.8	1,640
	I	2	9.6	2,520	4	6.4	1,397
	L	2	5.1	1,956	4	6.0	1,708
B	H	3	12.1	2,436	4	11.8	1,842
	I	2	9.6	2,255	4	6.8	1,974
	L	2	6.0	2,581	4	5.3	2,125
C	H	2	13.0	2,464	4	11.0	756
	I	2	9.8	2,921	4	7.6	1,884
	L	2	6.0	3,033	4	5.5	2,239
SW	H	10	16.4	1,252	......	....	....
	I	10	12.0	1,385	......	....	....
	L	10	6.4	1,364	......	....	....

[1]A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

[2]H, high; I, intermediate; L, low.

(Sheet 2 of 2)

Table 9.--Shear-strength values for khaya wood and plywood as obtained from block shear tests, and khaya plywood as obtained from tension shear tests

Construction[1]	Relative moisture content[2]	Block shear: Number of tests	Block shear: Moisture content	Block shear: Shear strength	Tension shear: Number of tests	Tension shear: Moisture content	Tension shear: Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Percent	P.s.i.		Percent	P.s.i.
			1/8-inch veneer				
A	H	10	13.2	1,096	10	12.5	1,023
	L	10	6.4	1,188	10	6.4	833
B	H	10	12.9	1,181	10	12.6	845
	L	10	5.8	1,247	10	6.4	830
C	H	10	13.5	1,137	10	12.8	979
	L	10	7.1	1,481	10	6.4	933
			1/16-inch veneer				
A	H	10	12.3	1,293	10	12.3	1,345
	L	10	10.7	1,523	10	6.3	1,084
B	H	10	12.3	1,521	8	11.9	1,486
	L	10	7.1	1,509	8	6.3	1,282
C	H	10	12.0	1,743	8	12.8	1,414
	L	10	6.8	1,696	8	6.1	1,378
			1/32-inch veneer				
A	H	8	13.0	1,500	10	12.3	1,495
	L	8	7.3	1,639	10	6.4	1,498
B	H	8	12.5	1,895	10	12.4	1,750
	L	8	6.8	1,745	10	6.1	1,752
C	H	8	13.0	2,119	10	11.9	1,845
	L	8	7.0	2,267	10	6.5	1,831

Table 9.--Shear-strength values for khaya wood and plywood as obtained from block shear tests, and khaya plywood as obtained from tension shear tests (Continued)

Construction[1]	Relative moisture content[2]	Block shear: Number of tests	Block shear: Moisture content	Block shear: Shear strength	Tension shear: Number of tests	Tension shear: Moisture content	Tension shear: Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
			Percent	P.s.i.		Percent	P.s.i.
			1/64-inch veneer				
A	H	......	....	....	9	12.6	1,775
	L	......	....	....	9	7.0	1,669
B	H	......	....	....	9	12.4	2,074
	L	......	....	....	9	6.4	1,897
C	H	......	....	....	9	12.4	1,927
	L	......	....	....	9	7.0	1,842
			Solid wood				
SW	H	10	15.1	1,253	......	....	....
	L	10	7.6	1,358	......	....	....

[1]A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

[2]H, high; L, low.

Table 10.--Shear-strength values for yellow birch wood and plywood as obtained from block shear tests, and yellow birch plywood as obtained from tension shear tests

Construction[1]	Block shear			Tension shear		
	Number of tests	Moisture content	Shear strength	Number of tests	Moisture content	Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Percent	P.s.i.		Percent	P.s.i.
			1/8-inch veneer			
A	10	12.6	1,785	10	12.6	1,720
B	10	11.8	1,934	10	12.4	1,604
C	10	12.3	2,128	10	12.6	1,695
			1/16-inch veneer			
A	5	12.5	1,833	10	12.6	2,138
B	5	12.5	2,213	9	12.4	2,139
C	5	11.9	2,518	10	12.6	2,223
			1/32-inch veneer			
A	10	12.0	2,307	10	12.2	2,123
B	10	12.0	2,891	10	11.9	2,324
C	10	11.6	3,674	10	12.0	2,727
			1/64-inch veneer			
A	....	....	....	10	11.5	2,512
B	....	....	....	10	12.0	2,944
C	....	....	....	10	12.0	3,090
			Solid wood			
SW	10	15.5	1,911	....	....	....

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

Table 11.--Shear-strength values for sweetgum wood and plywood as obtained from block shear tests, and sweetgum plywood as obtained from tension shear tests

Construction[1]	Block shear			Tension shear		
	Number of tests	Moisture content	Shear strength	Number of tests	Moisture content	Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Percent	P.s.i.		Percent	P.s.i.
			1/8-inch veneer			
A	10	12.3	1,278	5	12.6	1,065
B	10	12.6	1,408	5	13.2	1,103
C	10	12.2	1,539	5	12.3	1,144
			1/16-inch veneer			
A	10	11.9	1,593	10	11.8	1,496
B	10	11.7	1,855	7	11.9	1,569
C	10	11.5	2,065	7	11.9	1,637
			1/32-inch veneer			
A	8	12.3	1,846	8	12.2	1,731
B	8	12.0	2,129	8	12.5	1,849
C	8	12.2	2,740	8	13.2	1,898
			1/64-inch veneer			
A	....	....	....	10	11.4	1,945
B	....	....	....	10	11.2	2,333
C	....	....	....	10	10.7	2,437
			Solid wood			
SW	10	18.5	1,525	....	....	....

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

Table 12.--Shear-strength values for yellow-poplar wood and plywood as obtained from block shear tests, and yellow-poplar plywood as obtained from tension shear tests

Construction[1]	Block shear			Tension shear		
	Number of tests	Moisture content	Shear strength	Number of tests	Moisture content	Shear strength
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		Percent	P.s.i.		Percent	P.s.i.
			1/8-inch veneer			
A	10	12.6	1,086	10	11.8	942
B	10	12.6	1,184	10	11.6	862
C	10	13.2	1,322	10	11.9	1,040
			1/16-inch veneer			
A	10	13.4	1,345	10	11.9	1,427
B	10	13.0	1,423	10	12.2	1,460
C	10	13.0	1,701	8	13.1	1,552
			1/32-inch veneer			
A	8	12.9	1,602	10	11.4	1,778
B	8	12.4	1,836	10	10.7	1,800
C	8	12.7	2,281	10	11.4	1,968
			1/64-inch veneer			
A	....	....	....	8	11.0	1,867
B	....	....	....	8	11.1	2,062
C	....	....	....	8	10.9	2,051
			Solid wood			
SW	10	18.5	960	....	....	....

[1] A, all plies parallel; B, four parallel plies, one perpendicular ply; C, adjacent plies at right angles; SW, solid wood.

Table 13.--Comparison of average observed shear strengths of plywood panels tested in panel, block, and tension shear

Veneer thickness (inch)	1/8			1/16			1/32			1/64			1/8			1/16			1/32	1/64
Construction[1]	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	C	C
Type of test	Shear strength (pounds per square inch)												Ratio of shear strength to corresponding panel shear strength							
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)
Douglas-fir (high moisture content)																				
Panel shear				1,430	1,610	1,620			2,130			2,780				1.00	1.00	1.00	1.00	1.00
Block shear				1,356	1,608	1,646	1,798	2,028	2,365	2,091	2,436	2,464				.95	1.00	1.02	1.11	.89
Tension shear				982	1,221	1,201	1,481	1,641	1,864	1,640	1,842	[2]756				.69	.76	.74	.88	
Douglas-fir (intermediate moisture content)																				
Panel shear				1,590	1,860	1,790			2,560			3,010				1.00	1.00	1.00	1.00	1.00
Block shear				1,515	1,700		1,627	2,256	2,759	2,520	2,255	2,921				.95	.91		1.08	.97
Tension shear				1,071	1,294		1,103	1,577	1,908	1,397	1,974	1,884				.67	.70		.75	.63
Douglas-fir (low moisture content)																				
Panel shear				1,550	1,510	1,700			2,340			2,920				1.00	1.00	1.00	1.00	1.00
Block shear				1,255	1,469	1,863	1,564	2,299	2,544	1,956	2,581	3,033				.81	.97	1.10	1.09	1.04
Tension shear				1,242	1,286	1,380	1,608	1,598	1,895	1,708	2,125	2,239				.80	.85	.81	.81	.77
Khaya (high moisture content)																				
Panel shear	976	1,015	979	1,545	1,404	1,458			1,977			2,592	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Block shear	1,096	1,181	1,137	1,293	1,521	1,743	1,500	1,895	2,119				1.12	1.16	1.16	.84	1.08	1.20	1.07	
Tension shear	1,023	845	979	1,345	1,486	1,414	1,495	1,750	1,845	1,775	2,074	1,927	1.05	.83	1.00	.87	1.06	.97	.93	.74
Khaya (low moisture content)																				
Panel shear	1,080	1,060	1,131	1,543	1,490	1,608			2,286			2,953	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Block shear	1,188	1,247	1,481	1,523	1,509	1,696	1,639	1,745	2,267				1.10	1.18	1.31	.99	1.01	1.05	.99	
Tension shear	833	830	933	1,084	1,282	1,378	1,498	1,752	1,831	1,669	1,897	1,842	.77	.78	.82	.70	.86	.86	.80	.62
Yellow birch (high moisture content)																				
Panel shear	1,797	1,764	1,769	2,125	2,104	2,083			3,174			3,570	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Block shear	1,785	1,934	2,128	1,833	2,213	2,518	2,307	2,691	3,674				.99	1.10	1.20	.86	1.05	1.21	1.16	
Tension shear	1,720	1,604	1,695	2,138	2,139	2,223	2,123	2,324	2,727	2,512	2,944	3,090	.96	.91	.96	1.01	1.02	1.07	.86	.87
Sweetgum (high moisture content)																				
Panel shear	1,039	1,109	1,201	1,595	1,608	1,515			2,154			2,629	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Block shear	1,278	1,408	1,539	1,593	1,855	2,065	1,846	2,129	2,740				1.23	1.27	1.28	1.00	1.15	1.36	1.27	
Tension shear	1,065	1,103	1,144	1,496	1,569	1,637	1,731	1,849	1,898	1,945	2,333	2,437	1.03	1.00	.95	.94	.98	1.08	.88	.93
Yellow-poplar (high moisture content)																				
Panel shear	1,110	1,131	1,092	1,530	1,524	1,578			2,103			2,270	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Block shear	1,086	1,184	1,322	1,345	1,423	1,701	1,602	1,836	2,281				.98	1.05	1.21	.88	.93	1.08	1.09	
Tension shear	942	862	1,040	1,427	1,460	1,552	1,778	1,800	1,968	1,867	2,062	2,051	.85	.76	.95	.93	.96	.98	.94	.90
Average (Block shear strength / Panel shear strength)													1.08	1.15	1.23	.90	1.01	1.15	1.11	.97
Average (Tension shear strength / Panel shear strength)													.93	.86	.94	.83	.90	.93	.86	.78

[1]A, all plies parallel; B, four perpendicular plies, one parallel ply; C, adjacent plies at right angles.
[2]Value not used in computing ratios.

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Figure 1.--Plywood panel subjected to uniformly distributed edgewise shear stresses.

Z M 75330 F

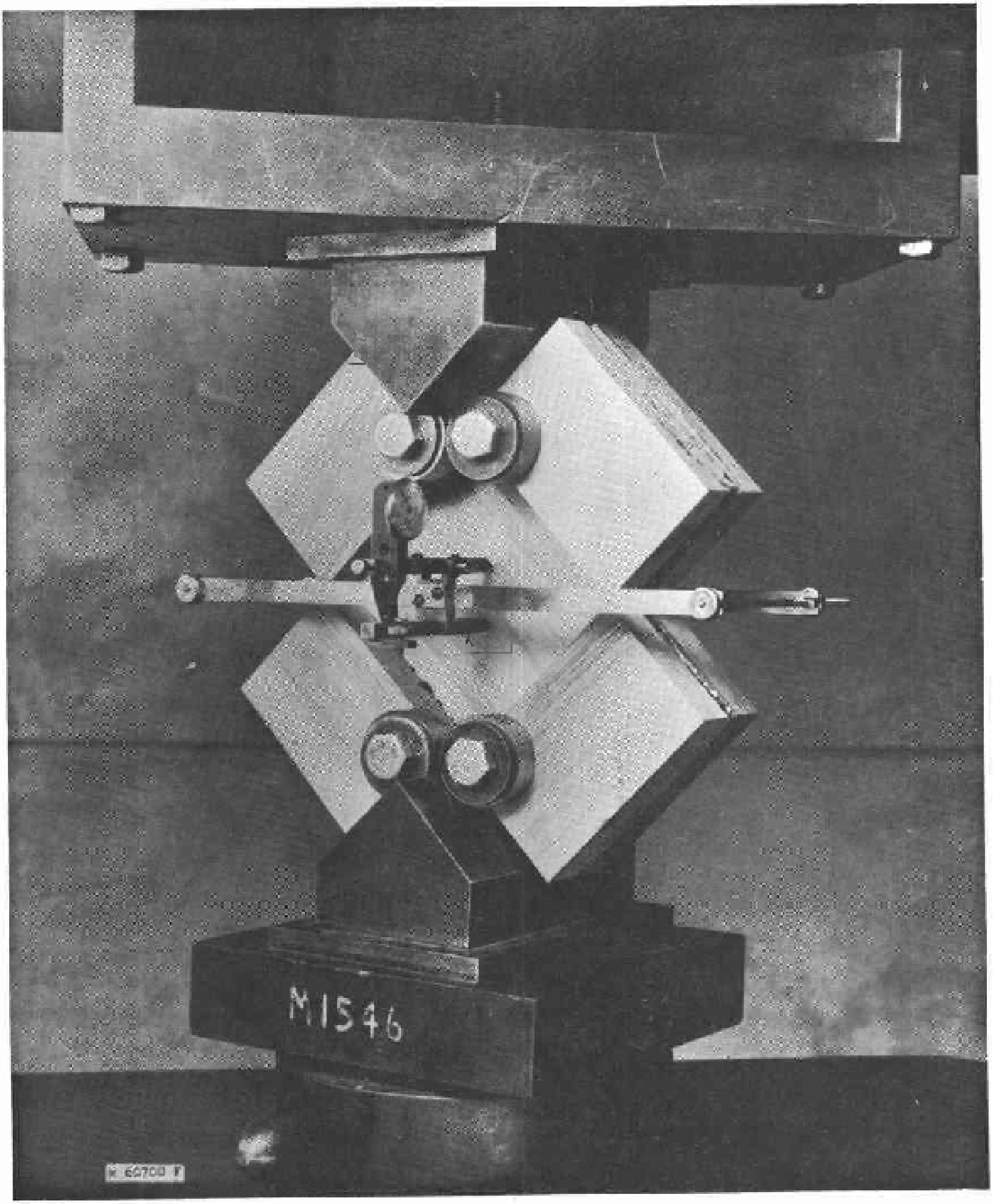


Figure 2.--Type of specimen and apparatus used in method 1 of series A.

Z M 78386 F

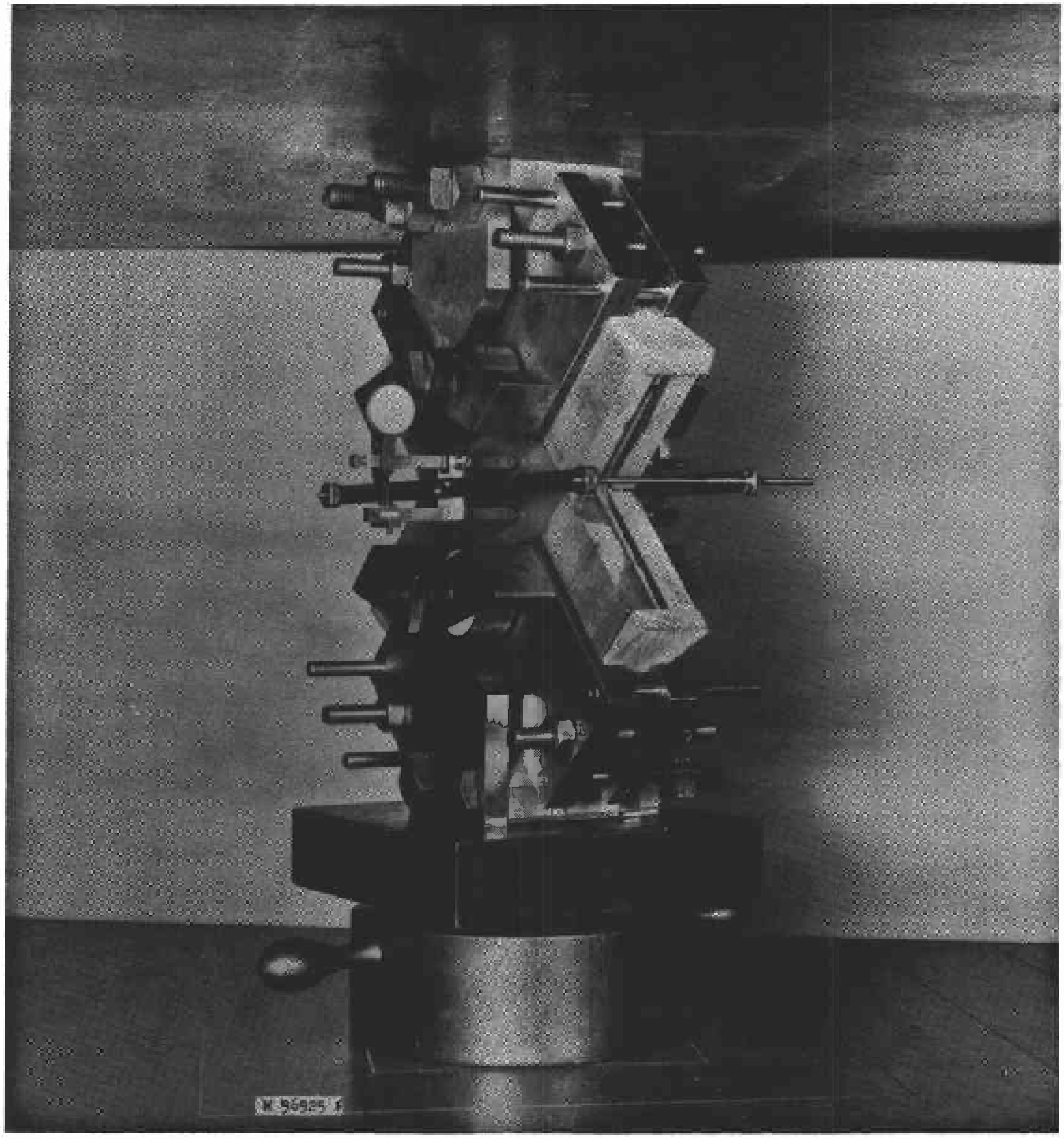


Figure 3.--Type of specimen and apparatus used in method 2 of series A.

Z M 78387 F

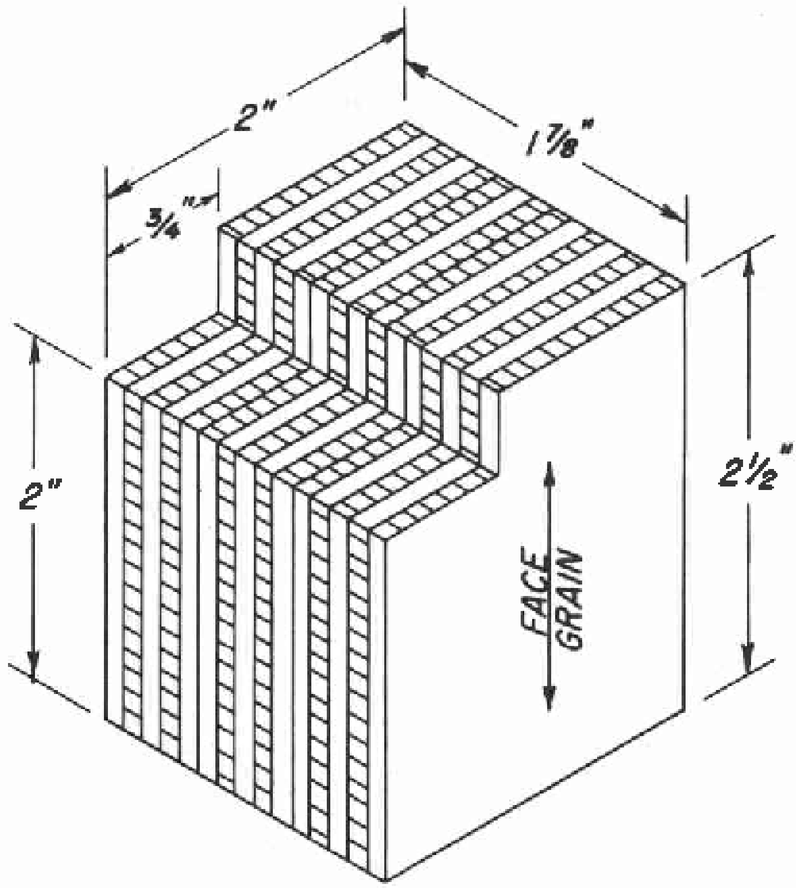
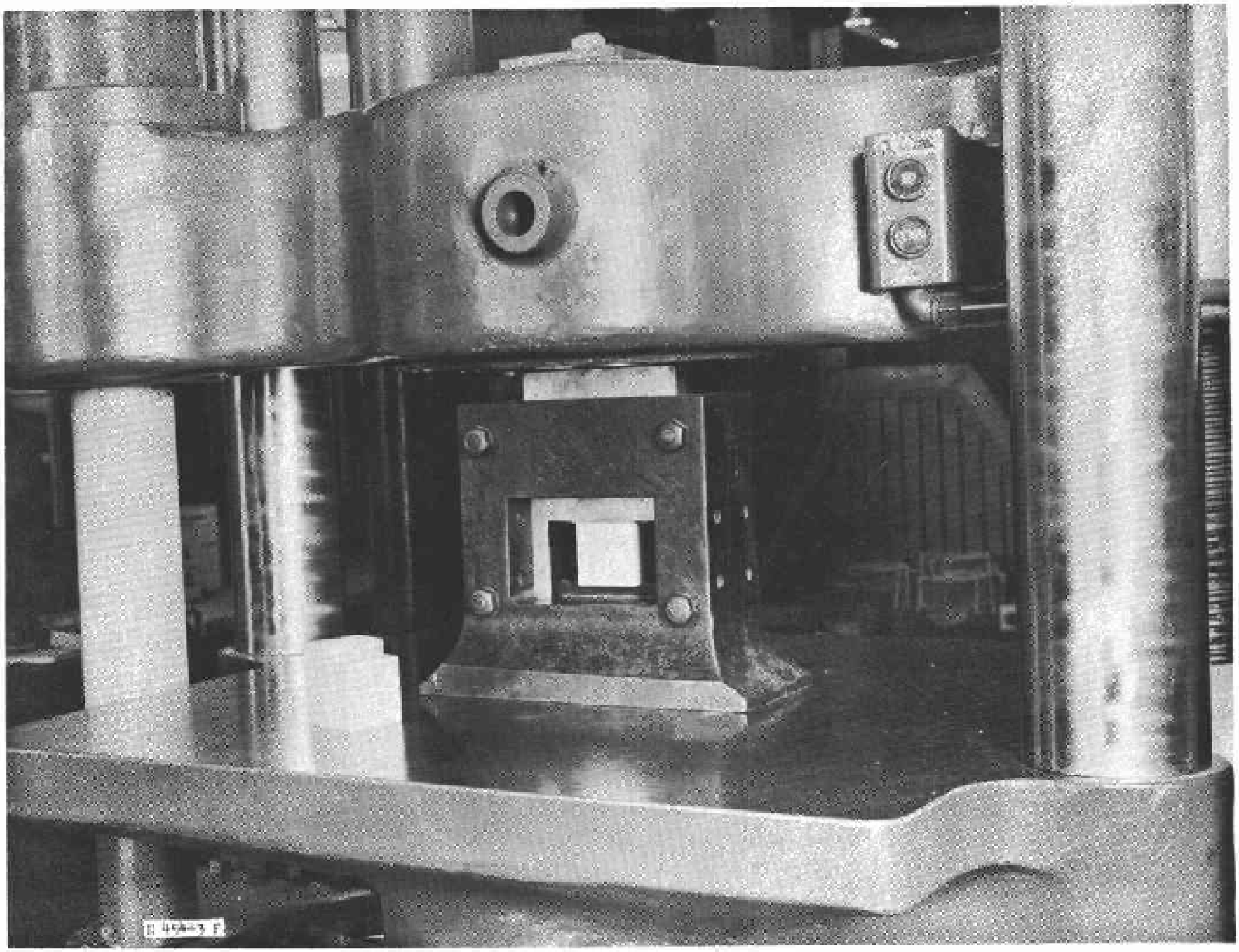


Figure 4.--Representative plywood block shear specimen, made of three thicknesses of plywood of 1/8-inch veneers.

Z M 78331 F



Z M 78388 F

Figure 5.--Standard shear tool used to test block shear specimens.

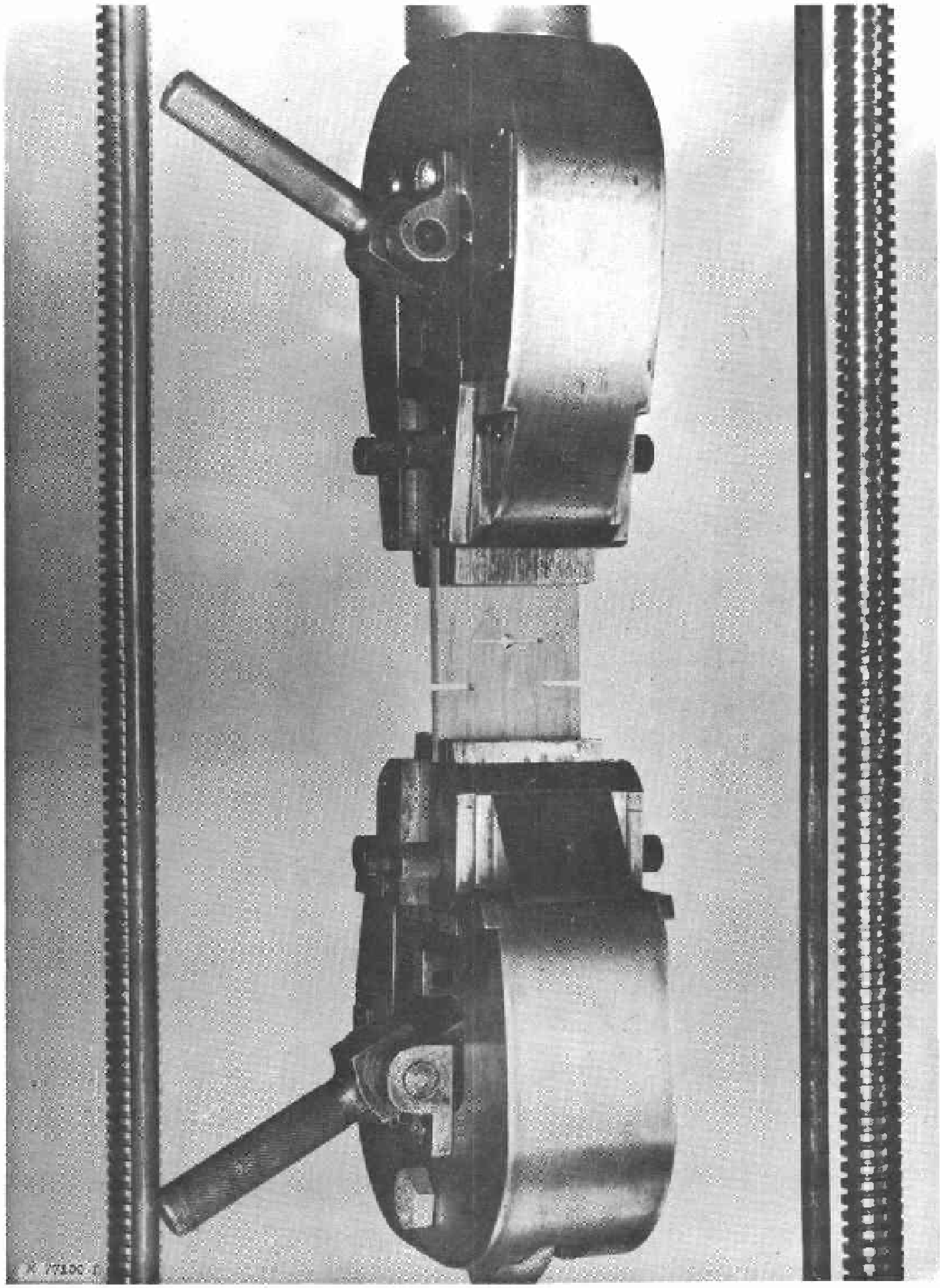


Figure 6.--Standard tension set-up used to test tension shear specimens.

Z M 78389 F

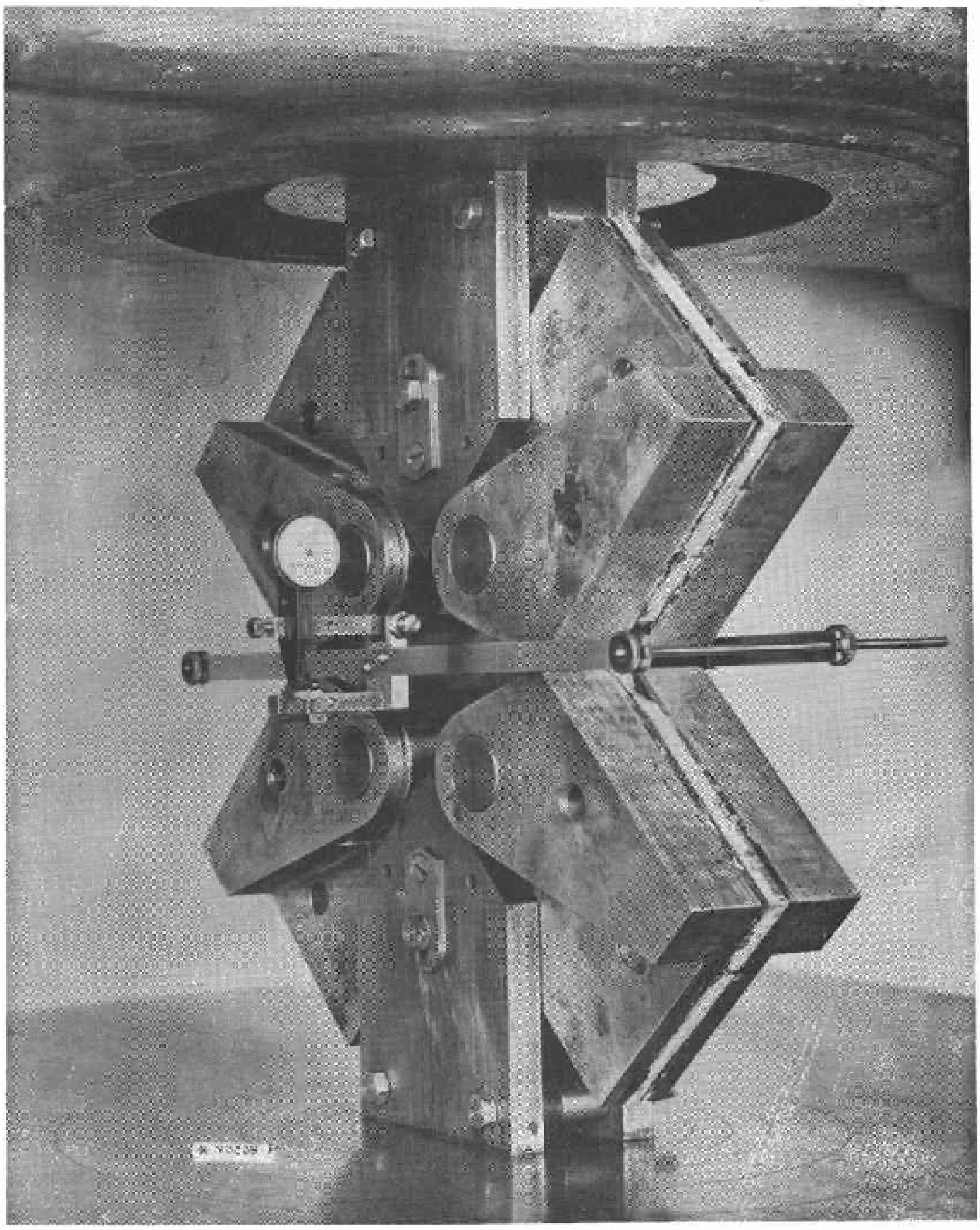


Figure 7.--Type of specimen and apparatus used for plywood 5/16 inch in thickness or more in series B.

Z M 78390 F

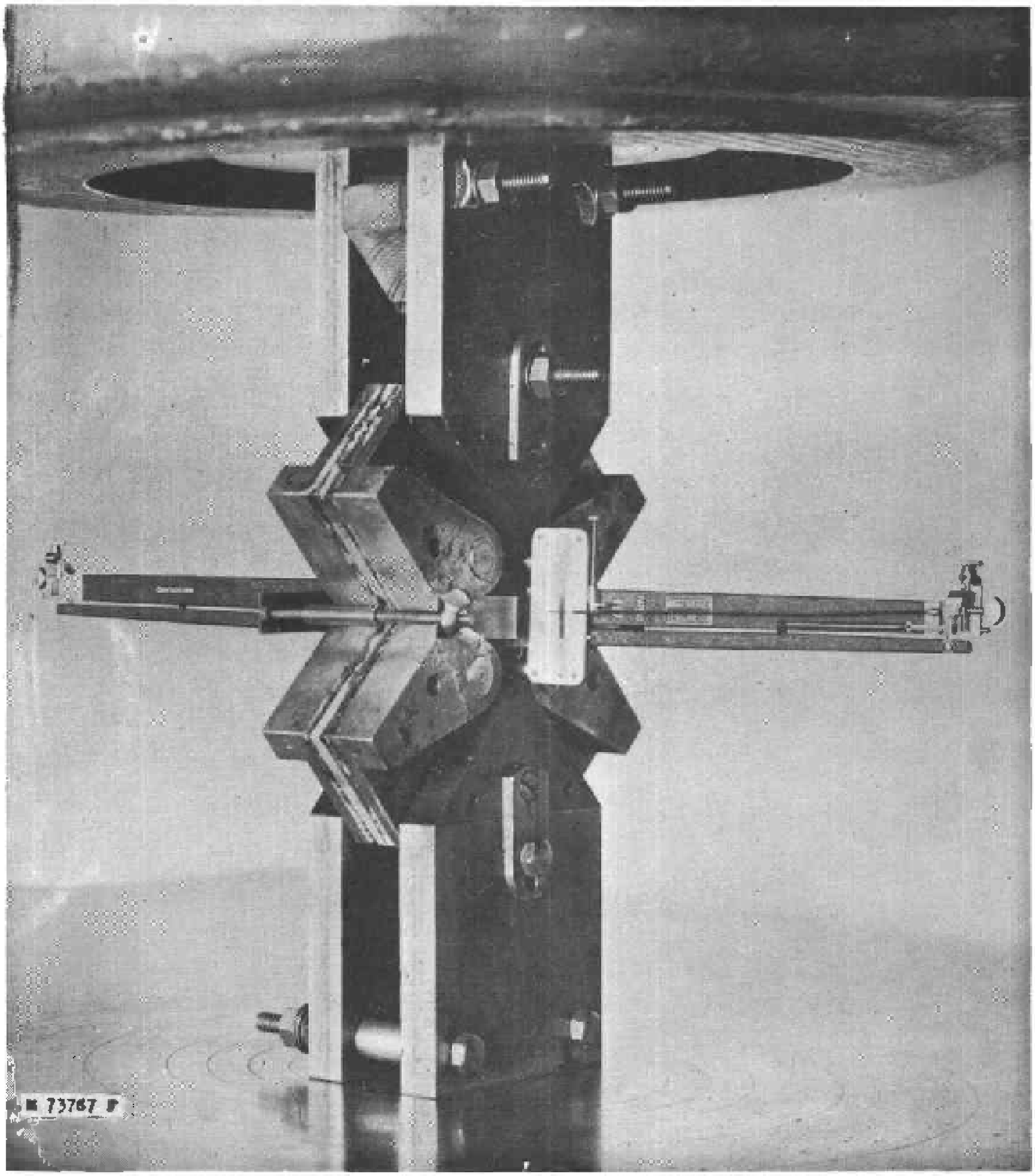


Figure 8.--Type of specimen and apparatus used for plywood under 5/16 inch in thickness in series B.

Z M 78391 F

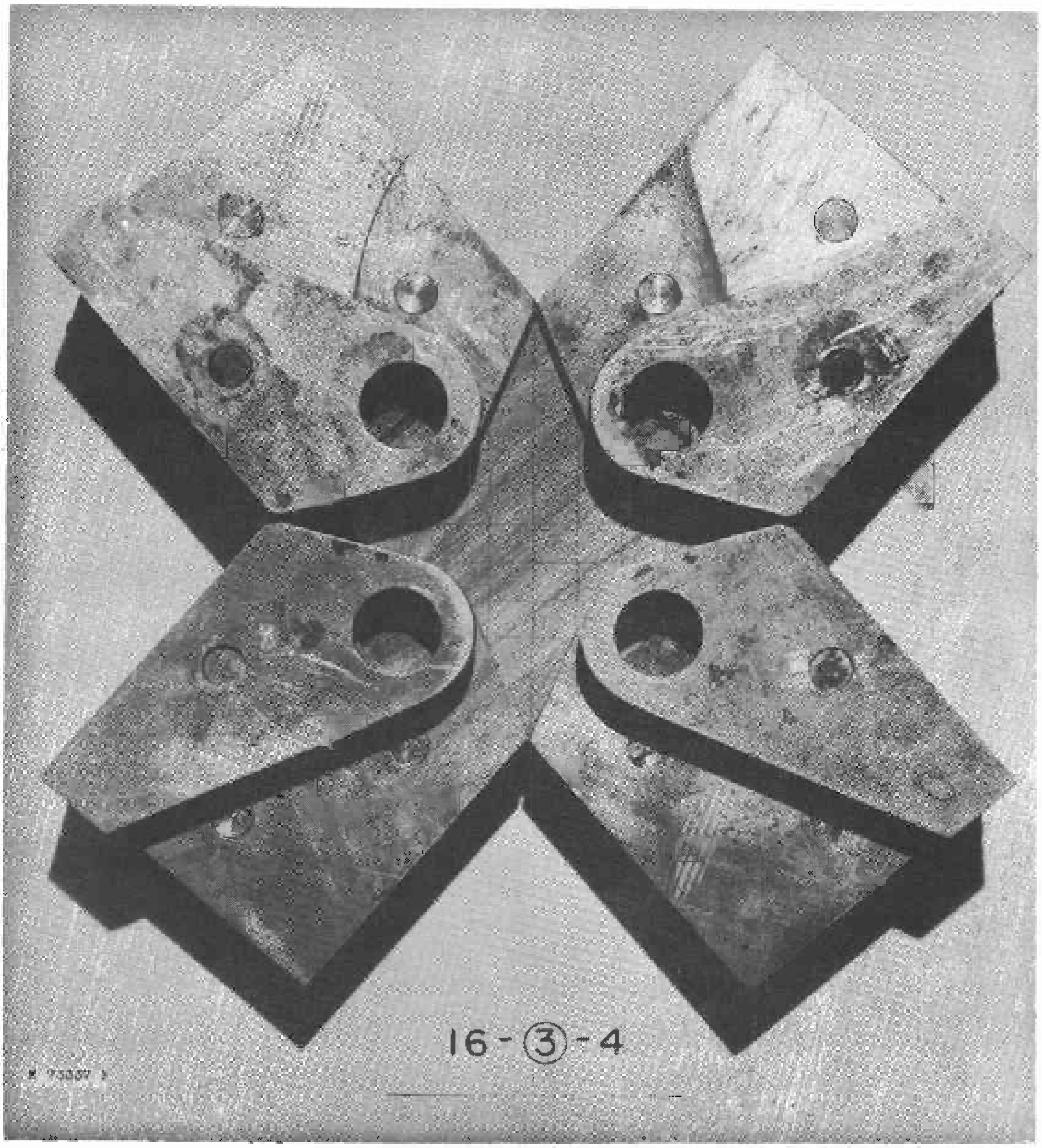


Figure 9.--Side view of a failed shear panel used in series B.
Z M 78392 F

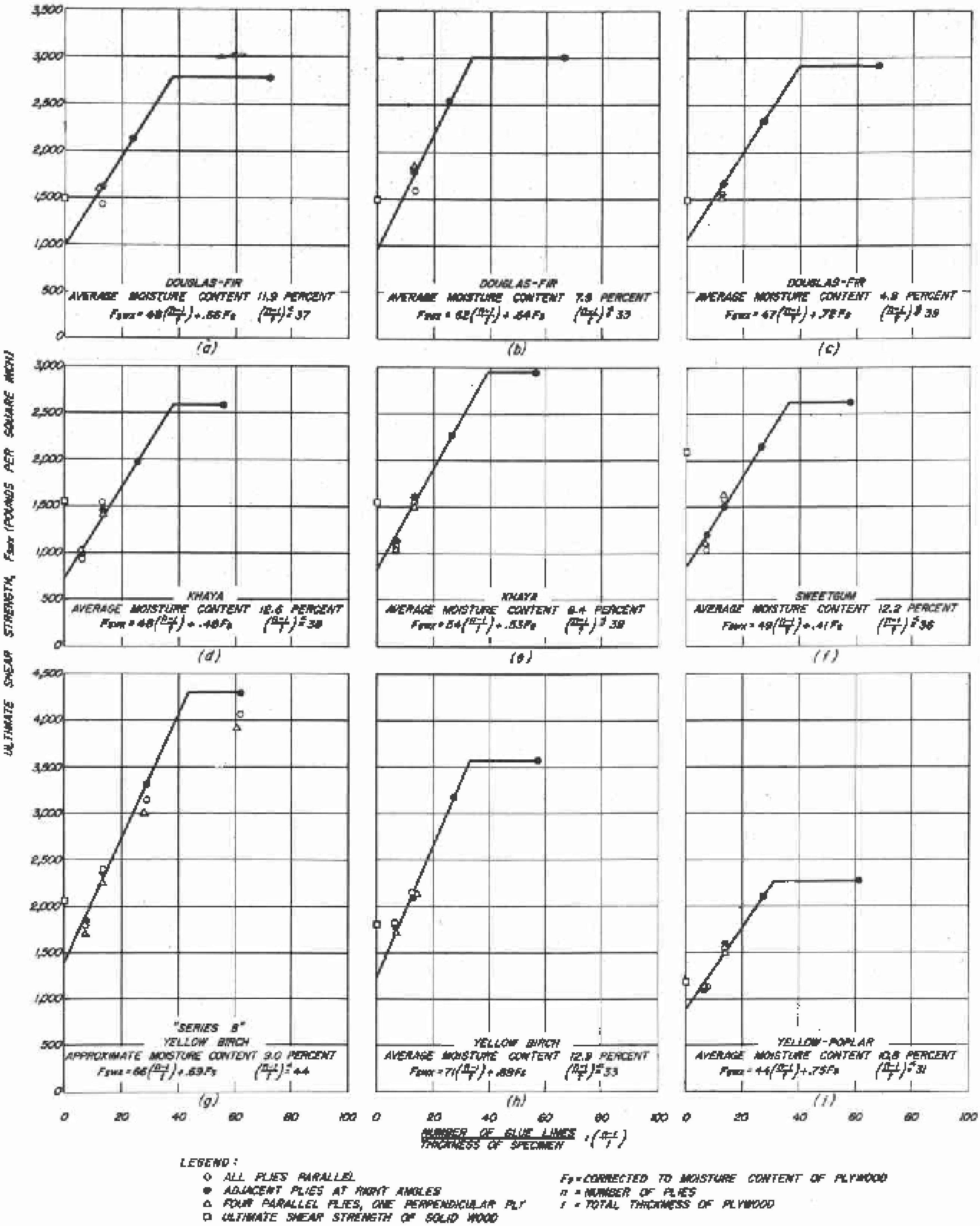


Figure 10.--Variation of ultimate shear strength with the ratio, $\frac{\text{number of plies minus one}}{\text{thickness of specimen}}$, for various species at different moisture contents.

2 M 78332 F

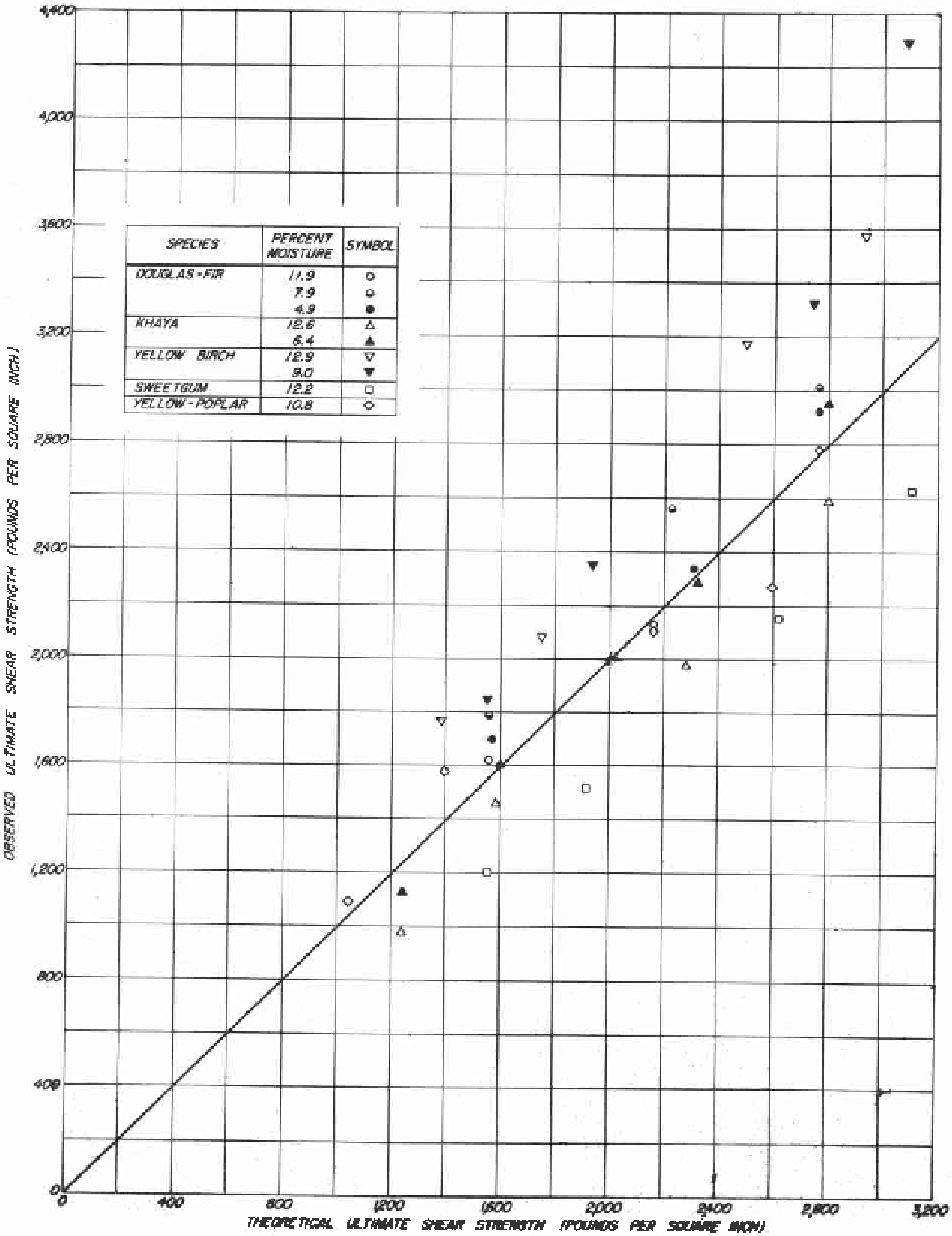


Figure 11.--Comparison of the computed to the observed shear strength of plywood. Observed values obtained from panel shear tests; computed values, from formula (2).

ZM 78333 F

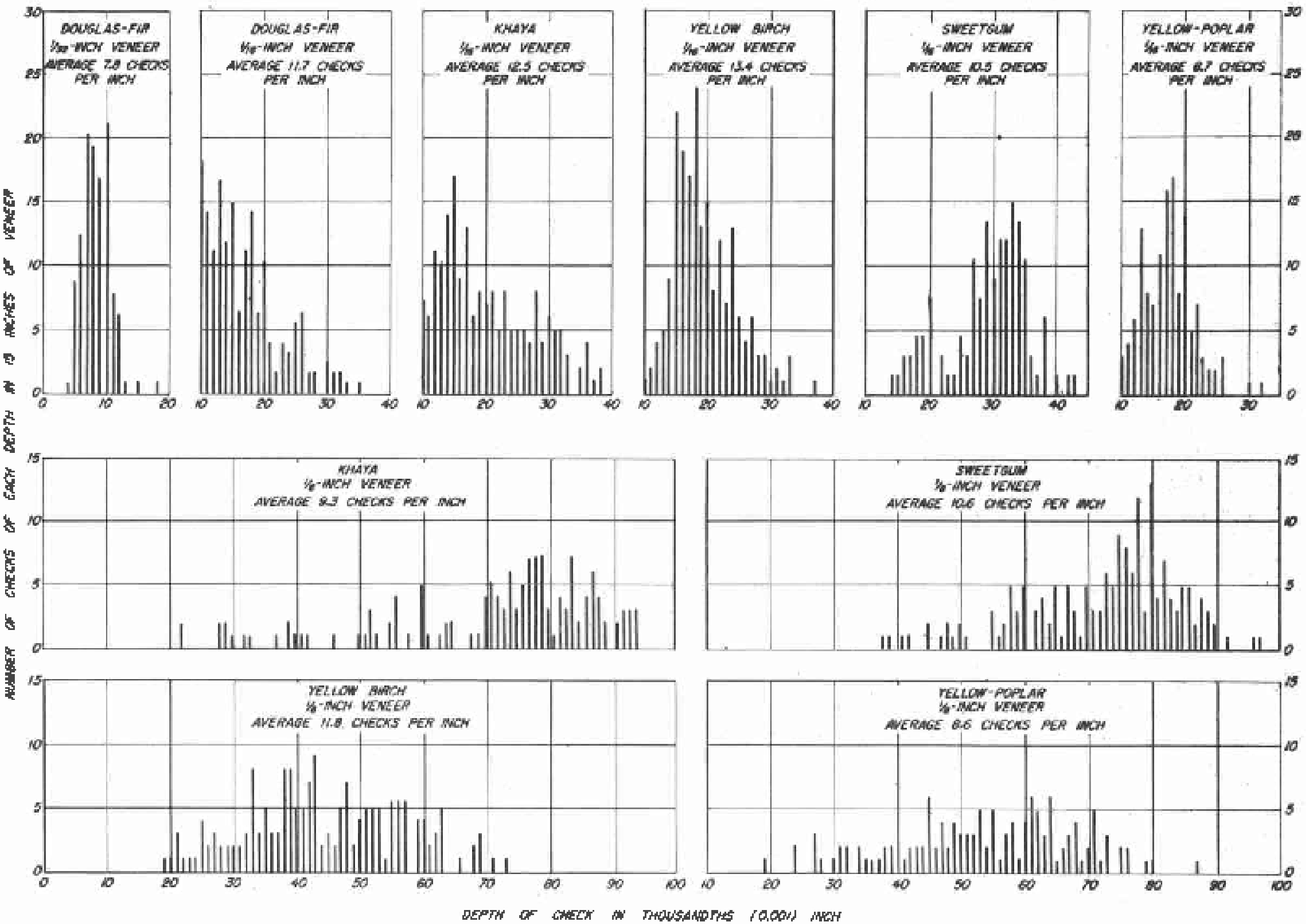


Figure 12.--Analysis of checks in veneers of series A.

Z M 78334 F

Norris, Charles Brazer
The effect of veneer thickness and grain direction on the shear strength of plywood, by C. B. Norris, Fred Werren, and P. F. McKinnon. 3rd. ed.
Madison, Wis., U.S. Forest Products Laboratory, 1961.
30 p., illus. (F.P.L. rpt. no. 1801)

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