Supplement to

COMPRESSION, TENSION, AND SHEAR TESTS ON YELLOWPOPLAR PLYWOOD PANELS OF SIZES THAT DO NOT BUCKLE WITH TESTS MADE AT VARIOUS ANGLES TO THE FACE GRAIN

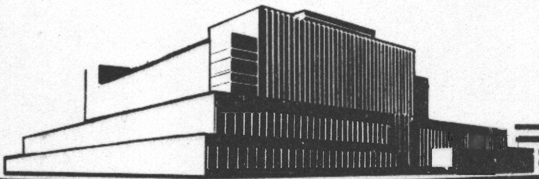
TENSION TESTS

~~Information Reviewed and Reaffirmed~~

~~March 1956~~

INFORMATION REVIEWED
AND REAFFIRMED
1962

No. 1328-B



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

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

Note: There will be four reports in this series to be published in the following order:

1328-A--Compression Tests
1328-B--Tension Tests
1328-C--Shear Tests
1328--Summary

TENSION TESTS[1]

By

C. B. NORRIS, Engineer
and
P. F. McKINNON, Engineer

Forest Products Laboratory,[2] Forest Service
U. S. Department of Agriculture

Summary

This supplement presents the results of 751 tension tests made on plywood of three, five, and seven plies of 1/16-inch veneer and five, seven, and nine plies of 1/32-inch veneer. Tests were made on specimens 0.8 inch wide, at angles between face grain and applied stress varying from 0° to 90° by increments of 15°.

A preliminary series of 210 tests was conducted to determine the effect of the width of specimen on the mechanical properties and type of failure.

Introduction

In many of the structural uses of plywood, particularly in aircraft, the direction of the applied force varies with respect to the face grain of the plywood. Consequently, rational design of such structures requires a knowledge of the effect of this angle on allowable stress values. The purpose of this supplement is to supply such information with respect to tension. From experience with compression tests,[3] it was anticipated that the results might be affected by the width of the specimen. A series of preliminary tests was made to determine the effect of specimen width. Series A consisted of tests of 210 specimens of five-ply, 5/16-inch plywood, and five-ply, 5/32-inch plywood, with widths varied from 1 to 5 inches by 1-inch increments. The angle between direction of face

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[1] This is one of a series of progress reports prepared by the Forest Products Laboratory relating to the use of wood in aircraft issued in cooperation with the Army-Navy-Civil Committee on Aircraft Design Criteria. Original report published 1945.

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

[3] FPL Report No. 1328-A, "Compression Tests," Supplement to 1328.

grain and stress was varied from 0° to 90° by increments of 15°; three tests were made with each combination of width and angle. In the major series, designated B, the plywoods tested were three-ply 3/16-inch, five-ply 5/16-inch and 5/32-inch, seven-ply 7/16-inch and 7/32-inch, and nine-ply 9/32-inch; the angle was varied from 0° to 90° by increments of 15°.

Materials

All material tested was yellow-poplar plywood made from rotary-cut veneers bonded by the hot-press method with a phenolic-resin film glue. All the veneers used in making any one panel were of equal thickness.

In order to eliminate, insofar as possible, variables other than those under investigation, the 1/32-inch veneers were rotary-cut from a restricted region in a single yellow-poplar log. The 1/16-inch veneers were, however, taken from two additional logs. The veneers for series A were taken from one of these logs and those for series B from the other. Both were about equal in quality of wood.

Specimens for series A were obtained from two groups of 24- by 24-inch yellow-poplar plywood panels. One group was made of five-ply 1/16-inch veneer; the other, of five-ply 1/32-inch veneer. Each group was divided into seven subgroups of three panels each. These subgroups were lettered from A to G, inclusive. All specimens of subgroup A were cut so that the face grain was parallel to the sides (and load axis); specimens of subgroup B were cut so that the face grain was at 15° to the sides; each successive subgroup had the angle increased by 15°. Five specimens, varying from 1 to 5 inches in width in 1-inch increments, were cut from each panel.

Specimens for series B were obtained from 24-inch square panels made at the Laboratory from 1/16- and 1/32-inch veneers. Panels of the 1/16-inch veneers had three, five, and seven plies; panels of the 1/32-inch veneers had five, seven, and nine plies. The plan for grouping of panels and cutting of specimens with regard to grain direction was the same as that used in series A.

The specimen number is a key to its classification; for example, the numbering of specimens 5-D-2-2 indicates:

Number of plies..... 5
Subgroup........... D (face grain is 45° to load axis)
Panel number........ 2 (in subgroup D)
Specimen number..... 2 (from panel No. 2)
The letters CP in the subgroup classification denote a control panel.

No distinction was made for veneer thickness except as shown in the tables. Hence, for each specimen made of 1/16-inch veneer, another of 1/32-inch veneer bore the same number.

Prior to obtaining tension specimens, matched compression specimens were taken from the same panels. The remainder of each panel was retained to furnish matched specimens for test in shear.

All veneers for making the plywood were conditioned at 22° C. (72° F.) in a 65-percent relative humidity room to bring them to a uniform and suitable moisture content before hot pressing. Likewise, all test specimens were conditioned in the same humidity room to bring about moisture equilibrium throughout the specimen and uniform moisture content among the specimens. The length of time that specimens were retained in the humidity room depended on the thickness.

Test Methods

Series A

All specimens in series A were tested in a 100,000-pound capacity hydraulic testing machine. The load was applied at a rate of head movement of 0.05 inch per minute. Figure 12 illustrates[4] the type of specimen and the apparatus used in the tests for series A.

The steel bars at the top, a, with a pin at the lower ends, hold the apparatus in the upper or fixed head of the machine. Similar bars anchor the apparatus in the lower or movable head of the machine. Gripping plates c, connected to bars a by the connecting link b and having ledges that bear against shoulders on hard maple blocks glued to the specimen, transmit load from the machine head to the specimen. The holes in connecting link b and in plates c were so formed that knife-edge bearings on the pins were obtained. Thus, plates c were free to shift up or down to provide equal bearing on the shoulders of the maple blocks. The bolts holding the plates to the specimen were of a loose fit, thus permitting the plates to move until uniform bearing was secured.

The maple blocks extended the full width of the specimen. They had a tapered section 2-1/2 inches long and a 1/2-inch shoulder-bearing surface. The distance from the shoulder to the end of the specimen was 3 inches.

Immediately prior to test, an extensometer was attached to the specimen and centered both horizontally and vertically. The specimen was then placed between the upper pair of gripping plates so that the shoulder of each maple block and the shoulder of each plate were in contact over the whole area of the block shoulders. Bolts to hold the plates firmly against the blocks were then inserted and tightened just enough to prevent slipping of the plates from the blocks during test. The lower plates were then brought into position and similar adjustments made.

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[4] The figure and table numbers of this report are consecutive with those of the previous Report No. 1328-A of this series.

An initial load, equal to one-half of the load increment to be used, was applied to the specimen, and readings of initial load and deformation were taken. Load was then applied at a constant rate of head movement until maximum load was reached. Deformations were recorded for each increment of load, from initial to the maximum.

Series B

The specimens used in this series were 16 inches long and of uniform thickness. The maximum sections at the ends were 1-1/2 inches wide and 2-7/8 inches long. The minimum sections, at the centers, were 2-1/2 inches long and 0.8 inch wide. The maximum and minimum sections were connected by circular arcs of 20-inch radius tangent to the minimum sections.

Specimens were tested in a 10,000-pound capacity mechanical testing machine. Load was applied at a rate of head movement of 0.05 inch per minute.

Figure 13 illustrates a specimen of series B under test. An extensometer was used to measure deformations.

Immediately prior to test, the extensometer was attached to the specimen and centered both horizontally and vertically as in the tests of series A. The specimen was then placed in the tension grips in the machine and centered. The test then proceeded in the same manner as for series A.

Tables and Charts

Typical failures of specimens of series A are shown in figures 14 to 23, inclusive.

Figure 24 shows how a variation in width of specimen, series A, affects the magnitude of the maximum load that it can sustain. Each value of average maximum load as plotted is the product of the average stress of each subgroup, width of specimen, and the average thickness of all specimens in each angle group. The lines drawn are those of best fit as determined by the method of least squares.

Tables 8 and 9 present the data from the tests in series A. In both of these tables column 1 identifies the specimen. Values of maximum tensile stress are shown in column 2. Fiber stress at proportional limit is listed in column 3. Column 4 gives values for the modulus of elasticity. Values in column 2A are the slopes of the graphs in figure 24. The values in columns 3A and 4A were determined in a similar manner.

Tables 10 through 15 present the results obtained from tests of series B. In each of these tables, column 1 contains the identification numbers for individual specimens.

Moisture content, expressed as a percentage of the oven-dry weight of the plywood, is given in column 2. Specific gravity values shown in column 3 are based on the volume of the plywood at time of test.

Maximum tensile strength, fiber stress at proportional limit, and modulus of elasticity are shown in columns 4, 5, and 6, respectively.

Table 16 presents results of tests in series B which show the effect of ply thickness on maximum tensile stress, while in table 17 is presented a comparison of stress ratios to parallel-ply area ratios.

Figure 25, series A, illustrates the variation of maximum tensile strength, stress at proportional limit, and modulus of elasticity with the angle between direction of the face grain and the direction of applied stress in tests of series A. Values for these properties are found in tables 8 and 9, columns 2A, 3A, and 4A.

Figures 26 and 27 contain graphs similar to those in figure 25, but the values are from the tests of series B. These values are recorded in tables 10 through 15.

The average stress-strain curves for all tests for each angle in each group of tests of series B are shown in figures 28 through 33. These average curves were obtained by plotting a stress-strain curve for each test in each subgroup of each angle. As there were 4 tests in each of the 4 subgroups for each angle, each curve represents the average of 16 tests.

Figure 34 shows how 45° specimens of series B failed in tension across the grain in all the plies and in shear in the glue lines.

Analysis of Results

Series A

Tests in this series were conducted on specimens, all of the same length but of various widths, to determine the effect of width upon the maximum tensile stress of the plywood at various angles to the direction of the face grain.

Graphs of the data obtained from these tests are shown in figure 24. The coordinates used are the specimen widths as abscissas, and maximum loads, corrected to the average thickness of specimen, as ordinates. Each point represents the average of three tests.

The straight lines shown on these graphs are those of best fit as determined by the method of least squares. Nearly all these lines intersect the "width" axis to the right of the origin, indicating that the material near the edges of each specimen carried less than the average stress. The maximum tensile stress of very wide plywood is given by the slopes of the lines divided by the thickness of the plywood. The maximum stresses obtained in this way are plotted, in figure 25, against the respective angles to the face grain.

An examination of the failures (figs. 14 through 23) of those specimens tested parallel and perpendicular to face grain (0° and 90°) suggests that stress concentrations at the junction of the plywood and the maple blocks caused failure. Such a stress concentration would cause a reduction in strength of these particular specimens. The low values shown in figure 25, particularly for the plywood made from 1/32-inch veneers, at these angles are probably due to such stress concentrations.

In series A, two difficulties were encountered:

(1) The maximum tensile stress was affected by the width of the specimen.

(2) Stress concentrations probably lowered the strengths of specimens tested at angles of 0° and 90° to the direction of the face grain.

Series B

The type of specimen selected for tests in this series (fig. 13) was chosen to overcome, as far as possible, the two difficulties encountered in series A. A narrow specimen was used so that the failure would not be influenced by restraint at the ends of the specimen. The specimen was tapered to avoid failure at the clamps due to stress concentrations. The width of the specimen was limited by the apparatus available.

Success in eliminating stress concentrations at the ends of the specimens was evidenced by the fact that nearly all failures occurred near the minimum section of the specimens.

An examination of the failures (fig. 34) revealed that there was a difference between the type of failure obtained in the specimens made of 1/16-inch veneers and tested at 45° to the direction of the face grain and similar specimens made of 1/32-inch veneers. The specimens made of the thicker veneers failed in tension by rupturing parallel to the grain of the individual plies and failed in shear in the glue lines. Only a limited amount of the failure occurred by rupturing across the grain of the individual plies. Such a failure has a forked appearance. If such a specimen is made wider, the area in tension across the grain increases directly with the width, and the glue area resisting shear increases as the square of the width. It is evident that if the specimen is made wide enough, a different kind of failure will occur. The same result can be obtained by decreasing the thickness of the individual plies instead of increasing the width of the specimen.

That this type of failure did not greatly affect the results obtained from tests in this series is shown by a comparison of the maximum stresses obtained at 45° with those obtained from the similar, but wider, specimens of series A. The curves for five-ply constructions given in figures 25 and 26 show that the 45° specimens of series A were not stronger than similar specimens of series B. Even though the veneers of the two series were not matched, it can be concluded that the forked type of failure illustrated in figure 34 did not greatly influence the values obtained from series B. However, the maximum tensile stress at 45° to the grain direction of the face plies, in tests of series B, is less for the plywood made of 1/16-inch veneers than for that of 1/32-inch veneers as is shown in column 4 of table 16.

The maximum tensile stress at 45° to the direction of the face grain involves the maximum shear stress parallel and perpendicular to the face grain. It is suggested that plywood made of thin veneers may be stronger in shear than that made of thick veneers. This agrees with other work in progress.

A similar effect, due to ply thickness, is not evident in the maximum tensile stress parallel and perpendicular to the direction of the grain of the faces. In column 2 of table 16 are listed for each panel construction the sums of the maximum tensile stresses parallel and perpendicular to the direction of the grain of the faces. These sums are equal to the sum of the maximum tensile stresses parallel and perpendicular to the grain of the individual veneers. The ultimate tensile stress perpendicular to the direction of the grain is so low, however, that the sum is substantially equal to the maximum tensile stress of the veneer parallel to the direction of the grain. It is evident then from the values listed that the maximum tensile stress in the direction of the grain is not influenced by the thickness of the veneers and also that the presence of the glue line has very little effect.

Since strength perpendicular to the grain is so low, the ratio of the tensile stress at 0° to that at 90° should be approximately equal to the ratio of the number of plies parallel to the applied stress at 0° to the number of plies parallel to the applied stress at 90°. These ratios are given in table 17 but are not identical. This is probably due to variations in the thicknesses of the individual plies from point to point in the plywood. On this basis it would be expected that differences would be greater for the panels made of the thinner veneers and table 17 indicates that this is the case.

Figure 26 shows that the minimum values of tensile stress and stress at proportional limit are at 45°. A comparison of this figure with figure 25 shows that the values for 0° and 90° in series B are higher than for those in series A. It follows that the maximum tensile stresses at 0° and 90° obtained in series A are too low, probably due to the stress concentrations previously noted.

Conclusions

For the constructions and species tested, the maximum tensile stress is less at 45° than it is at other angles to the direction of the face grain.

The maximum tensile stresses at 0° and at 90° to the direction of the face grain are approximately in the same ratio as the cross-sectional areas of the plies having a grain direction parallel to the direction of the stress.

The maximum tensile stress at 0° and at 90° to the direction of the face grain does not vary greatly with the thickness of the individual plies.

The maximum tensile stress at 45° to the direction of the face grain increases as the thickness of the individual plies decrease.

The proportional limit and modulus of elasticity of the plywood vary with the angle at which the tensile stress is applied much in the same manner as does the maximum tensile stress.

Table 8.--Results of preliminary tension tests (series A) on yellow-poplar plywood at various angles to the face grain (plywood made of 5 plies of 1/16-inch veneers -- width of specimens varied from 1 to 5 inches)

Specimens 1 inch wide

Specimen number (1)	Maximum tensile stress (2) Lb. per sq. in.	Fiber stress at proportional limit (3) Lb. per sq. in.	Modulus of elasticity (4) 1,000 lb. per sq. in.
θ = 0° [2]			
5-1-A-1	4,170	1,690	649
2	4,860	....	806
3	4,540	2,940	1,042
Average	4,520	2,320	832
θ = 15°			
5-1-B-1	3,660	1,910	780
2	3,590	1,820	494
3	3,570	....	264
Average	3,610	1,860	513
θ = 30°			
5-1-C-1	2,310	1,400	256
2	2,580	1,620	338
3	2,120	1,140	312
Average	2,340	1,390	302
θ = 45°			
5-1-D-1	1,860	1,500	197
2	2,280	....	134
3	2,100	1,370	210
Average	2,080	1,440	180
θ = 60°			
5-1-E-1	2,070	....	195
2	2,520	1,650	279
3	2,870	2,110	291
Average	2,490	1,880	255
θ = 75°			
5-1-F-1	3,760	2,470	466
2	4,360	....	580
3	3,460	1,760	488
Average	3,860	2,120	511
θ = 90°			
5-1-G-1	4,410	3,890	626
2	5,030	4,340	667
3	4,340	4,240	595
Average	4,590	4,160	629

Specimens 2 inches wide

Specimen number (1)	Maximum tensile stress (2) Lb. per sq. in.	Fiber stress at proportional limit (3) Lb. per sq. in.	Modulus of elasticity (4) 1,000 lb. per sq. in.
θ = 0°			
5-2-A-1	4,830	3,050	1,138
2	4,030	3,130	1,046
3	4,580	3,140	1,072
Average	4,480	3,110	1,085
θ = 15°			
5-2-B-1	4,070	1,510	678
2	3,840	1,610	511
3	3,940	2,020	474
Average	3,950	1,710	554
θ = 30°			
5-2-C-1	2,510	1,340	268
2	2,880	1,710	323
3	2,530	1,030	286
Average	2,640	1,360	292
θ = 45°			
5-2-D-1	2,200	780	252
2	2,310	1,200	259
3	2,420	1,300	235
Average	2,310	1,090	249
θ = 60°			
5-2-E-1	2,550	1,220	293
2	2,850	1,560	295
3	3,130	1,540	342
Average	2,840	1,440	310
θ = 75°			
5-2-F-1	3,960	1,580	475
2	3,780	2,790	640
3	4,120	2,900	490
Average	3,950	2,420	535
θ = 90°			
5-2-G-1	4,930	3,780	670
2	5,080	2,810	639
3	3,900	3,170	621
Average	4,640	3,250	643

Specimens 3 inches wide

Specimen number (1)	Maximum tensile stress (2) Lb. per sq. in.	Fiber stress at proportional limit (3) Lb. per sq. in.	Modulus of elasticity (4) 1,000 lb. per sq. in.
θ = 0°			
5-3-A-1	5,110	4,510	1,128
2	5,170	2,780	1,219
3	4,850	....	1,084
Average	5,040	3,640	1,144
θ = 15°			
5-3-B-1	4,530	2,750	728
2	3,780	2,380	492
3	3,780	2,000	452
Average	4,030	2,380	557
θ = 30°			
5-3-C-1	2,580	1,070	285
2	2,890	1,090	333
3	2,520	1,060	290
Average	2,660	1,070	303
θ = 45°			
5-3-D-1	2,300	1,100	228
2	2,330	1,030	250
3	2,700	1,040	277
Average	2,440	1,060	252
θ = 60°			
5-3-E-1	2,840	1,250	333
2	3,120	1,400	331
3	2,900	1,250	349
Average	2,950	1,300	338
θ = 75°			
5-3-F-1	4,690	1,880	482
2	3,120	2,410	464
3	4,400	1,720	514
Average	4,070	2,000	487
θ = 90°			
5-3-G-1	4,900	2,420	770
2	4,240	820	914
3	3,210	2,930	636
Average	4,120	2,060	773

Specimens 4 inches wide

Specimen number (1)	Maximum tensile stress (2) Lb. per sq. in.	Fiber stress at proportional limit (3) Lb. per sq. in.	Modulus of elasticity (4) 1,000 lb. per sq. in.
θ = 0°			
5-4-A-1	4,730	4,680	992
2	4,800	3,140	1,107
3	4,460	4,320	1,063
Average	4,660	4,050	1,054
θ = 15°			
5-4-B-1	3,740	2,690	606
2	3,640	1,580	512
3	4,110	2,350	456
Average	3,830	2,210	525
θ = 30°			
5-4-C-1	2,600	1,140	280
2	2,860	1,080	330
3	2,540	1,300	268
Average	2,670	1,170	293
θ = 45°			
5-4-D-1	2,130	1,150	204
2	2,210	1,100	228
3	2,390	1,290	224
Average	2,240	1,180	219
θ = 60°			
5-4-E-1	2,450	1,480	244
2	2,960	1,480	292
3	2,840	1,100	317
Average	2,750	1,350	284
θ = 75°			
5-4-F-1	4,350	2,010	443
2	4,280	3,100	616
3	3,320	....	484
Average	3,980	2,560	514
θ = 30°			
5-4-G-1	3,590	....	692
2	5,670	....	767
3	5,500	....	692
Average	4,920	....	717

Specimens 5 inches wide

Specimen number (1)	Maximum tensile stress (2) Lb. per sq. in.	Fiber stress at proportional limit (3) Lb. per sq. in.	Modulus of elasticity (4) 1,000 lb. per sq. in.
θ = 0°			
5-5-A-1	4,540	4,120	1,000
2	4,780	4,170	1,154
3	4,460	4,140	1,019
Average	4,590	4,140	1,058
θ = 15°			
5-5-B-1	3,880	1,800	565
2	4,010	1,590	561
3	3,960	1,240	480
Average	3,950	1,540	535
θ = 30°			
5-5-C-1	2,780	1,090	298
2	3,010	1,240	352
3	2,600	1,220	291
Average	2,800	1,180	314
θ = 45°			
5-5-D-1	2,350	860	246
2	2,540	1,090	272
3	2,430	1,030	243
Average	2,440	990	254
θ = 60°			
5-5-E-1	2,600	1,190	286
2	2,750	1,250	284
3	2,890	1,290	307
Average	2,750	1,240	292
θ = 75°			
5-5-F-1	4,510	1,820	505
2	3,730	1,690	607
3	4,460	1,890	481
Average	4,230	1,800	531
θ = 90°			
5-5-G-1	(3)	(3)	(3)
2	4,580	4,560	738
3	4,920	4,590	740
Average	4,750	4,580	739

Least-squares values (columns 2A, 3A, 4A)

Angle	Maximum tensile stress[1] (2A) Lb. per sq. in.	Fiber stress at proportional limit[1] (3A) Lb. per sq. in.	Modulus of elasticity[1] (4A) 1,000 lb. per sq. in.
θ = 0°	4,658	4,709	1,096
θ = 15°	3,971	1,668	532
θ = 30°	2,868	1,103	312
θ = 45°	2,459	965	255
θ = 60°	2,781	1,126	293
θ = 75°	4,264	1,804	527
θ = 90°	4,866	4,380	772

[1]Values in columns 2A, 3A, and 4A were computed by the method of least squares, and are plotted in figure 25.

[2]θ is the angle between the direction of the face grain and the direction of applied stress.

[3]Cull.

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Table 9.--Results of preliminary tension tests (series A) on yellow-poplar plywood at various angles to the face grain (plywood made of 5 plies of 1/32-inch veneers -- width of specimens varied from 1 to 5 inches)

Specimen number	Maximum tensile stress	Fiber stress at proportional limit	Modulus of elasticity	Specimen number	Maximum tensile stress	Fiber stress at proportional limit	Modulus of elasticity	Specimen number	Maximum tensile stress	Fiber stress at proportional limit	Modulus of elasticity	Specimen number	Maximum tensile stress	Fiber stress at proportional limit	Modulus of elasticity	Specimen number	Maximum tensile stress	Fiber stress at proportional limit	Modulus of elasticity	Maximum tensile stress[1]	Fiber stress at proportional limit[1]	Modulus of elasticity[1]
(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(1)	(2)	(3)	(4)	(2A)	(3A)	(4A)
	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.	Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
	Specimens 1 inch wide				Specimens 2 inches wide				Specimens 3 inches wide				Specimens 4 inches wide				Specimens 5 inches wide					
		[2]θ = 0°				θ = 0°				θ = 0°				θ = 0°				θ = 0°				
5-1-A-1	6,140	3,280	1,243	5-2-A-1	6,490	3,790	1,189	5-3-A-1	(3)	(3)	(3)	5-4-A-1	6,820	...	1,256	5-5-A-1	6,400	...	1,226	...	...	...
2	5,080	3,120	998	2	6,110	2,850	1,179	2	(3)	(3)	(3)	2	6,240	...	1,171	2	6,540	2,790	1,231	...	...	...
3	6,790	5,280	1,106	3	6,060	5,910	1,199	3	5,370	4,970	1,046	3	7,000	...	1,186	3	5,940	...	1,127	...	...	...
Average	6,000	3,890	1,116	Average	6,220	4,180	1,189	Average	5,370	4,970	1,046	Average	6,690	...	1,204	Average	6,290	2,790	1,195	6,523	2,864	1,215
		θ = 15°				θ = 15°				θ = 15°				θ = 15°				θ = 15°				
5-1-B-1	4,850	2,940	597	5-2-B-1	4,870	3,740	579	5-3-B-1	6,270	2,820	694	5-4-B-1	6,110	2,430	635	5-5-B-1	6,780	2,340	729	...	...	...
2	5,510	4,630	752	2	5,360	3,210	617	2	6,280	3,160	668	2	6,420	2,450	707	2	6,090	2,750	663	...	...	...
3	5,810	...	...	3	5,990	...	638	3	5,680	2,990	631	3	6,530	2,840	722	3	6,640	2,860	688	...	...	...
Average	5,390	3,780	674	Average	5,610	3,480	611	Average	6,080	2,990	664	Average	6,350	2,570	688	Average	6,500	2,650	693	6,845	2,216	718
		θ = 30°				θ = 30°				θ = 30°				θ = 30°				θ = 30°				
5-1-C-1	4,270	1,710	303	5-2-C-1	4,180	1,940	420	5-3-C-1	4,700	1,940	432	5-4-C-1	4,480	1,730	394	5-5-C-1	4,480	1,270	400	...	...	...
2	3,610	1,640	267	2	3,600	2,080	314	2	4,140	1,820	377	2	4,190	1,870	372	2	4,290	1,590	366	...	...	...
3	4,340	2,290	500	3	4,600	3,500	428	3	4,310	1,740	422	3	4,780	1,320	438	3	4,740	1,820	396	...	...	...
Average	4,070	1,880	357	Average	4,130	2,510	387	Average	4,380	1,830	410	Average	4,480	1,640	401	Average	4,500	1,560	387	4,657	1,339	399
		θ = 45°				θ = 45°				θ = 45°				θ = 45°				θ = 45°				
5-1-D-1	3,130	1,960	298	5-2-D-1	3,340	1,820	259	5-3-D-1	3,360	1,120	290	5-4-D-1	3,360	1,130	278	5-5-D-1	3,290	1,240	283	...	...	...
2	3,100	2,010	279	2	(3)	(3)	(3)	2	3,290	1,500	248	2	3,140	1,520	251	2	3,220	890	288	...	...	...
3	3,050	1,720	293	3	3,480	1,740	288	3	3,420	1,140	291	3	3,400	1,640	262	3	3,430	890	312	...	...	...
Average	3,090	1,900	290	Average	3,410	1,780	274	Average	3,360	1,250	276	Average	3,300	1,430	264	Average	3,310	1,010	294	3,340	858	287
		θ = 60°				θ = 60°				θ = 60°				θ = 60°				θ = 60°				
5-1-E-1	4,090	2,230	340	5-2-E-1	4,290	2,040	372	5-3-E-1	4,070	1,800	377	5-4-E-1	3,870	1,510	309	5-5-E-1	4,030	1,230	331	...	...	...
2	3,480	1,830	277	2	3,790	1,590	330	2	3,800	1,530	326	2	3,850	1,720	304	2	3,850	1,260	332	...	...	...
3	3,200	2,070	300	3	3,630	1,620	320	3	3,910	1,670	334	3	3,970	1,750	314	3	4,010	1,490	328	...	...	...
Average	3,590	2,040	306	Average	3,900	1,750	341	Average	3,930	1,670	346	Average	3,900	1,660	309	Average	3,960	1,330	330	4,023	1,232	325
		θ = 75°				θ = 75°				θ = 75°				θ = 75°				θ = 75°				
5-1-F-1	6,130	2,910	644	5-2-F-1	5,590	3,030	585	5-3-F-1	5,740	2,660	601	5-4-F-1	6,160	3,530	604	5-5-F-1	6,390	3,100	598	...	...	...
2	5,520	3,800	532	2	5,970	2,780	544	2	(3)	(3)	(3)	2	5,940	...	562	2	6,050	3,610	581	...	...	...
3	5,250	3,730	502	3	5,560	2,530	583	3	6,160	3,420	496	3	4,170	...	646	3	5,220	2,550	548	...	...	...
Average	5,630	3,480	559	Average	5,710	2,780	571	Average	5,950	3,040	548	Average	5,420	3,530	604	Average	5,890	3,090	576	5,788	3,137	591
		θ = 90°				θ = 90°				θ = 90°				θ = 90°				θ = 90°				
5-1-G-1	5,140	3,890	882	5-2-G-1	5,910	4,410	826	5-3-G-1	6,650	4,520	837	5-4-G-1	6,160	5,320	703	5-5-G-1	5,460	3,280	686	...	...	...
2	8,150	7,160	784	2	7,120	4,490	826	2	7,090	4,760	728	2	5,670	3,110	765	2	5,100	4,030	805	...	...	...
Average	6,640	5,520	833	Average	6,520	4,450	826	Average	6,870	4,640	782	Average	5,920	4,220	734	Average	5,280	3,660	746	5,014	3,346	707

[1] Values in columns 2A, 3A, and 4A were computed by the method of least squares, and are plotted in figure 25.

[2] θ is the angle between the direction of the face grain and the direction of applied stress.

[3] Cull.

Z M 54258 F

Table 10.--**Results of tension tests (series B) on three-ply yellow-poplar plywood at various angles to the face grain (plywood made of 1/16-inch veneer)**

Specimen number	Moisture content[1]	Specific gravity[2]	Maximum tensile strength	Fiber stress at proportional limit	Modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
			[3]θ = 0°		
3-A-1-1	9.7	0.481	10,460	10,100	1,572
2	9.2	.466	10,290	8,160	1,511
3	9.4	.451	12,030	6,330	1,583
4	9.2	.473	9,120	6,960	1,444
Average	9.4	.468	10,480	7,890	1,528
3-A-2-1	9.1	.496	10,400	10,300	1,520
2	9.2	.479	8,070	8,000	1,516
3	8.9	.470	11,300	11,300	1,467
4	8.9	.501	11,560	10,780	1,497
Average	9.0	.486	10,330	10,100	1,500
3-A-3-1	9.0	.444	10,860	10,800	1,403
2	9.6	.439	9,910	9,410	1,307
3	8.4	.447	11,260	11,000	1,383
4	9.3	.433	11,390	7,590	1,356
Average	9.1	.441	10,860	9,700	1,362
3-A-4-1	9.8	.481	11,550	8,330	1,586
2	9.3	.478	13,260	9,430	1,625
3	9.4	.465	13,840	10,120	1,562
4	10.6	.450	11,240	11,100	1,415
Average	9.8	.468	12,470	9,740	1,547
Average of Group	9.3	.466	11,034	9,357	1,484.2
			θ = 15°		
3-B-1-1	9.2	.466	4,760	....	703
2	9.0	.482	4,510	3,170	725
3	9.2	.451	4,930	2,820	704
4	9.2	.455	5,060	3,510	756
Average	9.2	.464	4,820	3,170	722
3-B-2-1	9.0	.432	5,240	3,450	802
2	9.1	.426	5,390	4,570	867
3	8.5	.424	4,920	3,610	840
4	8.8	.431	5,070	2,910	766
Average	8.8	.428	5,160	3,640	819
3-B-3-1	8.9	.431	5,100	3,740	771
2	8.8	.457	4,780	3,930	686
3	8.7	.436	4,700	2,920	712
4	8.8	.436	4,260	3,070	686
Average	8.8	.440	4,710	3,420	714
3-B-4-1	9.2	.469	5,160	2,920	886
2	9.1	.454	5,700	3,280	816
3	9.2	.468	4,890	3,960	734
4	9.3	.420	4,990	2,920	759
Average	9.2	.453	5,180	3,270	799
Average of Group	9.0	.446	4,966	3,385	763.3

Specimen number	Moisture content[1]	Specific gravity[2]	Maximum tensile strength	Fiber stress at proportional limit	Modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
			θ = 30°		
3-C-1-1	8.9	0.465	2,890	1,390	344
2	9.0	.428	3,020	1,420	364
3	8.9	.432	2,870	1,380	370
4	8.7	.440	2,950	1,400	365
Average	8.9	.441	2,930	1,400	361
3-C-2-1	8.6	.436	3,190	1,800	375
2	8.9	.398	3,190	1,530	396
3	8.6	.414	3,040	1,660	349
4	8.8	.422	3,010	1,540	390
Average	8.7	.418	3,110	1,630	378
3-C-3-1	8.5	.442	3,110	1,430	421
2	8.4	.439	3,110	1,880	362
3	8.3	.418	2,720	1,430	363
4	8.3	.448	2,900	1,290	403
Average	8.4	.437	2,960	1,510	387
3-C-4-1	8.3	.439	3,180	1,880	375
2	8.4	.446	3,110	1,450	378
3	8.5	.459	3,170	1,440	424
4	8.5	.466	3,440	1,580	418
Average	8.4	.452	3,220	1,590	399
Average of Group	8.6	.437	3,056	1,531	381.1
			θ = 45°		
3-D-1-1	9.0	.450	2,340	2,090	277
2	8.6	.481	2,510	1,790	247
3	8.3	.454	2,440	1,260	273
4	8.4	.475	2,810	1,410	297
Average	8.6	.465	2,520	1,640	274
3-D-2-1	8.7	.450	2,190	1,830	245
2	8.8	.429	2,100	1,280	242
3	8.7	.412	2,520	1,400	291
4	8.8	.450	2,440	1,400	265
Average	8.8	.435	2,310	1,480	261
3-D-3-1	9.0	.450	2,120	1,210	246
2	8.9	.466	2,410	1,220	260
3	8.4	.476	2,430	1,220	248
4	8.3	.459	2,480	1,220	271
Average	8.6	.463	2,360	1,220	256
3-D-4-1	8.3	.458	2,620	1,470	272
2	8.3	.453	2,790	1,360	309
3	8.4	.448	2,660	1,040	361
4	8.5	.432	2,500	1,130	304
Average	8.4	.448	2,640	1,250	312
Average of Group	8.6	.453	2,460	1,396	275.5

Specimen number	Moisture content[1]	Specific gravity[2]	Maximum tensile strength	Fiber stress at proportional limit	Modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
			θ = 60°		
3-E-1-1	8.8	0.484	2,540	1,120	306
2	8.8	.485	2,880	1,230	338
3	8.9	.467	2,630	1,360	310
4	8.9	.459	2,620	1,380	313
Average	8.8	.474	2,670	1,270	317
3-E-2-1	8.9	.436	2,720	1,440	289
2	8.7	.430	2,680	1,240	298
3	8.8	.460	2,980	1,140	339
4	8.7	.467	2,960	1,630	351
Average	8.8	.448	2,840	1,360	319
3-E-3-1	8.9	.446	2,720	1,390	303
2	9.0	.443	2,910	1,400	320
3	8.8	.436	3,000	1,520	337
4	....	....	2,970	1,380	324
Average	8.9	.442	2,900	1,420	321
3-E-4-1	....	....	2,640	....	291
2	8.6	.474	2,640	1,240	28[illegible]
3	8.8	.463	3,030	1,470	341
4	8.7	.465	3,300	1,670	337
Average	8.7	.467	2,900	1,460	314
Average of Group	8.8	.458	2,826	1,374	317.9
			θ = 75°		
3-F-1-1	8.6	.408	4,300	2,100	599
2	8.9	.416	4,170	2,320	522
3	8.6	.408	3,980	1,700	482
4	8.6	.433	4,240	2,130	496
Average	8.7	.416	4,170	2,060	525
3-F-2-1	9.1	.468	4,040	2,080	437
2	8.9	.456	4,340	1,660	523
3	9.2	.479	3,880	1,560	457
4	8.8	.488	3,710	2,450	500
Average	9.0	.473	3,990	1,940	479
3-F-3-1	8.9	.388	4,210	1,640	513
2	8.8	.403	4,130	2,160	452
3	8.6	.453	4,290	2,200	48[illegible]
4	8.3	.428	4,730	2,510	530
Average	8.6	.418	4,340	2,130	496
3-F-4-1	8.2	.465	4,360	2,730	554
2	8.5	.468	4,730	3,080	514
3	(4)	(4)	(4)	(4)	(4)
4	8.3	.481	4,400	2,920	504
Average	8.3	.471	4,500	2,910	524
Average of Group	8.7	.445	4,234	2,216	504.8

Specimen number	Moisture content[1]	Specific gravity[2]	Maximum tensile strength	Fiber stress at proportional limit	Modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
			θ = 90°		
3-G-1-1	8.5	0.435	7,170	4,960	762
2	8.1	.417	6,800	4,470	616
3	7.9	.434	6,800	4,310	644
4	7.9	.445	7,920	4,320	831
Average	8.1	.433	7,170	4,520	713
3-G-2-1	8.2	.442	6,060	4,160	572
2	8.1	.456	6,620	4,140	676
3	8.2	.483	6,620	....	714
4	8.3	.484	5,520	3,920	672
Average	8.2	.466	6,200	4,070	658
3-G-3-1	8.8	.482	4,640	4,320	648
2	8.9	.460	3,610	3,470	598
3	8.8	.480	7,010	5,180	746
4	8.6	.460	5,970	4,800	579
Average	8.8	.470	5,310	4,440	643
3-G-4-1	8.8	.471	5,580	5,030	666
2	....	....	....	4,350	580
3	8.3	.474	6,600	4,890	689
4	8.4	.465	7,580	4,780	714
Average	8.5	.470	6,590	4,760	662
Average of Group	8.4	.460	6,300	4,473	669.2

[1]Moisture content based on oven-dry weight.

[2]Specific gravity based on volume at test.

[3]θ is the angle between face grain and applied stress.

[4]Cull.

7 M 54259 F

Table 11.--Results of tension tests (series B) on five-ply yellow-poplar plywood at various angles to face grain (plywood made of 1/16-inch veneer)

Specimen number	Moisture content[1]	Specific gravity[2]	Maximum tensile strength	Fiber stress at proportional limit	Modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
			[3]θ = 0°		
5-A-1-1	8.8	0.453	9,180	6,830	1,153
2	8.5	.462	10,350	8,660	1,195
3	....	....	....	....	....
4	....	....	....	....	....
Average	8.6	.458	9,760	7,730	1,174
5-A-2-1	8.5	.453	11,270	10,380	1,186
2	8.4	.445	10,080	8,320	1,066
3	8.6	.446	9,370	9,170	1,176
4	9.0	.446	9,580	6,470	1,199
Average	8.6	.448	10,080	8,580	1,157
5-A-3-1	8.4	.452	10,970	8,620	1,334
2	8.5	.431	10,520	8,980	1,301
3	8.8	.403	10,960	10,480	1,177
4	8.8	.404	9,220	8,920	1,042
Average	8.6	.422	10,420	9,250	1,214
5-A-4-1	8.8	.418	10,360	7,030	1,138
2	8.8	.418	9,880	7,420	1,236
3	8.9	.424	10,380	10,120	1,144
4	9.2	.417	11,260	5,180	1,264
Average	8.9	.419	10,470	7,440	1,196
Average of Group	8.7	.437	10,241	8,325	1,186.5
			θ = 30°		
5-C-1-1	8.6	0.438	2,980	1,750	372
2	8.8	.433	3,060	1,240	379
3	....	....	....	....	....
4	....	....	....	....	....
Average	8.7	.436	3,020	1,500	376
5-C-2-1	8.7	.418	3,000	1,230	358
2	9.0	.442	2,720	1,750	317
3	9.1	.419	2,930	1,540	360
4	9.2	.427	3,120	1,230	373
Average	9.0	.426	2,940	1,440	352
5-C-3-1	8.7	.436	3,130	1,120	398
2	8.6	.465	3,300	1,650	368
3	8.5	.423	3,260	1,550	368
4	8.5	.431	3,110	1,020	426
Average	8.6	.439	3,200	1,340	390
5-C-4-1	8.2	.427	3,290	1,560	381
2	8.6	.432	3,100	1,780	370
3	8.6	.444	3,240	1,530	385
4	8.9	.414	3,280	1,770	392
Average	8.6	.429	3,230	1,670	382
Average of Group	8.7	.432	3,109	1,484	374.8
			θ = 60°		
5-E-1-1	8.2	0.450	3,180	1,490	331
2	8.2	.441	3,000	1,750	318
3	8.2	.438	2,960	1,350	338
4	8.5	.428	3,260	1,270	335
Average	8.3	.439	3,100	1,460	330
5-E-2-1	8.2	.396	3,020	1,210	332
2	8.0	.415	2,870	1,310	291
3	8.7	.394	3,050	1,320	300
4	8.6	.402	2,960	1,150	339
Average	8.4	.402	2,980	1,250	316
5-E-3-1	8.2	.432	3,170	1,240	348
2	8.5	.447	3,100	1,170	438
3	8.7	.428	3,160	1,500	312
4	8.2	.430	3,130	2,370	319
Average	8.4	.434	3,140	1,570	354
5-E-4-1	8.4	.452	3,280	1,820	347
2	8.3	.458	3,180	1,650	338
3	8.4	.459	3,220	1,860	326
4	8.6	.444	3,340	1,440	392
Average	8.4	.453	3,260	1,690	351
Average of Group	8.4	.432	3,118	1,494	337.8
			θ = 90°		
5-G-1-1	8.8	0.473	7,360	4,110	1,022
2	8.9	.454	8,850	4,130	918
3	9.0	.468	8,140	6,780	846
4	....	....	....	....	....
Average	8.9	.465	8,280	5,010	929
5-G-2-1	8.9	.461	7,200	2,880	951
2	9.1	.448	7,650	3,700	775
3	9.3	.452	8,050	2,460	894
4	9.4	.447	6,820	3,640	693
Average	9.2	.452	7,430	3,170	828
5-G-3-1	8.4	.445	6,760	3,720	784
2	8.4	.444	7,640	2,480	886
3	8.8	.444	6,980	2,870	815
4	9.2	.436	6,620	3,040	822
Average	8.7	.442	7,000	3,030	827
5-G-4-1	9.1	.421	6,270	3,840	654
2	9.2	.414	6,080	5,260	695
3	9.4	.435	7,820	4,050	872
4	8.4	.416	6,080	5,620	650
Average	9.0	.422	6,560	4,690	718
Average of Group	8.9	.445	7,255	3,905	818.5
			θ = 15°		
5-B-1-1	8.5	.444	5,380	3,360	730
2	8.6	.456	5,160	2,300	868
3	8.2	.419	5,130	2,320	774
4	....	....	....	....	....
Average	8.4	.440	5,220	2,660	791
5-B-2-1	9.2	.413	5,000	3,070	631
2	9.0	.418	5,080	2,480	707
3	8.8	.422	5,540	2,070	713
4	9.4	.450	5,180	2,690	622
Average	9.1	.426	5,200	2,580	668
5-B-3-1	8.2	.442	4,780	2,930	638
2	8.2	.424	5,220	3,160	710
3	8.3	.428	5,240	2,520	831
4	8.7	.435	4,980	2,910	710
Average	8.4	.432	5,060	2,880	722
5-B-4-1	8.6	.392	4,650	2,870	668
2	8.6	.398	4,610	2,480	689
3	8.2	.394	4,190	2,910	576
4	8.2	.414	3,980	2,480	637
Average	8.4	.400	4,360	2,680	642
Average of Group	8.6	.425	4,941	2,703	700.3
			θ = 45°		
5-D-1-1	8.5	.438	2,920	1,270	319
2	7.5	.434	2,990	1,280	316
3	7.7	.432	2,800	1,270	314
4	....	....	....	....	....
Average	7.9	.435	2,900	1,270	316
5-D-2-1	8.6	.425	2,740	1,230	301
2	8.1	.438	2,640	1,240	280
3	8.5	.416	2,700	1,310	279
4	8.7	.477	2,840	1,140	295
Average	8.5	.439	2,730	1,230	289
5-D-3-1	8.4	.413	2,850	1,280	276
2	8.7	.413	2,730	1,550	268
3	8.9	....	2,700	1,230	276
4	8.8	.419	2,720	1,130	290
Average	8.7	.415	2,750	1,300	278
5-D-4-1	8.1	.391	2,820	1,080	304
2	8.2	.422	2,800	1,320	278
3	8.5	.418	2,670	1,230	282
4	8.9	.424	2,650	1,300	258
Average	8.4	.414	2,740	1,230	280
Average of Group	8.4	.426	2,771	1,257	289.1
			θ = 75°		
5-F-1-1	8.0	.442	5,260	2,890	620
2	8.2	.434	4,820	2,910	602
3	8.3	.440	5,600	3,530	622
4	....	....	....	....	....
Average	8.2	.439	5,230	3,110	615
5-F-2-1	8.8	.436	5,320	3,060	550
2	8.8	.437	5,040	2,460	636
3	8.8	.416	5,240	2,860	584
4	8.9	.417	4,810	2,850	519
Average	8.8	.426	5,100	2,810	572
5-F-3-1	8.6	.440	4,820	2,460	616
2	8.7	.452	4,640	2,470	561
3	8.6	.447	4,930	2,480	594
4	8.5	.436	4,320	2,470	554
Average	8.6	.444	4,680	2,470	581
5-F-4-1	8.8	.450	4,580	2,460	486
2	8.9	.460	4,520	1,860	612
3	9.1	.455	4,460	2,470	494
4	9.2	.448	4,650	2,450	500
Average	9.0	.453	4,550	2,310	523
Average of Group	8.7	.441	4,867	2,645	570

[1]Moisture content based on oven-dry weight.

[2]Specific gravity based on volume at test.

[3]θ is the angle between face grain and applied stress.

Z M 54260 F

Table 12.--Results of tension tests (series B) on seven-ply yellow-poplar plywood at various angles to face grain (plywood made of 1/16-inch veneer)

[3]θ = 0°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-A-1-1	8.7	0.461	9,180	4,390	1,371
2	8.3	.454	7,840	5,550	1,221
3	8.3	.460	8,350	5,540	1,167
4	8.0	.455	9,860	4,080	1,326
Average	8.3	.458	8,810	4,890	1,271
7-A-2-1	8.0	.465	10,330	6,490	1,248
2	7.8	.462	10,260	7,370	1,249
3	7.8	.460	10,280	5,610	1,233
4	7.5	.434	9,200	5,010	1,106
Average	7.8	.455	10,020	6,120	1,209
7-A-3-1	8.4	.506	9,280	6,400	1,143
2	7.8	.445	9,370	6,420	1,127
3	7.6	.456	8,700	5,830	1,215
4	7.5	.431	9,300	5,850	1,142
Average	7.8	.460	9,160	6,120	1,157
7-A-4-1	7.9	.442	8,350	5,670	1,239
2	8.2	.451	8,960	6,530	1,256
3	8.0	.441	8,010	6,520	1,231
4	7.9	.448	8,180	4,710	1,215
Average	8.0	.446	8,380	5,860	1,235
Average of group	8.0	.455	9,091	5,748	1,218.1

θ = 30°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-C-1-1	8.5	0.460	3,200	1,760	360
2	8.3	.460	3,160	1,640	368
3	8.2	.454	3,160	1,550	373
4	8.3	.467	3,220	1,620	382
Average	8.3	.460	3,180	1,640	371
7-C-2-1	8.7	.437	2,880	1,580	350
2	8.6	.426	3,000	1,460	374
3	8.7	.424	2,860	1,750	341
4	8.3	.431	2,910	1,460	364
Average	8.6	.430	2,910	1,560	357
7-C-3-1	8.4	.439	2,800	1,520	354
2	8.4	.432	2,700	1,540	354
3	8.6	.429	2,980	1,690	357
4	8.3	.438	2,810	1,540	336
Average	8.4	.434	2,820	1,570	350
7-C-4-1	8.8	.414	2,780	1,450	330
2	8.8	.416	2,620	1,440	315
3	8.7	.396	2,680	1,430	305
4	8.5	.400	2,100	1,420	316
Average	8.7	.406	2,540	1,440	316
Average of group	8.5	.433	2,866	1,553	348.7

θ = 60°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-E-1-1	8.0	0.430	2,960	1,440	319
2	8.3	.421	2,990	1,680	315
3	8.5	.420	2,780	1,280	321
4	8.4	.418	2,420	1,190	301
Average	8.3	.422	2,790	1,400	314
7-E-2-1	8.3	.429	2,620	1,430	324
2	8.5	.434	2,320	1,450	293
3	8.1	.435	2,260	1,450	300
4	8.4	.434	2,300	1,480	309
Average	8.3	.433	2,500	1,450	306
7-E-3-1	8.4	.434	2,880	1,470	322
2	8.6	.440	2,880	1,690	326
3	8.6	.450	2,770	1,620	350
4	8.7	.439	2,770	1,460	320
Average	8.6	.441	2,820	1,560	329
7-E-4-1	8.4	.416	2,740	1,530	309
2	8.8	.424	2,630	1,230	312
3	8.6	.430	2,750	1,230	316
4	8.5	.428	2,820	1,510	312
Average	8.6	.424	2,740	1,380	312
Average of group	8.5	.430	2,712	1,446	315.6

θ = 90°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-G-1-1	8.8	0.460	8,790	3,540	950
2	8.6	.472	8,490	5,270	916
3	8.7	.471	9,340	4,100	1,050
4	8.7	.470	8,960	5,210	944
Average	8.7	.468	8,900	4,530	965
7-G-2-1	8.4	.418	5,000	2,940	770
2	8.4	.422	5,280	4,690	778
3	8.3	.435	6,710	4,250	950
4	8.5	.428	5,680	2,750	918
Average	8.4	.426	5,670	3,660	854
7-G-3-1	8.6	.432	7,090	4,410	891
2	8.6	.443	8,300	4,400	867
3	8.5	.438	8,450	4,700	854
4	8.4	.512	7,570	5,580	953
Average	8.5	.456	7,850	4,770	891
7-G-4-1	7.9	.419	5,060	4,450	860
2	8.4	.424	4,000	1,900	916
3	8.3	.430	5,830	4,750	990
4	8.1	.427	4,530	4,430	798
Average	8.2	.425	4,860	3,880	906
Average of group	8.4	.439	6,818	4,211	904.1

θ = 15°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
7-B-1-1	8.3	.448	4,840	3,180	686
2	8.5	.447	4,660	3,160	638
3	8.1	.456	4,560	2,990	654
4	8.2	.436	4,630	2,680	610
Average	8.3	.447	4,670	3,000	647
7-B-2-1	8.0	.436	4,080	2,920	667
2	8.0	.444	4,420	3,250	612
3	8.0	.469	4,300	2,380	661
4	8.1	.454	4,350	3,270	606
Average	8.0	.451	4,290	2,960	636
7-B-3-1	8.0	.448	4,340	2,810	618
2	8.3	.439	4,360	3,140	658
3	8.3	.438	4,990	3,110	694
4	8.4	.445	4,330	2,060	636
Average	8.2	.442	4,500	2,780	652
7-B-4-1	8.3	.445	4,640	2,500	580
2	8.4	.441	4,570	2,340	616
3	8.3	.446	4,470	2,340	600
4	8.4	.452	4,590	2,480	624
Average	8.4	.446	4,570	2,420	605
Average of group	8.2	.447	4,508	2,788	635

θ = 45°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
7-D-1-1	8.7	.422	1,920	1,000	247
2	8.7	.432	2,400	1,070	284
3	8.4	.425	2,570	1,310	290
4	8.4	.430	2,450	1,170	278
Average	8.6	.427	2,340	1,140	275
7-D-2-1	8.4	.449	2,620	1,400	282
2	8.5	.454	2,630	1,260	308
3	8.6	.442	2,600	1,250	291
4	8.4	.431	2,550	1,250	291
Average	8.5	.444	2,600	1,290	293
7-D-3-1	8.2	.411	2,570	1,070	289
2	8.5	.410	2,690	1,070	302
3	8.5	.417	2,460	1,060	295
4	8.8	.406	2,410	990	285
Average	8.5	.411	2,530	1,050	293
7-D-4-1	8.5	.435	2,560	1,340	300
2	8.7	.438	2,460	1,270	296
3	8.1	.439	2,160	960	279
4	8.6	.412	1,990	940	255
Average	8.5	.431	2,290	1,128	282
Average of group	8.5	.428	2,440	1,151	285.8

θ = 75°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
7-F-1-1	8.7	.450	4,810	2,450	609
2	8.6	.458	4,850	2,430	605
3	8.6	.438	4,760	2,190	458
4	8.9	.449	4,340	2,170	527
Average	8.7	.449	4,690	2,310	550
7-F-2-1	8.7	.445	4,740	2,020	582
2	8.8	.446	5,170	2,220	662
3	8.9	.436	4,880	2,810	586
4	9.0	.438	5,140	2,630	620
Average	8.8	.441	4,980	2,420	612
7-F-3-1	9.0	.446	4,460	2,500	546
2	9.0	.448	4,490	2,490	554
3	9.1	.424	4,570	2,340	590
4	9.0	.447	4,590	2,640	537
Average	9.0	.441	4,530	2,490	557
7-F-4-1	8.8	.438	4,660	2,360	572
2	8.8	.444	5,080	2,660	598
3	9.0	.445	5,140	2,530	606
4	8.7	.451	4,920	2,380	599
Average	8.8	.444	4,950	2,480	594
Average of group	8.8	.439	4,788	2,426	578.2

[1]Moisture content based on oven-dry weight.

[2]Specific gravity based on volume at test.

[3]θ is the angle between face grain and applied stress.

Z M 54261 F

Table 13.--Results of tension tests (series B) on five-ply yellow-poplar plywood at various angles to face grain (plywood made of 1/32-inch veneer)

[3] θ = 0°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-A-1-1	8.0	0.400	6,870	3,060	3,700
2	8.4	.395	7,670	5,550	1,156
3	8.1	.402	7,870	5,640	998
4	8.6	.410	6,440	6,220	1,004
Average	8.3	.402	7,210	5,120	1,714
5-A-2-1	8.7	.390	9,600	5,880	1,188
2	8.7	.382	9,260	5,980	1,048
3	7.7	.394	9,960	6,100	1,080
4	8.2	.397	9,570	6,820	1,166
Average	8.3	.391	9,600	6,200	1,120
5-A-3-1	8.0	.376	6,680	6,510	1,095
2	8.2	.362	8,680	5,890	1,047
3	8.1	.373	9,020	6,380	1,010
4	8.1	.372	8,240	4,800	1,066
Average	8.1	.371	8,160	5,900	1,054
5-A-4-1	8.7	.362	8,200	5,360	957
2	8.6	.373	9,750	5,430	1,120
3	8.7	.374	9,000	5,680	1,172
4	8.5	.396	8,650	4,440	1,097
Average	8.6	.376	8,900	5,230	1,086
Average of group	8.3	.385	8,466	5,609	1,244

θ = 15°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-B-1-1	7.8	.384	5,900	2,120	651
2	7.9	.391	5,960	2,470	611
3	8.4	.397	6,580	3,250	698
4	8.1	.388	5,590	2,400	602
Average	8.0	.390	6,010	2,560	640
5-B-2-1	7.8	.410	6,460	2,550	688
2	8.1	.388	6,920	2,380	694
3	8.2	.400	5,590	1,890	578
4	8.3	.394	6,330	2,660	650
Average	8.1	.398	6,320	2,370	652
5-B-3-1	7.8	.401	6,500	3,620	727
2	7.8	.404	6,920	2,920	743
3	7.8	.406	6,290	2,480	689
4	8.0	.424	6,700	3,000	790
Average	7.8	.409	6,600	3,000	737
5-B-4-1	7.6	.420	6,780	2,500	752
2	7.7	.423	6,700	2,360	646
3	8.0	.425	6,350	2,280	701
4	7.6	.424	6,530	1,770	744
Average	7.7	.423	6,590	2,230	711
Average of group	7.9	.405	6,381	2,541	685.2

θ = 30°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-C-1-1	7.8	0.331	4,120	1,680	406
2	7.6	.427	4,040	1,520	440
3	7.8	.421	3,960	1,580	393
4	7.8	.351	3,820	1,700	368
Average	7.8	.382	3,980	1,620	402
5-C-2-1	7.4	.420	4,070	1,990	406
2	8.0	.407	3,940	1,980	411
3	7.9	.415	3,670	1,790	403
4	8.0	.402	3,740	2,160	352
Average	7.8	.411	3,860	1,980	393
5-C-3-1	8.0	.337	3,480	1,840	351
2	8.2	.373	3,510	1,860	351
3	8.4	.396	3,640	1,800	332
4	7.8	.402	3,920	2,210	345
Average	8.1	.377	3,640	1,930	345
5-C-4-1	8.2	.420	4,310	1,980	450
2	7.9	.431	4,440	1,730	438
3	7.9	.416	4,330	2,080	400
4	7.5	.432	4,230	1,940	427
Average	7.9	.425	4,330	1,930	429
Average of group	7.9	.399	3,951	1,865	392.1

θ = 0°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-CP-A-1	7.8	.394	9,380	....	1,079
2	7.6	.398	8,060	6,020	1,056
3	7.6	.373	7,040	3,680	1,008
4	7.5	.391	8,100	4,680	1,006
Average	7.6	.389	8,140	4,790	1,037
5-CP-C-1	8.2	.360	6,500	4,460	1,076
2	8.2	.360	7,080	4,480	963
3	7.9	.366	7,820	4,740	958
4	8.0	.378	7,970	7,260	972
Average	8.1	.366	7,340	5,240	992
5-CP-E-1	7.9	.428	10,450	6,240	1,341
2	7.8	.418	9,760	7,000	1,296
3	8.3	.429	10,560	6,840	1,314
4	8.2	.436	11,250	6,380	1,372
Average	8.0	.428	10,500	6,620	1,331
5-CP-G-1	8.6	.394	9,350	....	1,158
2	8.2	.410	9,370	5,820	1,186
3	8.0	.398	8,660	7,020	1,047
4	7.7	.370	6,660	5,200	990
Average	8.1	.393	8,510	6,010	1,095
Average of group	8.0	.394	8,626	5,701	1,113.9

θ = 45°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-D-1-1	8.6	0.376	3,130	1,610	303
2	7.9	.384	3,210	1,750	299
3	7.8	.376	2,990	1,580	295
4	8.4	.385	3,120	1,700	324
Average	8.2	.380	3,110	1,660	305
5-D-2-1	8.0	.430	3,790	2,030	320
2	7.4	.427	3,820	1,230	384
3	8.6	.370	3,740	1,850	308
4	8.3	.420	3,780	1,190	365
Average	8.1	.412	3,780	1,580	344
5-D-3-1	8.2	.416	3,790	1,850	334
2	7.8	.414	3,670	2,010	298
3	7.9	.408	3,650	1,170	353
4	8.0	.402	3,500	1,970	318
Average	8.0	.410	3,650	1,750	326
5-D-4-1	8.2	.397	3,390	1,840	288
2	8.4	.442	3,260	1,840	287
3	8.2	.413	3,420	960	350
4	8.4	.404	3,460	1,090	356
Average	8.3	.414	3,380	1,430	320
Average of group	8.1	.404	3,482	1,604	323.9

θ = 60°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-E-1-1	7.8	.426	4,360	1,930	390
2	8.1	.432	4,410	1,810	400
3	8.1	.436	4,380	1,780	400
4	8.2	.429	4,350	1,920	377
Average	8.0	.431	4,380	1,860	392
5-E-2-1	7.0	.408	4,130	1,910	360
2	8.4	.421	4,300	2,060	360
3	7.8	.412	3,890	1,990	365
4	7.4	.407	4,400	1,710	390
Average	7.6	.412	4,180	1,920	369
5-E-3-1	8.0	.397	4,040	1,850	362
2	8.2	.401	3,950	1,730	356
3	8.4	.396	3,810	1,950	342
4	8.0	.400	3,840	1,820	337
Average	8.2	.398	3,910	1,840	349
5-E-4-1	7.3	.420	3,700	1,680	340
2	7.6	.413	3,670	2,180	320
3	7.1	.386	3,720	2,230	343
4	8.0	.382	3,570	1,400	349
Average	7.5	.400	3,660	1,870	338
Average of group	7.8	.410	4,032	1,872	361.9

θ = 0°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-CP-B-1	8.2	0.413	8,530	5,140	1,141
2	7.5	.416	9,820	5,460	1,262
3	7.3	.415	7,940	6,000	1,270
4	7.7	.404	7,820	5,980	1,207
Average	7.7	.412	8,530	5,640	1,220
5-CP-D-1	8.0	.361	8,250	5,400	1,008
2	8.2	.363	8,160	5,440	1,078
3	8.2	.370	8,220	....	939
4	7.9	.370	7,820	4,470	993
Average	8.1	.366	8,110	5,100	1,004
5-CP-F-1	8.5	.378	8,980	7,120	1,250
2	8.3	.364	8,340	6,240	1,009
3	8.3	.384	9,080	6,420	1,166
4	7.7	.388	9,360	....	1,104
Average	8.2	.378	8,940	6,590	1,132
5-CP-H-1	8.2	.428	7,520	5,560	1,341
2	8.1	.422	11,400	5,650	1,362
3	8.0	.440	10,740	7,680	1,360
4	7.8	.426	10,200	6,980	1,316
Average	8.0	.429	9,960	6,470	1,345
Average of group	8.0	.396	8,886	5,967	1,175.4

θ = 75°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-F-1-1	7.8	.402	5,560	1,760	645
2	7.6	.385	5,180	2,300	596
3	7.7	.406	5,780	3,310	570
4	7.6	.398	5,280	2,890	551
Average	7.7	.398	5,450	2,560	590
5-F-2-1	7.8	.378	6,130	2,690	580
2	7.8	.388	3,630	2,270	547
3	8.0	.384	5,640	2,820	537
4	7.8	.378	5,270	2,200	499
Average	7.8	.382	5,170	2,500	541
5-F-3-1	7.5	.450	5,840	2,210	605
2	9.9	.454	6,600	3,120	610
3	7.6	.442	5,620	2,420	562
4	7.6	.444	3,630	2,380	559
Average	8.2	.448	5,420	2,530	584
5-F-4-1	7.7	.409	6,100	3,090	518
2	7.6	.417	6,100	2,640	551
3	7.8	.444	5,320	2,270	536
4	7.8	.411	6,270	2,770	538
Average	7.7	.413	5,950	2,690	536
Average of group	7.9	.410	5,497	2,571	562.8

θ = 90°

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
5-G-1-1	7.7	0.395	7,350	3,540	810
2	7.6	.399	7,040	3,780	788
3	7.5	.386	6,640	3,450	670
4	7.6	.368	6,420	3,230	681
Average	7.6	.387	6,860	3,500	737
5-G-2-1	7.4	.407	6,400	3,150	792
2	7.3	.404	6,880	4,720	774
3	7.0	.398	5,510	3,740	738
4	7.2	.408	6,620	4,440	688
Average	7.2	.404	6,350	4,010	748
5-G-3-1	7.7	.432	7,580	4,310	899
2	7.2	.426	7,440	4,340	748
3	7.6	.431	8,020	4,280	800
4	7.6	.429	8,190	4,490	809
Average	7.5	.430	7,810	4,360	814
5-G-4-1	7.8	.415	8,000	4,870	812
2	7.7	.416	8,010	4,020	843
3	8.0	.413	8,700	4,950	877
4	7.8	.412	7,560	4,880	813
Average	7.8	.414	8,070	4,680	836
Average of group	7.5	.409	7,272	4,137	783.9

[1] Moisture content based on oven-dry weight.

[2] Specific gravity based on volume at test.

[3] θ is the angle between face grain and applied stress.

Z M 54262 F

Table 14.—**Results of tension tests (series B) on seven-ply yellow-poplar plywood at various angles to face grain (plywood made of 1/32-inch veneer)**

$\theta = 0°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-A-1-1	9.0	0.371	6,340	4,900	1,077
2	8.9	.362	7,660	3,180	1,010
3	9.2	.358	7,520	....	1,006
4	9.0	.374	6,180	....	872
Average	9.0	.366	6,920	4,040	991
7-A-2-1	9.2	.374	8,820	6,040	1,112
2	9.0	.402	10,020	5,360	1,094
3	9.4	.381	8,710	5,630	1,038
4	9.1	.398	8,710	....	1,044
Average	9.2	.389	9,060	5,680	1,072
7-A-3-1	8.8	.362	6,700	5,530	888
2	8.9	.349	6,480	6,480	1,097
3	9.0	.382	7,520	3,490	1,248
4	8.8	.351	6,820	....	932
Average	8.9	.361	6,880	5,170	1,041
7-A-4-1	9.1	.362	7,360	2,750	1,159
2	9.1	.372	7,080	3,660	938
3	9.0	.371	8,040	7,360	968
4	9.4	.359	8,100	3,930	1,131
Average	9.2	.366	7,640	4,420	1,049
Average of Group	9.1	.371	7,629	4,859	1,038.4

$\theta = 30°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-C-1-1	9.4	0.374	3,810	1,660	354
2	9.4	.391	3,710	1,640	338
3	9.3	.390	3,680	1,700	337
4	9.1	.393	3,730	1,930	328
Average	9.3	.387	3,730	1,730	339
7-C-2-1	9.2	.385	3,880	2,390	355
2	9.3	.360	4,020	1,810	398
3	9.2	.379	3,950	2,120	343
4	9.3	.381	4,050	2,130	357
Average	9.2	.376	3,980	2,110	363
7-C-3-1	8.9	.394	4,050	1,940	399
2	8.7	.380	4,020	2,090	386
3	8.8	.399	3,980	2,080	361
4	8.8	.356	4,060	1,780	395
Average	8.8	.382	4,030	1,970	385
7-C-4-1	8.6	.375	3,800	1,580	368
2	8.9	.364	3,790	1,740	358
3	9.2	.374	3,820	1,890	354
4	8.8	.371	3,760	1,900	340
Average	8.9	.371	3,790	1,780	355
Average of Group	9.0	.379	3,882	1,899	360.7

$\theta = 45°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-D-1-1	9.4	0.352	3,320	1,030	294
2	9.2	.372	3,200	1,430	281
3	9.2	.368	3,270	1,470	265
4	9.0	.378	3,290	1,390	275
Average	9.2	.368	3,270	1,330	279
7-D-2-1	8.9	.380	3,520	1,330	294
2	8.6	.374	3,460	1,600	292
3	8.7	.357	3,320	1,230	284
4	8.4	.376	3,640	1,240	282
Average	8.6	.372	3,480	1,350	288
7-D-3-1	9.2	.367	3,080	1,360	270
2	9.6	.367	3,260	1,260	257
3	10.1	.368	3,540	1,640	254
4	9.8	.367	3,080	1,690	253
Average	9.7	.367	3,240	1,490	258
7-D-4-1	9.3	.352	3,400	1,380	266
2	9.8	.379	3,180	1,600	258
3	9.7	.395	3,320	1,610	273
4	9.6	.369	3,470	1,580	267
Average	9.6	.374	3,340	1,540	266
Average of Group	9.3	.370	3,334	1,428	272.8

$\theta = 0°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-CP-B-1	9.4	0.338	8,800	8,430	892
2	9.1	.346	7,990	....	797
3	9.1	.340	7,220	5,880	854
4	9.0	.334	7,950	4,500	858
Average	9.2	.340	7,990	6,270	850
7-CP-D-1	9.1	.413	10,210	8,640	1,030
2	9.3	.393	9,260	6,270	996
3	9.2	.402	8,660	7,200	1,014
4	9.1	.394	8,860	6,200	1,103
Average	9.2	.400	9,250	7,080	1,036
7-CP-F-1	9.3	.414	9,400	5,130	1,146
2	9.2	.418	9,350	6,340	1,070
3	9.2	.408	9,200	4,640	1,077
4	9.2	.432	9,360	6,320	1,061
Average	9.2	.418	9,330	5,610	1,088
7-CP-H-1	9.1	.396	9,940	4,720	1,026
2	10.1	.399	8,220	....	966
3	10.1	.390	7,920	8,000	970
4	9.3	.413	9,530	5,580	998
Average	9.6	.400	9,400	6,100	990
Average of Group	9.3	.389	8,992	6,275	991.1

$\theta = 90°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-G-1-1	9.1	0.372	8,040	4,560	788
2	10.2	.360	8,760	3,860	867
3	8.4	.408	9,110	5,120	884
4	10.2	.365	8,120	4,820	838
Average	9.5	.376	8,510	4,590	844
7-G-2-1	10.2	.365	8,360	3,950	868
2	10.0	.342	8,140	4,880	814
3	9.2	.381	8,270	4,930	780
4	10.3	.350	8,890	4,660	800
Average	9.9	.360	8,420	4,600	816
7-G-3-1	10.4	.367	6,780	4,380	782
2	10.8	.346	8,980	4,890	829
3	10.5	.342	8,770	5,600	787
4	10.5	.366	8,920	4,130	818
Average	10.6	.355	8,360	4,750	804
7-G-4-1	9.2	.373	7,230	4,820	796
2	9.3	.396	8,440	4,580	830
3	9.5	.409	9,150	4,820	904
4	....	....	....	....	....
Average	9.3	.393	8,270	4,740	843
Average of Group	9.8	.371	8,397	4,667	825.7

$\theta = 15°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-B-1-1	9.0	.396	6,170	5,220	650
2	9.0	.432	6,070	2,480	724
3	8.6	.378	5,930	2,760	670
4	8.8	.383	5,890	3,490	670
Average	8.8	.397	6,020	3,490	678
7-B-2-1	8.5	.386	6,050	2,650	596
2	8.8	.384	5,800	2,500	617
3	9.0	.450	6,040	3,210	614
4	8.8	.394	5,760	3,360	616
Average	8.8	.404	5,910	2,930	611
7-B-3-1	9.2	.403	5,460	3,460	592
2	9.0	.382	5,480	3,320	554
3	8.7	.365	5,280	3,590	588
4	8.7	.356	5,320	3,420	611
Average	8.9	.376	5,380	3,450	586
7-B-4-1	8.9	.399	5,580	3,320	598
2	9.0	.360	5,640	2,900	645
3	9.2	.412	6,200	3,620	644
4	8.7	.372	5,980	3,170	616
Average	9.0	.386	5,850	3,250	626
Average of Group	8.9	.391	5,791	3,279	625.3

$\theta = 0°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-CP-A-1	9.0	.395	7,980	....	1,110
2	8.9	.373	7,720	7,460	1,089
3	8.8	.369	6,890	....	1,045
4	8.6	.385	7,820	6,010	1,022
Average	8.8	.380	7,600	6,740	1,066
7-CP-C-1	9.1	.412	10,000	3,670	1,243
2	9.0	.431	8,840	4,640	1,195
3	8.8	.414	9,600	3,710	1,238
4	8.9	.454	9,440	6,120	1,288
Average	9.0	.428	9,470	4,540	1,241
7-CP-E-1	9.0	.385	8,210	6,300	1,100
2	9.0	.369	10,250	....	1,080
3	8.9	.380	10,210	....	1,095
4	8.9	.413	8,240	8,240	1,120
Average	9.0	.387	9,230	7,270	1,099
7-CP-G-1	9.0	.373	9,030	5,790	1,026
2	9.2	.369	8,780	....	1,125
3	8.9	.363	8,960	6,400	1,012
4	8.9	.364	9,470	....	1,106
Average	9.0	.367	9,060	6,100	1,067
Average of Group	8.9	.391	8,840	5,834	1,118.4

$\theta = 60°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-E-1-1	10.3	.379	3,600	1,600	276
2	10.2	.354	3,590	1,610	268
3	10.2	.392	3,590	1,620	268
4	10.2	.379	3,690	1,610	285
Average	10.2	.376	3,620	1,610	274
7-E-2-1	10.0	.442	4,020	1,680	333
2	9.8	.446	3,990	1,580	333
3	9.7	.428	3,960	1,580	314
4	9.6	.436	3,950	1,710	298
Average	9.8	.438	3,980	1,640	320
7-E-3-1	9.9	.400	3,810	1,560	308
2	9.8	.386	3,830	1,700	298
3	9.9	.386	3,860	1,700	315
4	9.6	.403	3,820	1,680	305
Average	9.8	.394	3,830	1,660	306
7-E-4-1	9.8	.382	3,820	1,710	296
2	9.2	.393	3,710	1,720	308
3	9.6	.396	3,750	1,710	305
4	9.5	.390	3,730	1,680	306
Average	9.5	.390	3,750	1,700	304
Average of Group	9.8	.400	3,795	1,653	301.0

$\theta = 75°$

Specimen number (1)	Moisture content[1] (2)	Specific gravity[2] (3)	Maximum tensile strength (4)	Fiber stress at proportional limit (5)	Modulus of elasticity (6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
7-F-1-1	8.7	.383	4,920	2,250	420
2	8.9	.390	4,960	2,950	441
3	8.7	.380	5,120	2,600	456
4	8.4	.376	5,180	2,720	473
Average	8.7	.382	5,040	2,630	448
7-F-2-1	8.5	.369	6,100	3,160	540
2	8.9	.368	5,980	3,070	541
3	8.6	.379	6,360	2,780	562
4	8.4	.409	5,900	2,760	519
Average	8.6	.381	6,080	2,940	540
7-F-3-1	8.9	.383	5,540	2,620	472
2	8.4	.365	5,450	2,920	480
3	8.4	.396	5,400	2,760	531
4	8.3	.369	5,180	3,050	448
Average	8.5	.378	5,390	2,840	483
7-F-4-1	8.5	.375	4,360	2,050	458
2	8.4	.368	4,490	2,490	465
3	8.8	.362	4,460	2,610	414
4	8.7	.367	4,370	2,590	480
Average	8.6	.368	4,420	2,440	454
Average of Group	8.6	.377	5,236	2,711	481.2

[1]Moisture content based on oven-dry weight.

[2]Specific gravity based on volume at test.

[3]θ is the angle between face grain and applied stress.

Z M 54263 F

Table 15.--Results of tension tests (series B) on nine-ply yellow-poplar plywood at various angles to face grain (plywood made of 1/32-inch veneer)

Specimen number	Moisture content[1]	Specific gravity[2]	Maximum tensile strength	Fiber stress at proportional limit	Modulus of elasticity
(1)	(2)	(3)	(4)	(5)	(6)
	Percent		Lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.
			[3]θ = 0°		
9-A-1-1	7.6	0.457	11,940	....	1,261
2	7.2	.455	11,840	....	1,200
3	7.6	.471	12,350	11,450	1,242
4	7.4	.479	12,220	....	1,310
Average	7.4	.466	12,090	11,450	1,253
9-A-2-1	7.8	.462	11,380	....	1,300
2	7.7	.493	10,010	6,220	1,339
3	7.4	.477	12,820	....	1,348
4	7.6	.474	13,320	12,020	1,336
Average	7.6	.476	11,880	9,120	1,331
9-A-3-1	7.6	.475	9,840	7,000	1,443
2	7.5	.479	11,140	9,360	1,337
3	7.4	.458	11,420	10,240	1,344
4	7.2	.466	11,900	8,840	1,338
Average	7.4	.470	11,080	8,860	1,366
9-A-4-1	7.7	.434	11,130	8,140	1,130
2	7.6	.426	8,780	7,980	1,022
3	7.4	.421	9,180	6,710	1,002
4	7.1	.410	8,940	5,310	998
Average	7.4	.423	9,510	7,040	1,038
Average of group	7.5	.459	11,138	8,479	1,247
			θ = 15°		
9-B-1-1	7.6	.387	4,440	3,880	562
2	8.0	.380	5,310	2,600	594
3	7.8	.380	5,160	2,630	625
4	7.7	.371	5,560	3,070	698
Average	7.8	.380	5,120	3,040	620
9-B-2-1	6.8	.475	7,240	2,870	972
2	6.8	.445	6,670	2,840	805
3	7.0	.446	6,370	2,380	826
4	6.8	.427	7,060	3,340	856
Average	6.8	.448	6,840	2,860	865
9-B-3-1	7.1	.460	6,910	3,140	938
2	7.0	.441	6,880	3,360	846
3	6.8	.400	6,760	2,900	798
4	7.2	.398	6,900	3,360	748
Average	7.0	.425	6,860	3,190	832
9-B-4-1	7.0	.429	6,520	2,810	740
2	7.1	.440	6,720	2,330	933
3	7.1	.428	6,370	3,230	778
4	7.2	.430	6,540	2,960	750
Average	7.1	.432	6,540	2,830	800
Average of group	7.2	.421	6,338	2,981	779.3
			θ = 30°		
9-C-1-1	7.8	0.404	3,600	1,720	434
2	7.9	.393	3,700	1,400	393
3	7.8	.414	3,920	1,940	429
4	7.7	.420	4,010	1,520	433
Average	7.8	.408	3,810	1,640	420
9-C-2-1	7.2	.433	....	1,750	412
2	7.4	.426	3,860	1,750	382
3	7.0	.422	3,710	1,640	354
4	7.2	.423	3,840	1,400	376
Average	7.2	.426	3,800	1,640	381
9-C-3-1	7.2	.433	4,150	1,280	452
2	7.4	.372	3,980	1,140	432
3	7.4	.420	3,910	1,250	398
4	7.7	.356	4,070	1,700	409
Average	7.4	.395	4,030	1,340	423
9-C-4-1	7.6	.425	3,930	1,560	400
2	7.6	.362	4,070	1,320	422
3	7.2	.436	4,220	1,920	413
4	7.1	.419	4,120	1,080	460
Average	7.4	.411	4,080	1,470	424
Average of group	7.5	.410	3,939	1,523	411.8
			θ = 0°		
9-CP-A-1	7.6	.435	11,150	....	1,148
2	7.6	.452	11,010	6,740	1,246
3	7.8	.456	11,300	....	1,324
4	7.8	.452	11,440	6,680	1,376
Average	7.7	.449	11,220	6,710	1,274
9-CP-C-1	8.2	.392	7,900	5,120	799
2	8.1	.386	6,660	4,160	774
3	8.2	.397	8,520	2,550	1,042
4	8.2	.388	7,670	3,690	907
Average	8.2	.391	7,690	3,880	880
9-CP-E-1	8.0	.405	9,360	6,070	1,146
2	8.0	.418	9,960	3,280	1,236
3	7.8	.422	10,770	4,210	1,257
4	7.9	.421	8,200	5,400	1,032
Average	7.9	.416	9,570	4,740	1,168
9-CP-G-1	8.0	.437	9,760	2,830	681
2	7.4	.430	8,240	....	1,178
3	7.6	.442	8,270	4,280	1,140
4	7.5	.421	7,620	4,960	1,077
Average	7.6	.432	8,470	4,020	1,019
Average of group	7.9	.422	9,239	4,613	1,085
			θ = 45°		
9-D-1-1	7.7	0.428	3,760	1,160	381
2	7.2	.437	3,680	1,090	376
3	7.5	.441	3,790	1,810	325
4	7.3	.452	3,700	1,730	367
Average	7.4	.440	3,730	1,450	362
9-D-2-1	7.4	.438	3,930	1,320	399
2	7.6	.440	3,790	960	408
3	7.4	.430	3,740	1,320	382
4	7.4	.442	3,510	1,190	354
Average	7.4	.438	3,740	1,200	386
9-D-3-1	7.4	.428	3,870	1,810	419
2	7.2	.458	3,730	840	443
3	7.7	.438	3,850	1,560	370
4	7.2	.460	3,870	1,080	414
Average	7.4	.446	3,830	1,320	412
9-D-4-1	7.2	.438	4,400	1,200	478
2	7.2	.436	4,370	1,440	458
3	7.6	.432	4,240	1,200	487
4	7.5	.444	4,320	1,790	412
Average	7.4	.438	4,330	1,410	459
Average of group	7.4	.439	3,909	1,344	404.6
			θ = 60°		
9-E-1-1	7.4	.442	4,880	1,840	480
2	7.3	.449	5,130	2,080	546
3	7.3	.429	4,330	2,080	526
4	7.4	.418	4,500	1,930	460
Average	7.4	.434	4,710	1,980	503
9-E-2-1	7.4	.424	4,280	1,810	384
2	7.1	.420	4,360	1,090	473
3	7.2	.417	4,110	1,570	398
4	7.5	.426	4,330	1,680	417
Average	7.3	.422	4,270	1,540	418
9-E-3-1	7.6	.440	4,470	1,920	432
2	7.3	.422	4,440	1,450	466
3	7.6	.420	4,520	1,560	454
4	7.4	.412	4,520	1,200	478
Average	7.5	.424	4,490	1,530	458
9-E-4-1	7.4	.444	4,960	1,840	466
2	7.6	.430	4,960	1,610	520
3	7.2	.438	4,900	1,230	512
4	7.2	.448	4,660	1,080	496
Average	7.4	.440	4,870	1,440	498
Average of group	7.4	.430	4,584	1,623	469.2
			θ = 0°		
9-CP-B-1	7.5	0.430	12,040	6,120	1,330
2	7.4	.420	10,140	7,510	1,252
3	7.2	.422	11,010	5,650	1,241
4	7.2	.408	7,810	5,680	1,124
Average	7.3	.420	10,250	6,240	1,237
9-CP-D-1	7.0	.433	9,100	5,020	1,036
2	7.3	.442	8,120	5,920	986
3	7.2	.448	8,300	4,620	1,004
4	6.8	.434	8,330	8,210	972
Average	7.1	.439	8,460	5,940	1,000
9-CP-F-1	7.6	.432	11,480	6,570	1,326
2	7.1	.442	11,980	5,850	1,258
3	7.6	.430	11,980	6,240	1,212
4	7.6	.422	11,360	6,460	1,231
Average	7.5	.432	11,700	6,280	1,257
9-CP-H-1	7.4	.441	9,620	4,960	1,378
2	7.2	.425	10,560	....	1,156
3	7.2	.448	12,920	7,760	1,317
4	7.3	.424	10,460	7,340	1,158
Average	7.3	.434	10,890	6,690	1,252
Average of group	7.3	.431	10,326	6,261	1,186
			θ = 75°		
9-F-1-1	7.1	.357	5,550	2,800	541
2	6.9	.288	5,030	2,340	495
3	7.1	.333	4,560	1,880	489
4	7.1	.334	5,520	1,740	443
Average	7.0	.328	5,160	2,190	492
9-F-2-1	6.7	.363	5,860	1,700	658
2	6.6	.358	5,660	1,810	659
3	6.6	.349	5,410	1,350	629
4	6.5	.350	7,940	1,940	993
Average	6.6	.355	6,220	1,700	735
9-F-3-1	6.6	.368	5,100	2,110	470
2	6.6	.380	5,460	2,510	478
3	6.7	.369	5,640	2,500	459
4	6.7	.382	5,500	1,900	530
Average	6.6	.375	5,420	2,260	484
9-F-4-1	6.8	.421	5,520	2,430	559
2	6.7	.421	5,370	2,260	545
3	6.9	.426	4,940	2,660	494
4	....	....	....	....	....
Average	6.8	.423	5,280	2,450	533
Average of group	6.8	.370	5,537	2,129	562.8
			θ = 90°		
9-G-1-1	8.3	0.331	5,150	2,480	479
2	8.1	.327	5,480	2,290	494
3	7.8	.326	5,530	2,080	534
4	8.4	.332	5,570	3,010	489
Average	8.2	.329	5,430	2,460	499
9-G-2-1	7.6	.428	8,960	4,240	911
2	7.8	.419	10,300	4,490	966
3	7.5	.423	9,810	5,460	880
4	7.5	.423	10,050	4,910	998
Average	7.6	.423	9,780	4,780	939
9-G-3-1	7.8	.330	6,320	2,920	595
2	7.3	.323	5,500	1,690	719
3	7.4	.325	5,690	1,940	768
4	7.3	.374	6,040	2,290	572
Average	7.4	.338	5,890	2,210	664
(4)					
(4)					
(4)					
(4)					
(4)					
Average of group	7.7	.363	7,033	3,150	700.4

[1]Moisture content based on oven-dry weight.

[2]Specific gravity based on volume at test.

[3]θ is the angle between face grain and applied stress.

[4]No specimen.

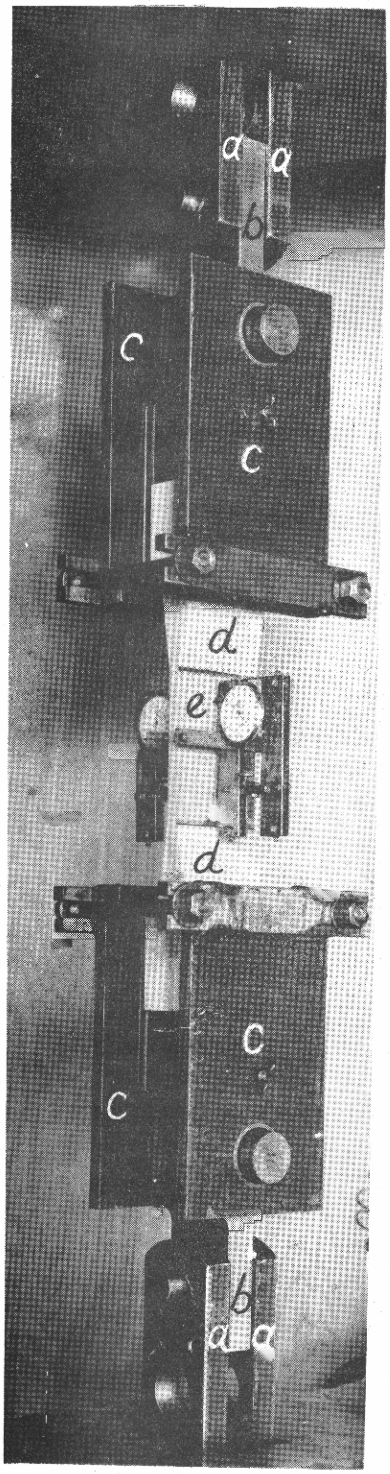
Z M 54264 F

Table 16.--Effect of ply thickness on maximum tensile stress (Series B)

Number of Plies	Sum of maximum stresses at 0° and 90°	Deviation from average value	Maximum stress at 45°	Deviation from average value
(1)	(2)	(3)	(4)	(5)
	Lb.per sq.in.	Percent	Lb.per sq.in.	Percent
		1/16-inch veneers		
3	17,334	+3	2,460	-4
5	17,496	+3	2,771	+9
7	15,907	-6	2,440	-5
Average...	16,913		2,557	
		1/32-inch veneers		
5	15,928	-4	3,482	-3
7	16,884	+1	3,334	-7
9	17,267	+3	3,909	+10
Average...	16,693		3,575	

Table 17.--Comparison of Stress ratios to parallel-ply-area ratios (Series B)

Number of plies	Maximum stress at 90°	Maximum stress at 0°	Ratio of maximum stress 0° to 90°	Ratio of parallel ply area 0° to 90°
(1)	(2)	(3)	(4)	(5)
	Lb.per sq.in.	Lb.per sq.in.		
		1/16-inch veneers		
3	6,300	11,034	1.75	2.00
5	7,255	10,241	1.41	1.50
7	6,818	9,091	1.31	1.33
		1/32-inch veneers		
5	7,272	8,656	1.19	1.50
7	8,397	8,487	1.01	1.33
9	7,033	10,234	1.46	1.20



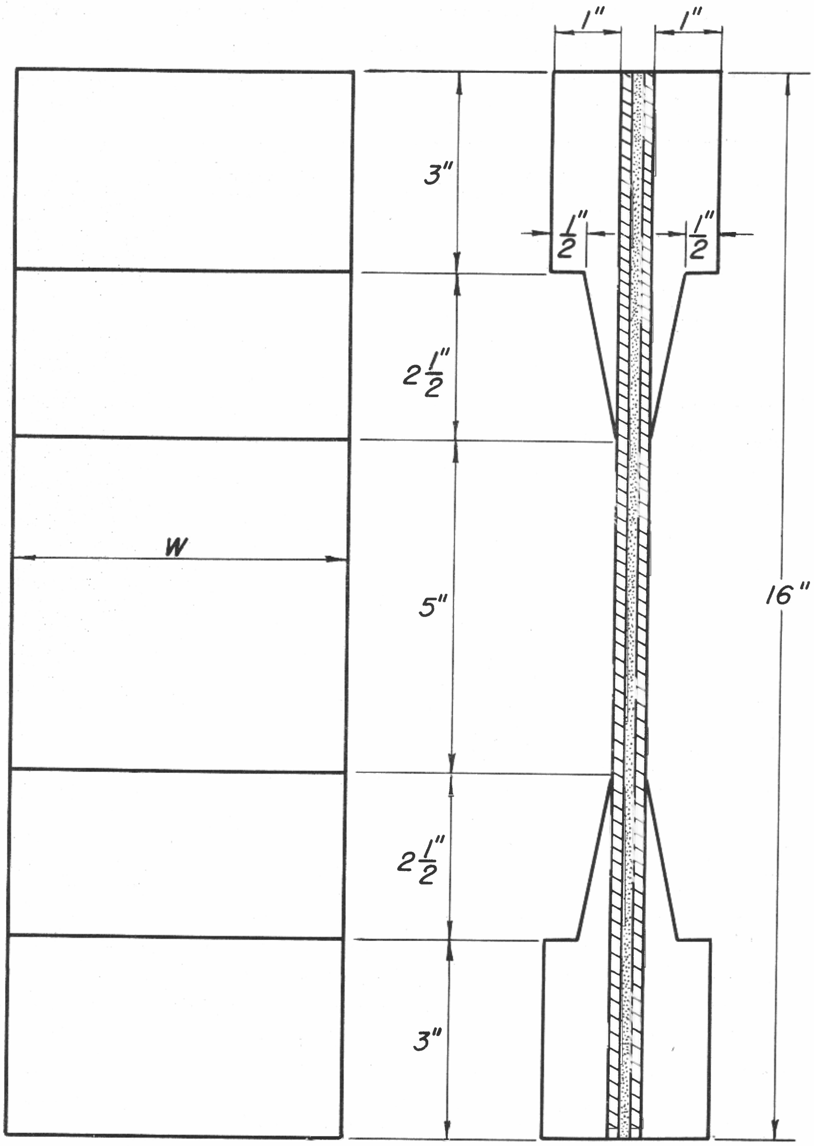


Figure 12.--Left; apparatus, with specimen in place, used in tests of series A. Steel bars a are attached to upper and lower heads of the testing machine, connecting links b transmit the load to gripping plates c equipped with ledges that bear against shoulders on the hard maple blocks d glued to the specimen e. Extensometers attached to the specimen measure deformation. Right; details of specimen used in tests of series A.

Z M 54397 F

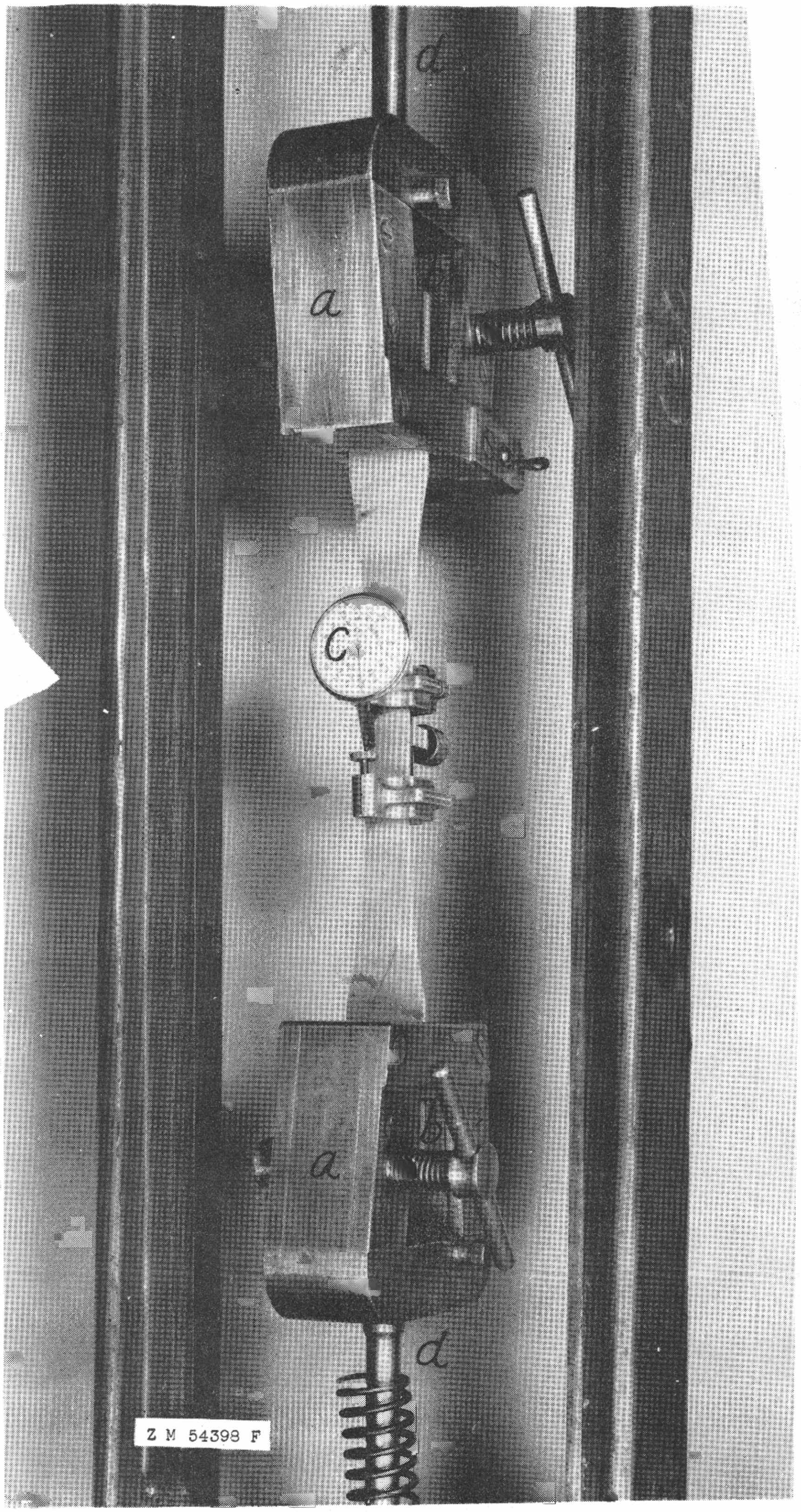


Figure 13.--Apparatus and type of specimen used in the tests of series B. Steel horseshoe-shaped frames a encase wedge-shaped gripping blocks b. An extensometer c of 1-inch gage length is attached to the specimen to measure deformations. Stress is transmitted from the upper and lower heads of the testing machine through tension bars d.

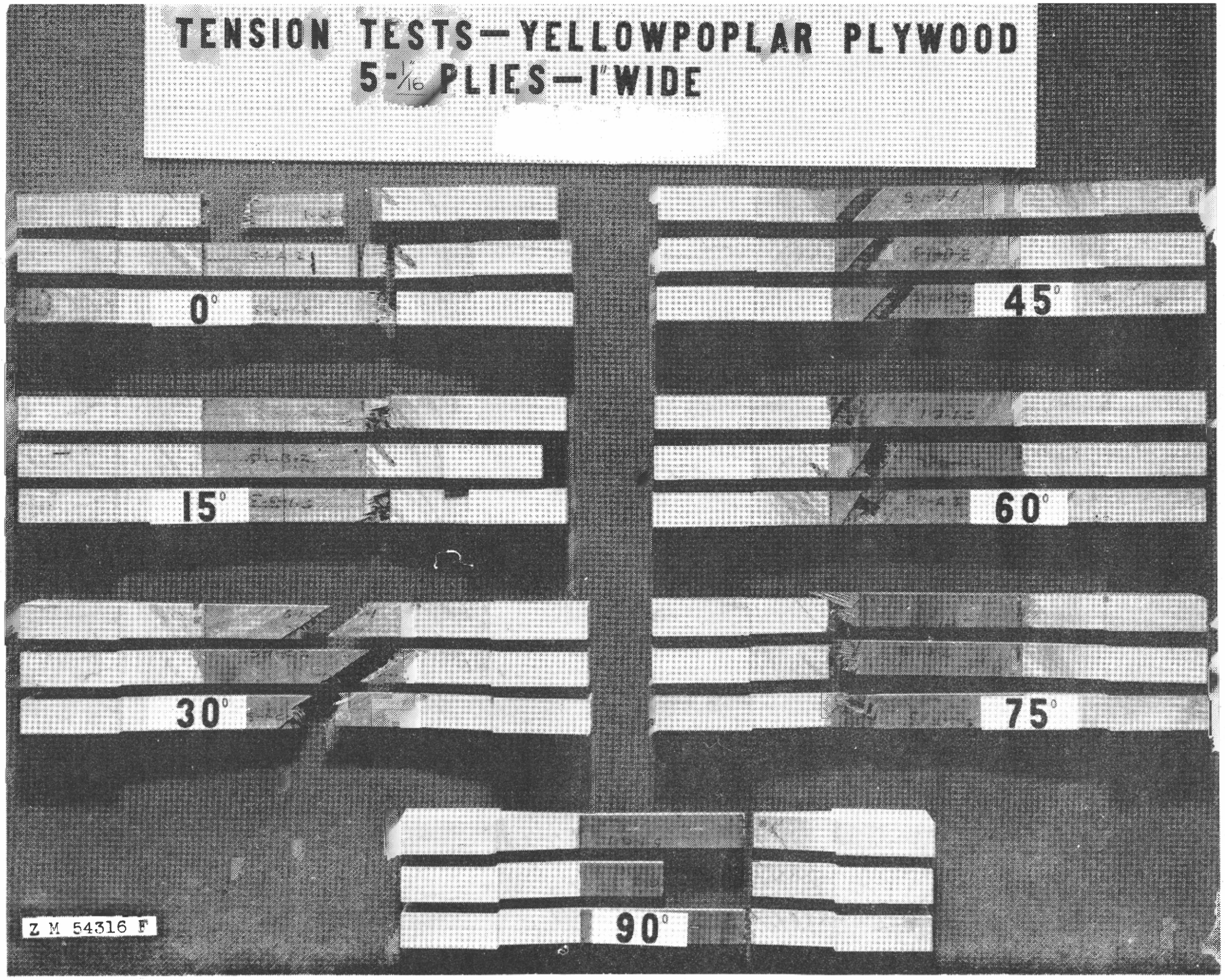


Figure 14.--Types of failure in tension tests of yellowpoplar plywood made of five 1/16-inch plies, 1 inch wide.

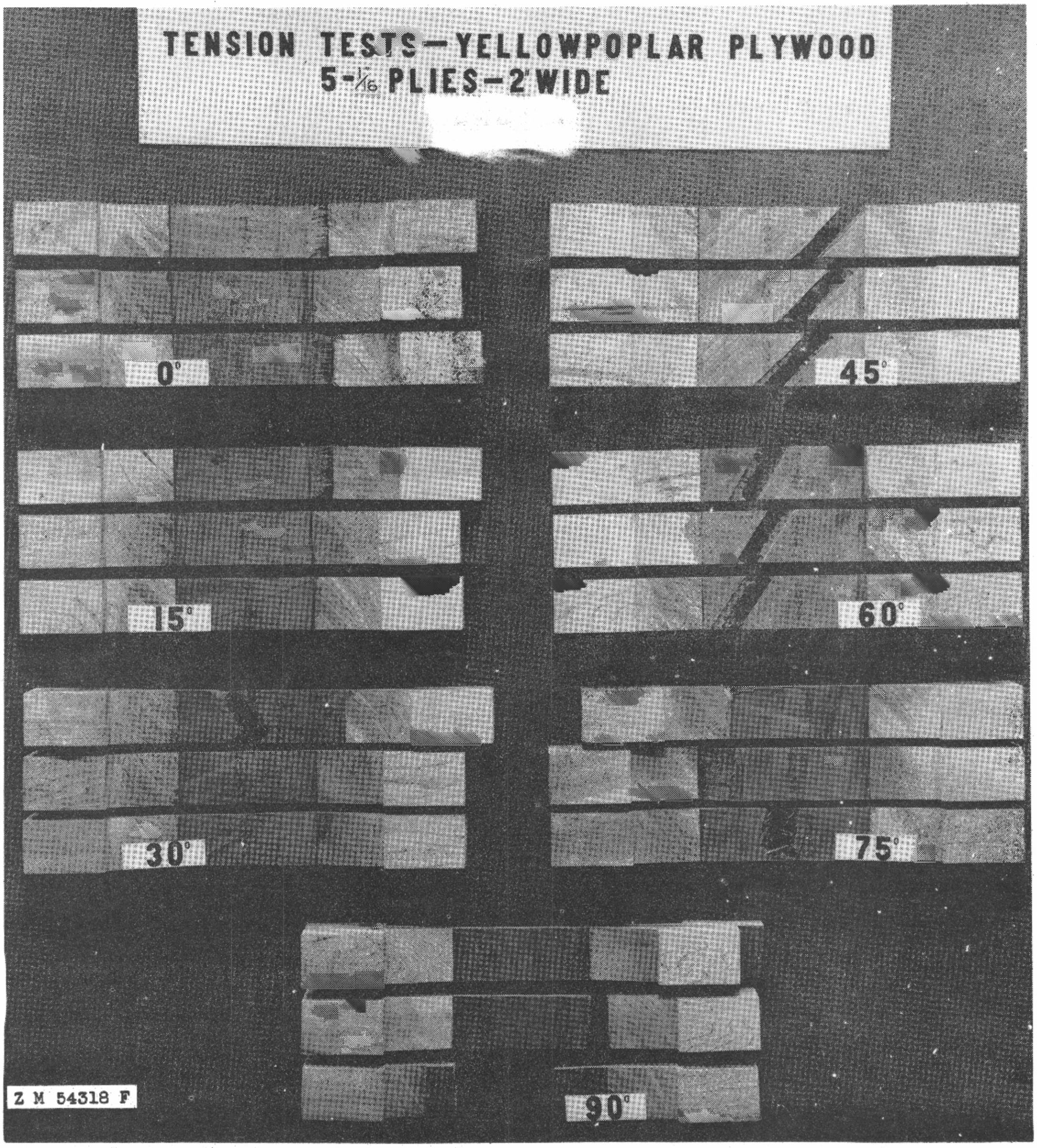


Figure 15.--Types of failure in tension tests of yellowpoplar plywood made of five 1/16-inch plies, 2 inches wide.

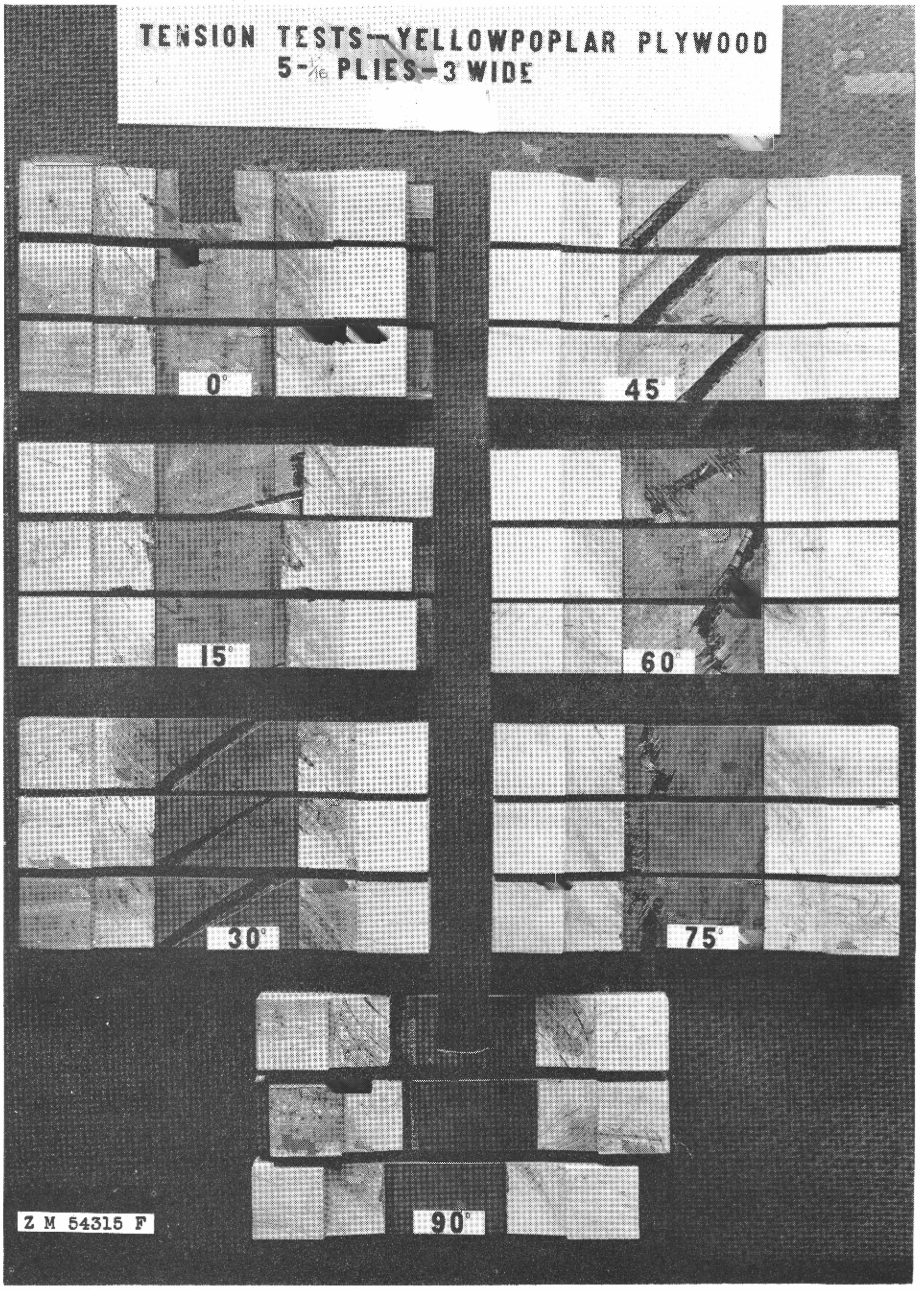


Figure 16.--Types of failure in tension tests of yellowpoplar plywood made of five 1/16-inch plies, 3 inches wide.

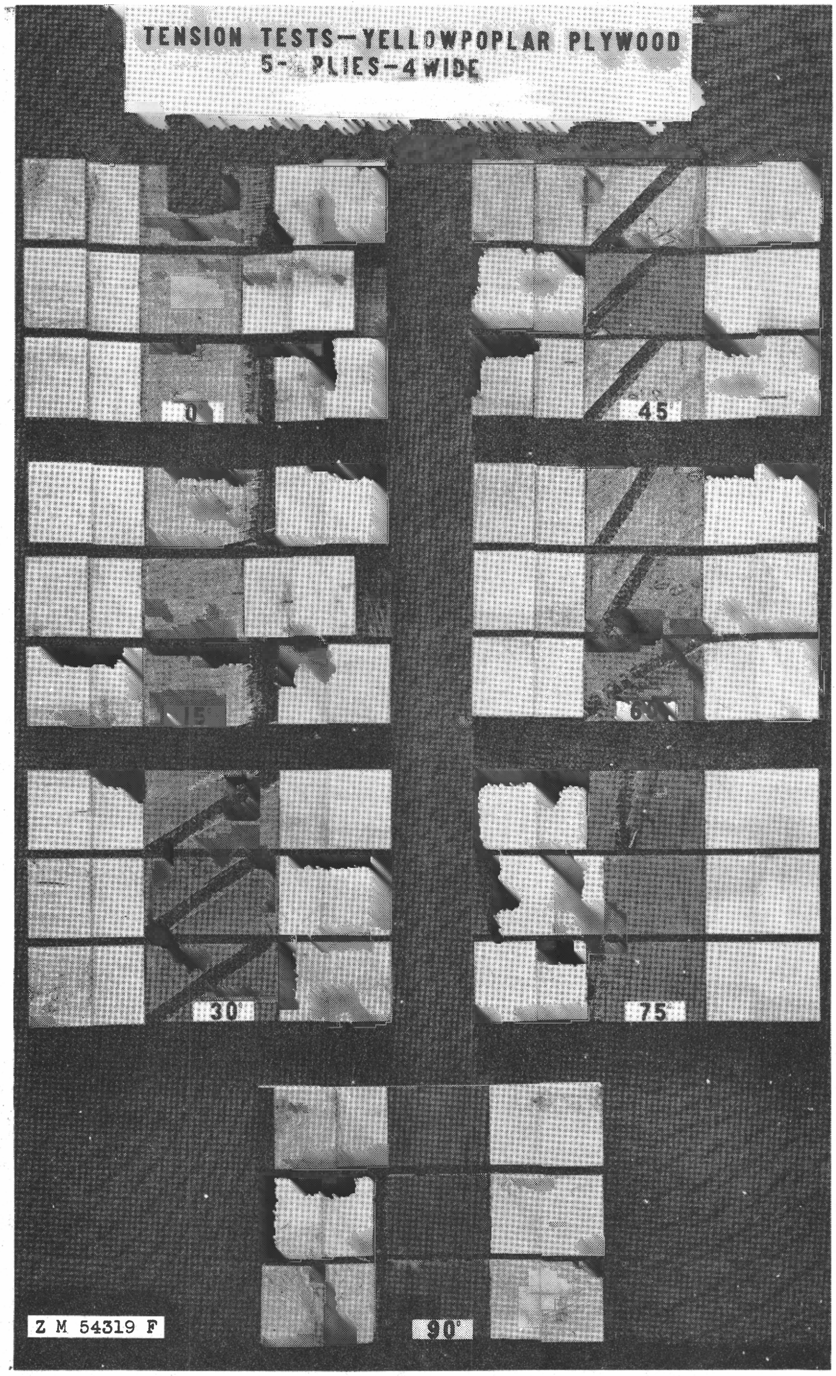


Figure 17.--Types of failure in tension tests of yellowpoplar plywood made of five 1/16-inch plies, 4 inches wide.

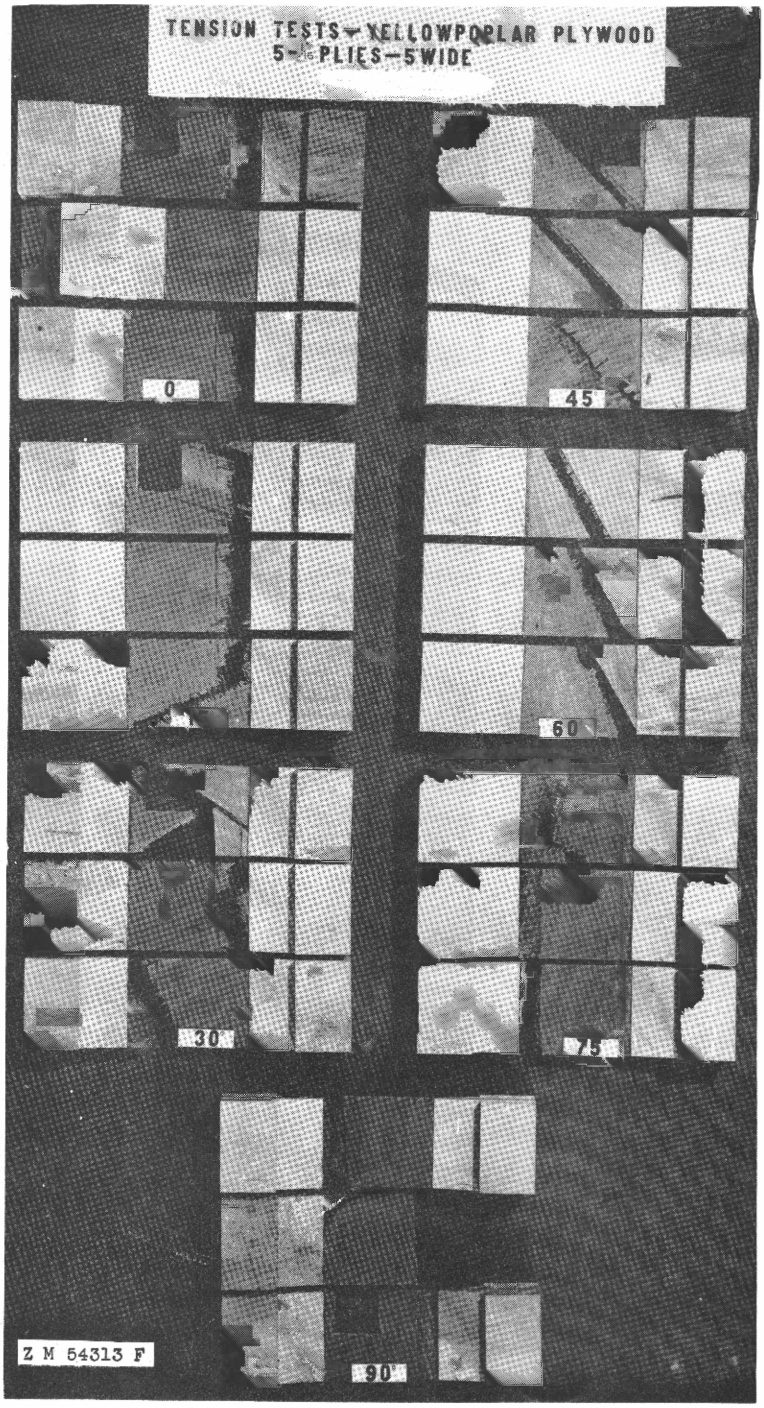


Figure 18.--Types of failure in tension tests of yellowpoplar plywood made of five 1/16-inch plies, 5 inches wide.

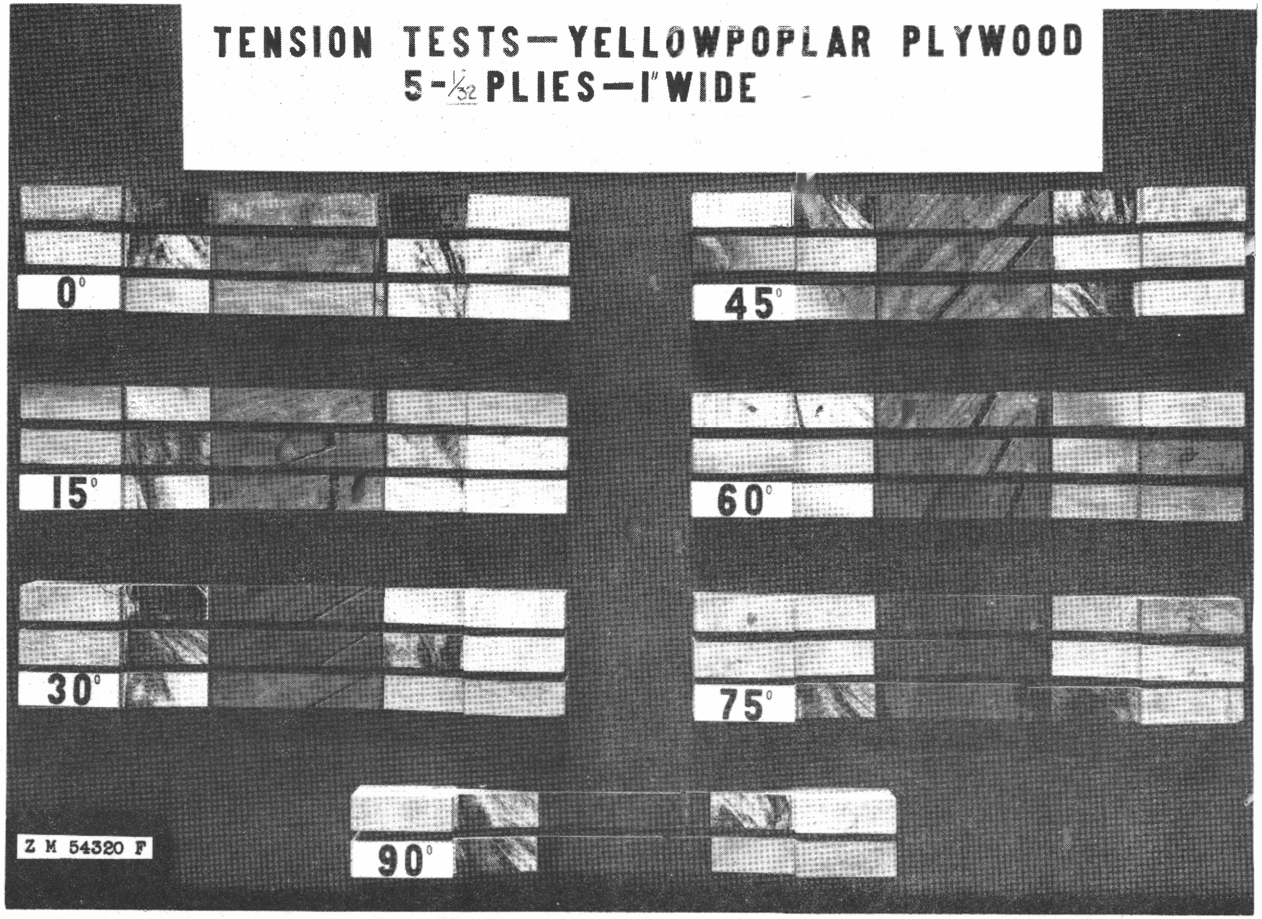


Figure 19.--Types of failure in tension tests of yellowpoplar plywood made of five 1/32-inch plies, 1 inch wide.

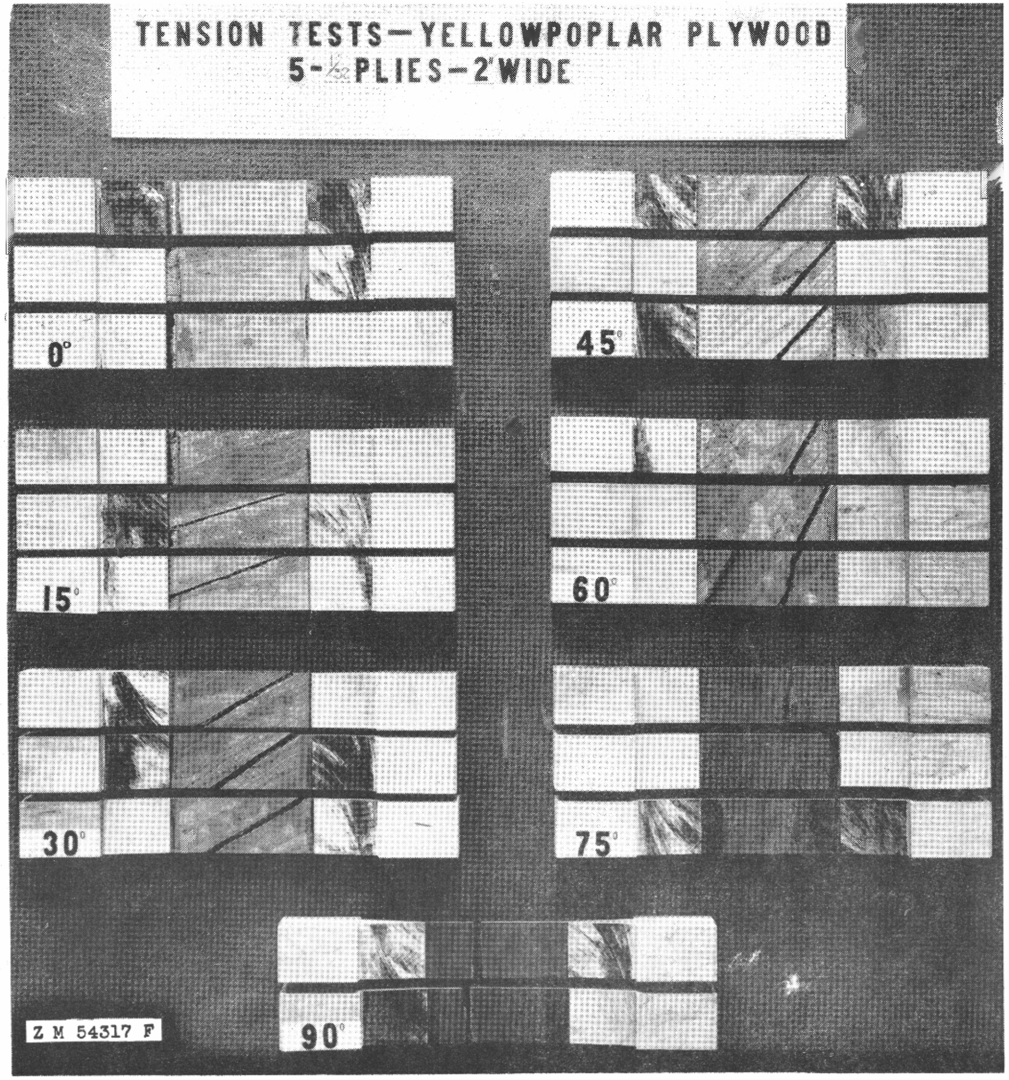


Figure 20.--Types of failure in tension tests of yellowpoplar plywood made of five 1/32-inch plies, 2 inches wide.

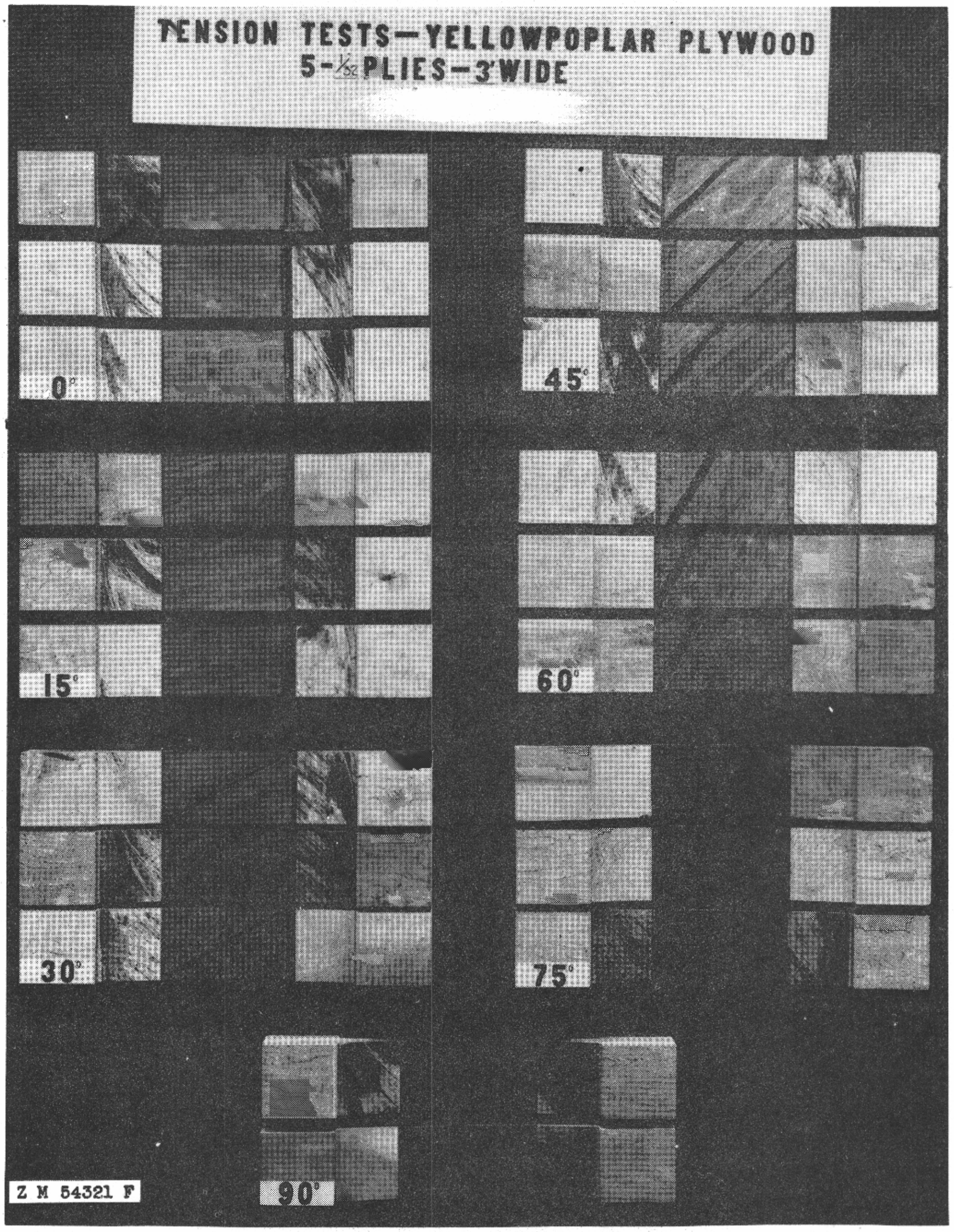


Figure 21.--Types of failure in tension tests of yellowpoplar plywood made of five 1/32-inch plies, 3 inches wide.

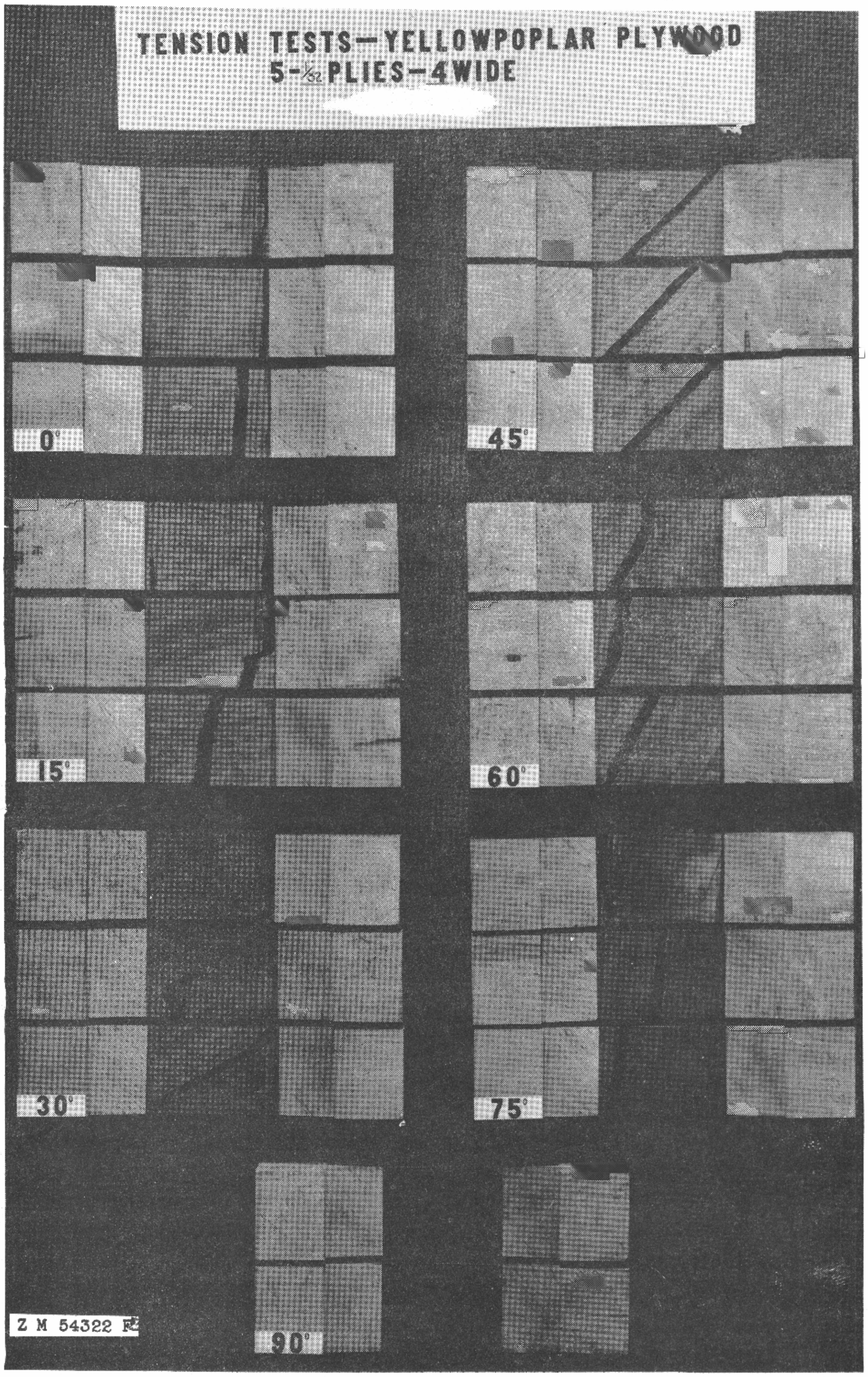


Figure 22.--Types of failure in tension tests of yellowpoplar plywood made of five 1/32-inch plies, 4 inches wide.

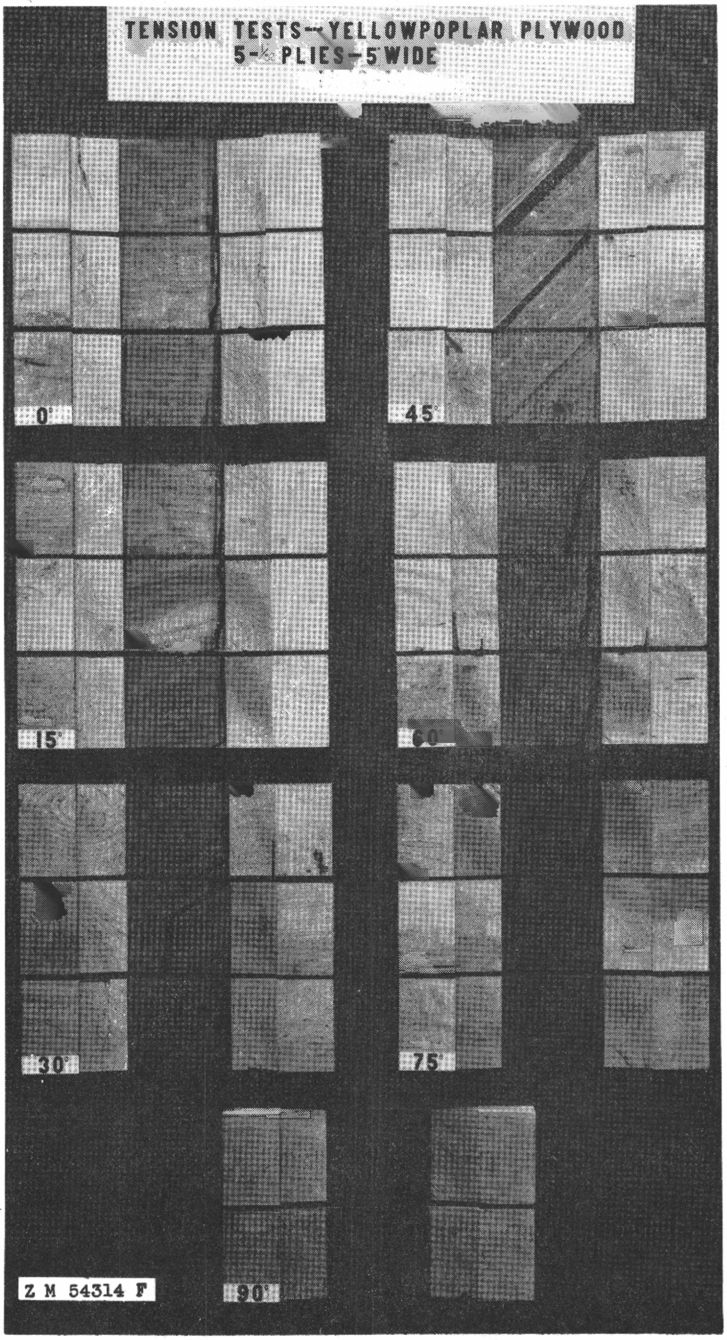


Figure 23.--Types of failure in tension tests of yellowpoplar plywood made of five 1/32-inch plies, 5 inches wide.

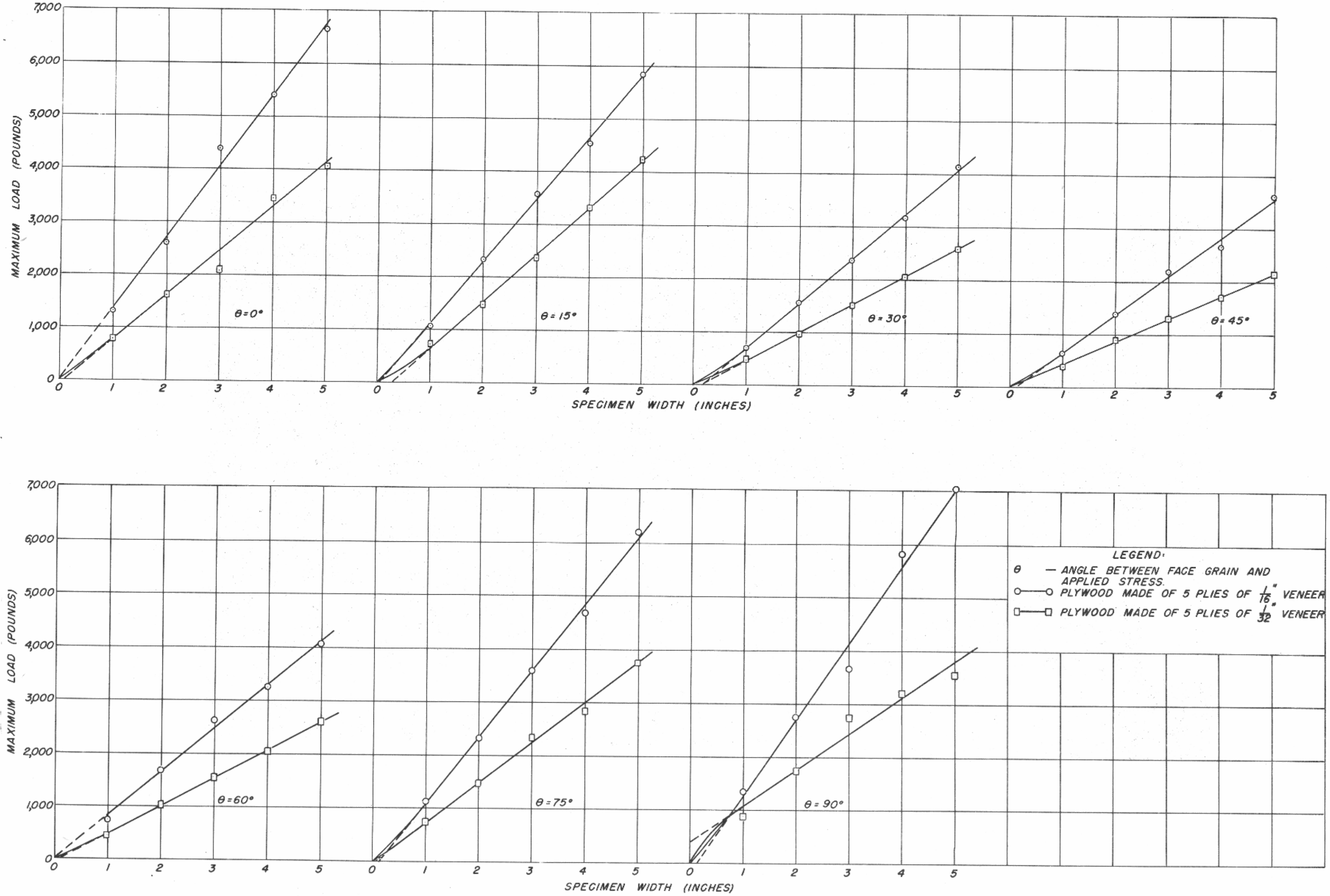


Figure 24.--Average maximum tensile loads on yellow-poplar plywood (series A) at various angles to the face grain for specimens of various widths.

Z M 61110 F

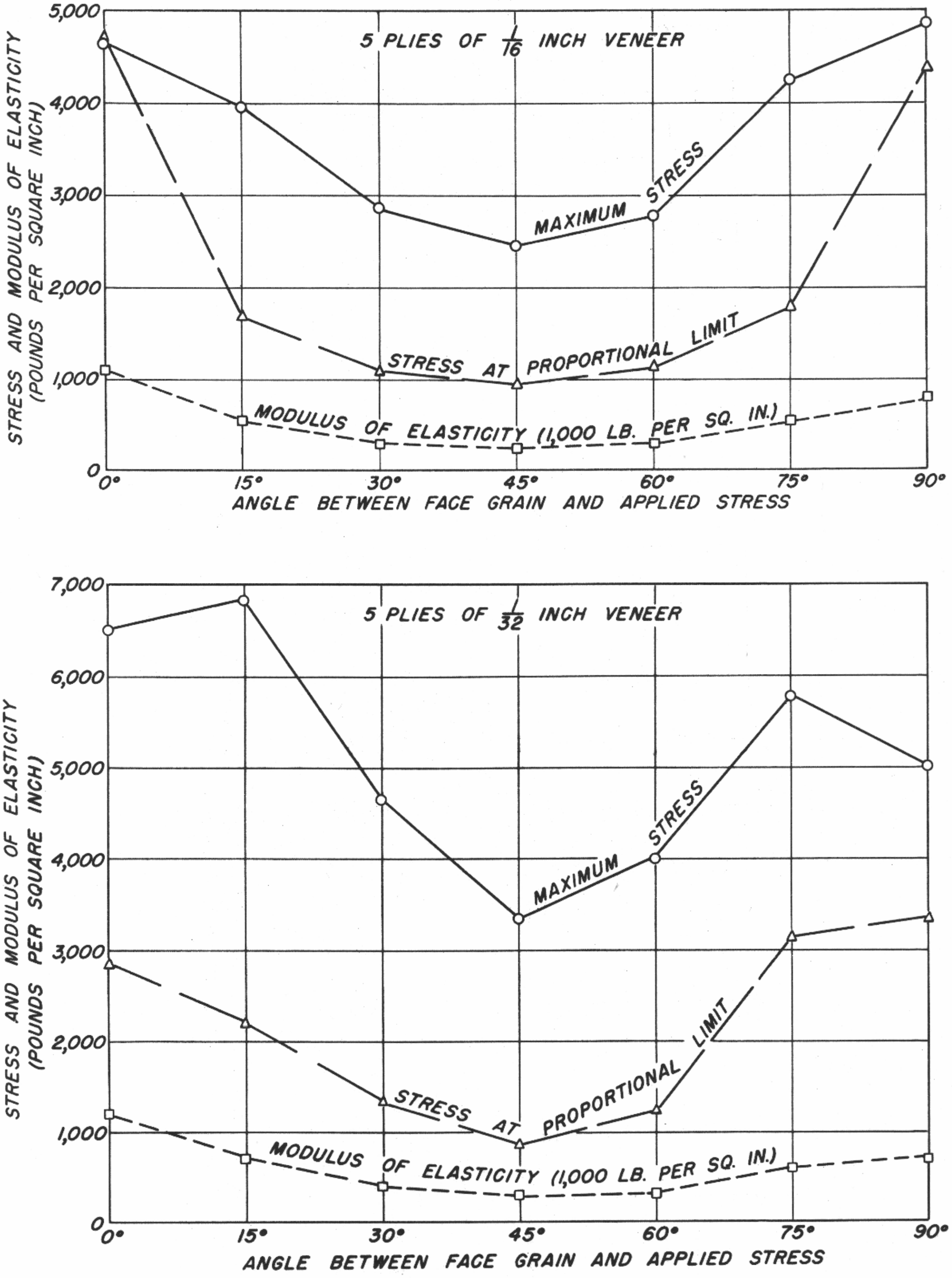


Figure 25.--Tension tests on yellow-poplar plywood (series A) at various angles to the face grain.

Z M 61111 F

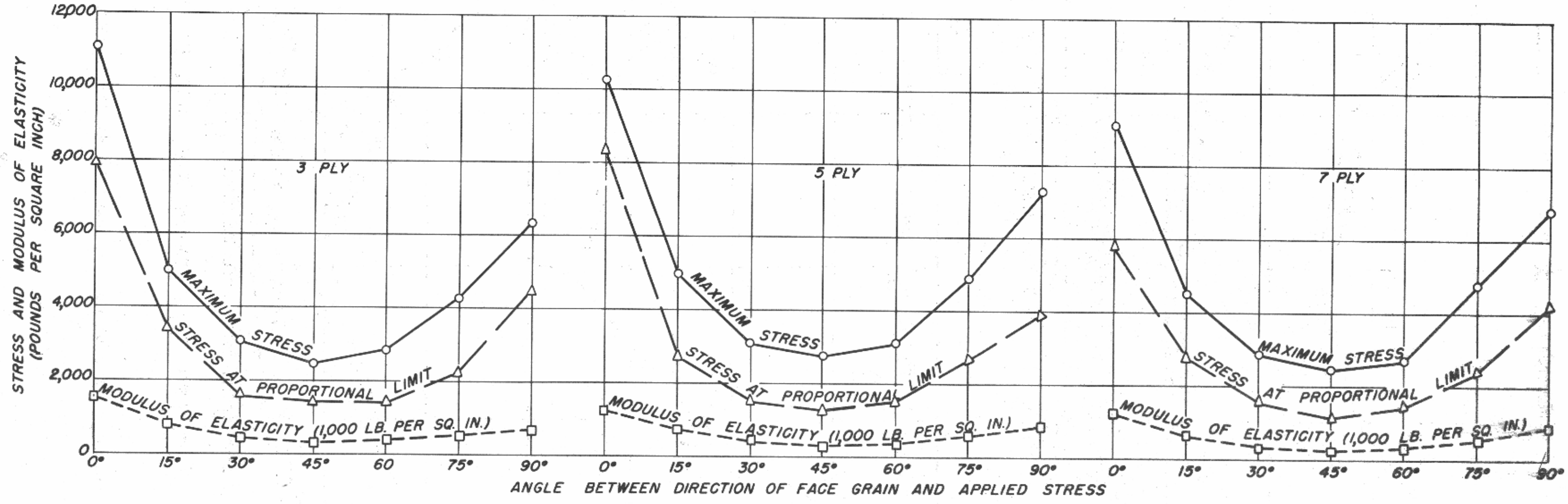


Figure 26.--Tension tests on yellow-poplar (series B) at various angles to the face grain. Plywood was made of 1/16-inch veneers.

Z M 61112 F

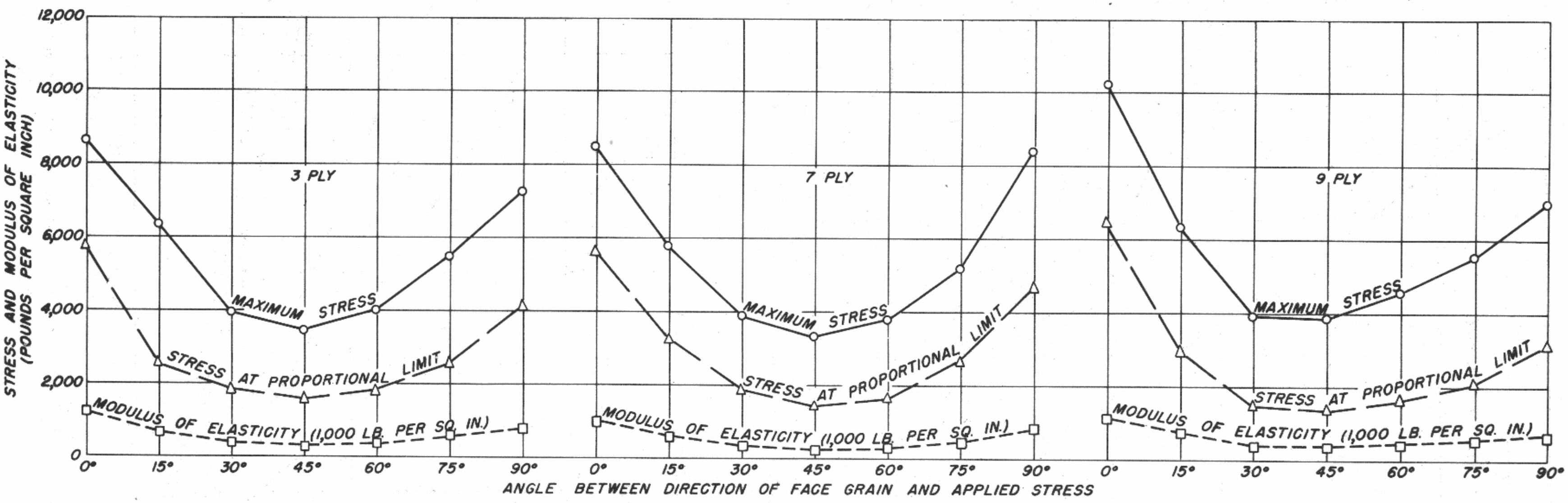


Figure 27.--Tension tests on yellow-poplar plywood (series B) at various angles to the face grain. Plywood was made of 1/32-inch veneers.

Z M 61113 F

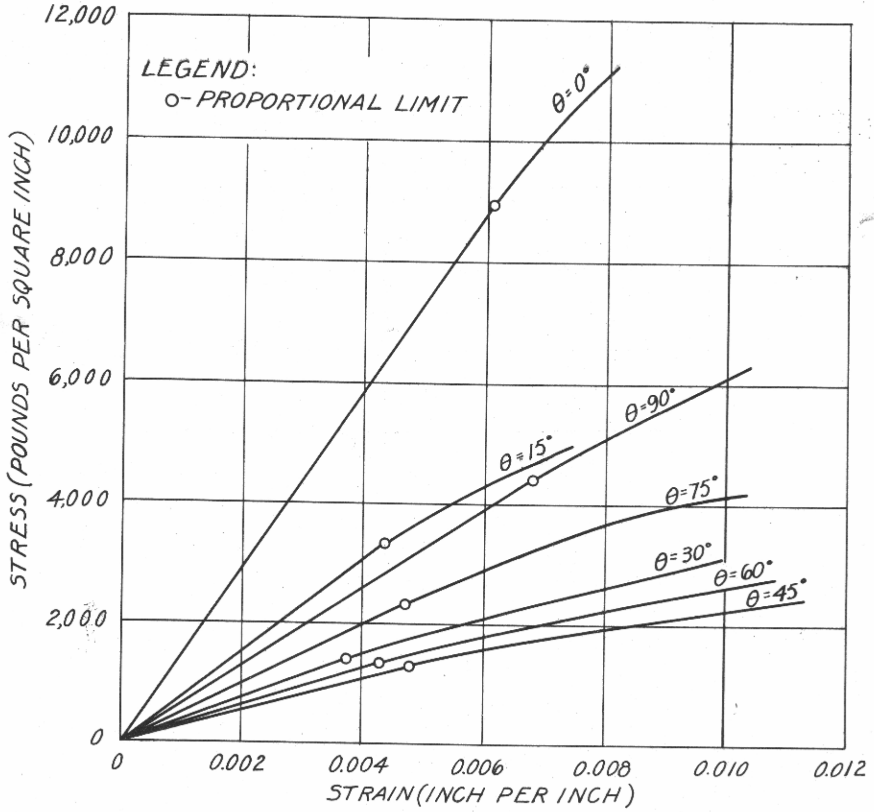


Figure 28.--Tension tests on yellow-poplar plywood at various angles to the face grain. Plywood was made of three 1/16-inch plies. Each curve represents values from 16 tests of series B.

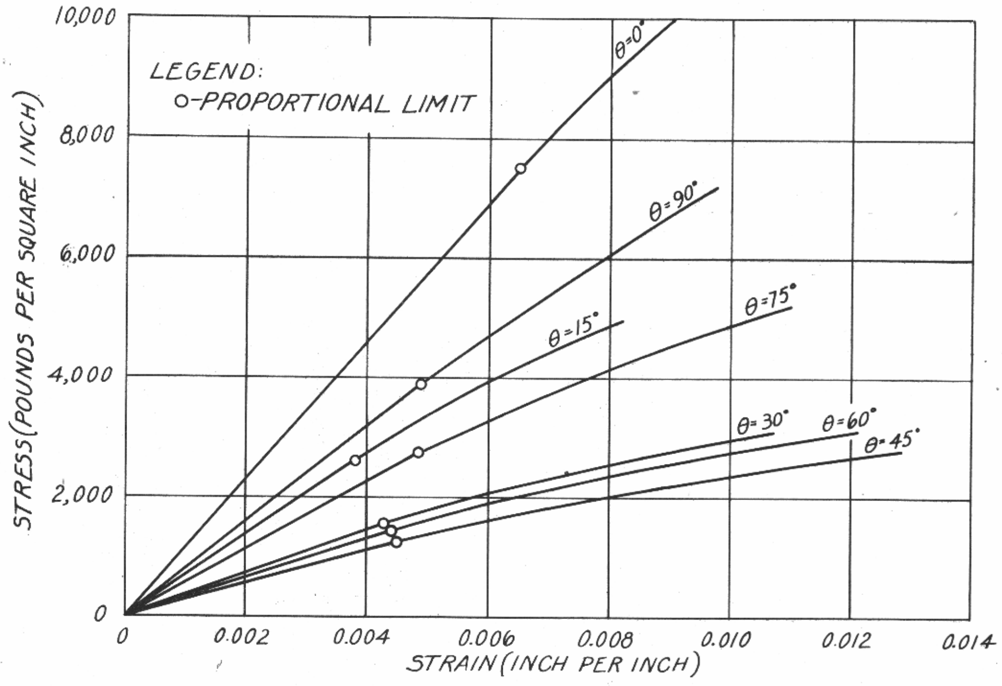


Figure 29.--Tension tests on yellow-poplar plywood at various angles to the face grain. Plywood was made of five 1/16-inch plies. Each curve represents values from 16 tests of series B.

Z M 54244 F

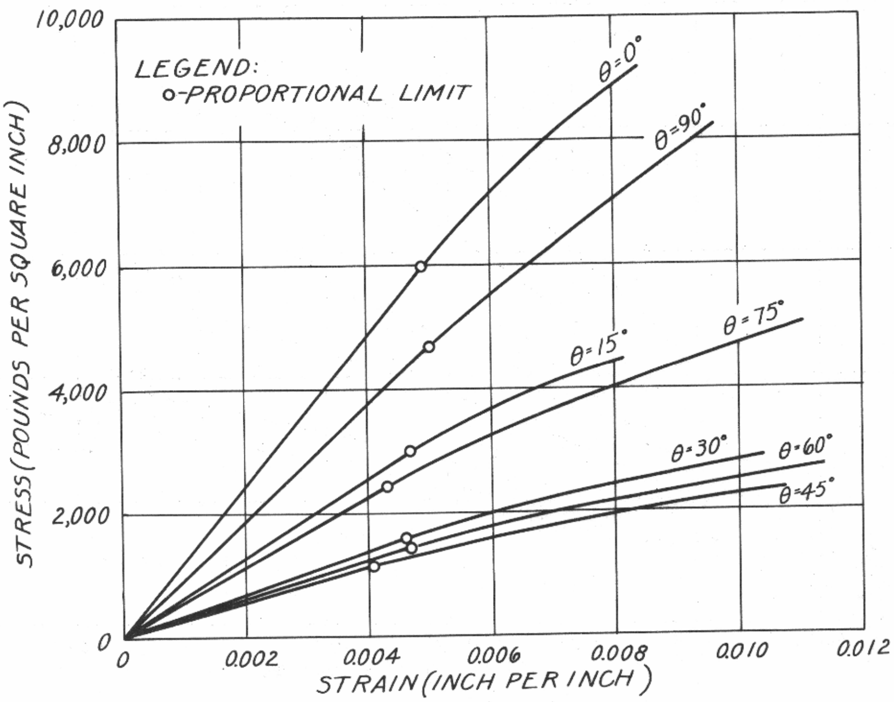


Figure 30.--Tension tests on yellow-poplar plywood at various angles to the face grain. Plywood was made of seven 1/16-inch plies. Each curve represents values from 16 tests of series B.

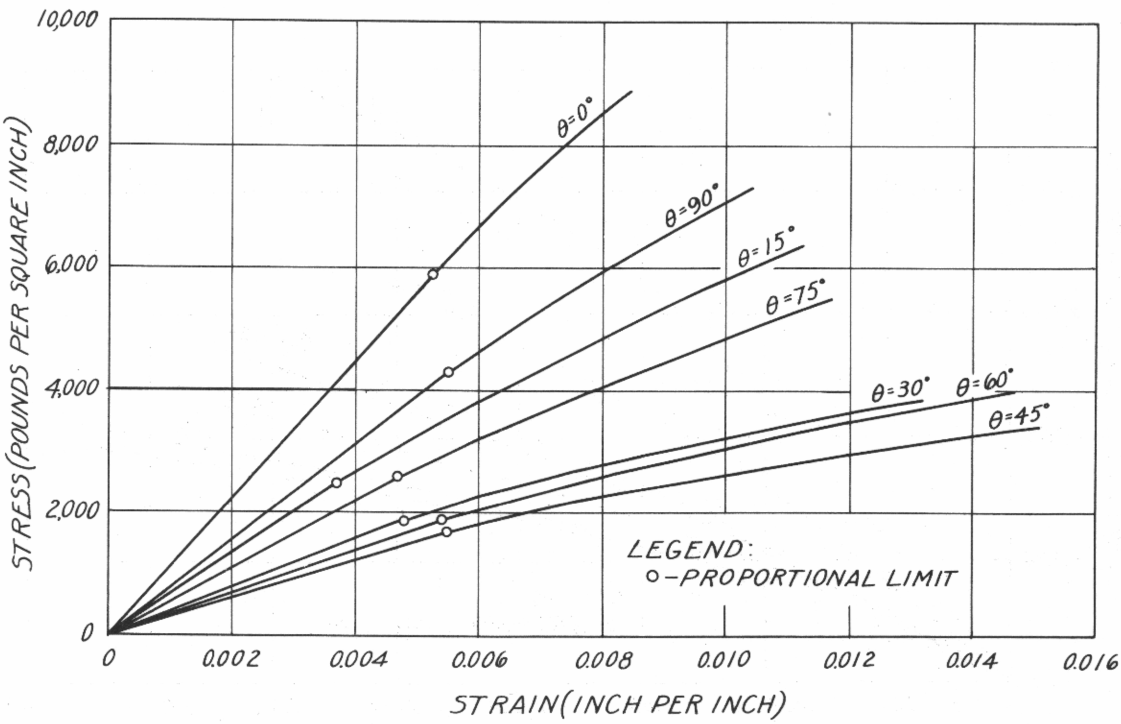


Figure 31.--Tension tests on yellow-poplar plywood at various angles to the face grain. Plywood was made of five 1/32-inch plies. Curve for $\theta = 0°$ represents values from 48 tests, each of the remaining curves represent values from 16 tests of series B.

Z M 54245 F

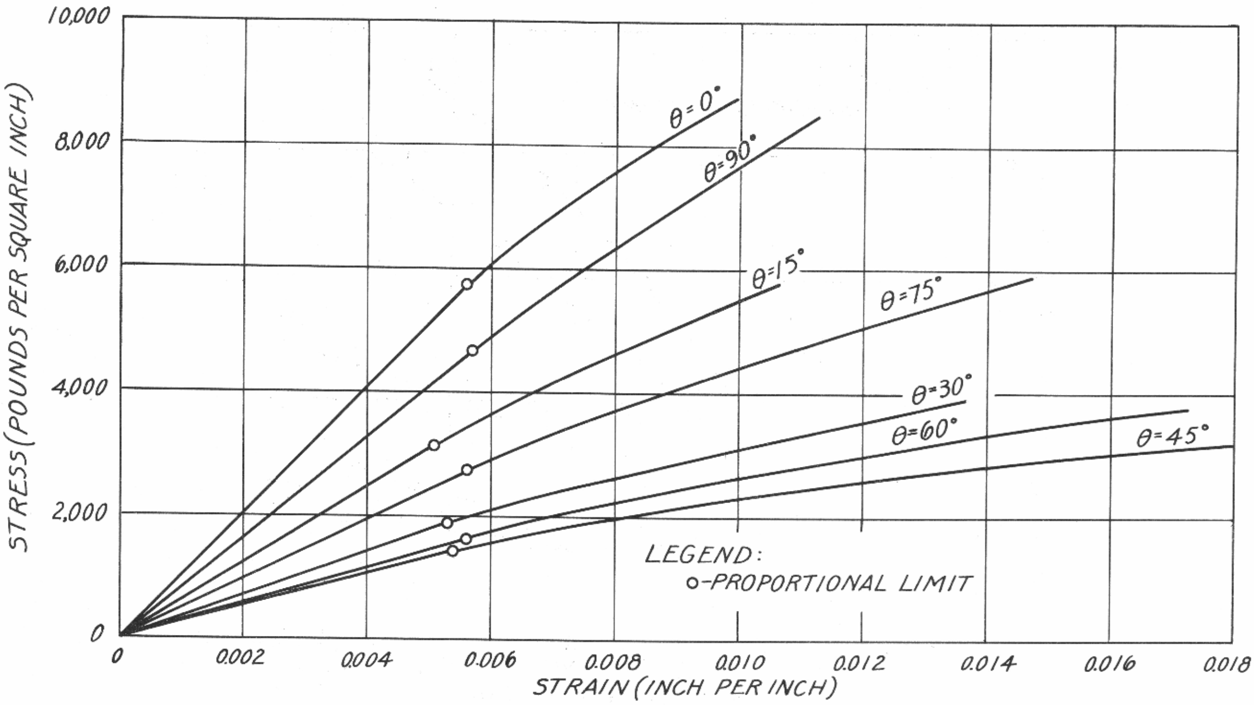


Figure 32.--Tension tests on yellow-poplar plywood at various angles to the face grain. Plywood was made of seven 1/32-inch plies. Curve for θ = 0° represents values from 48 tests, each of the remaining curves represent values from 16 tests of series B.

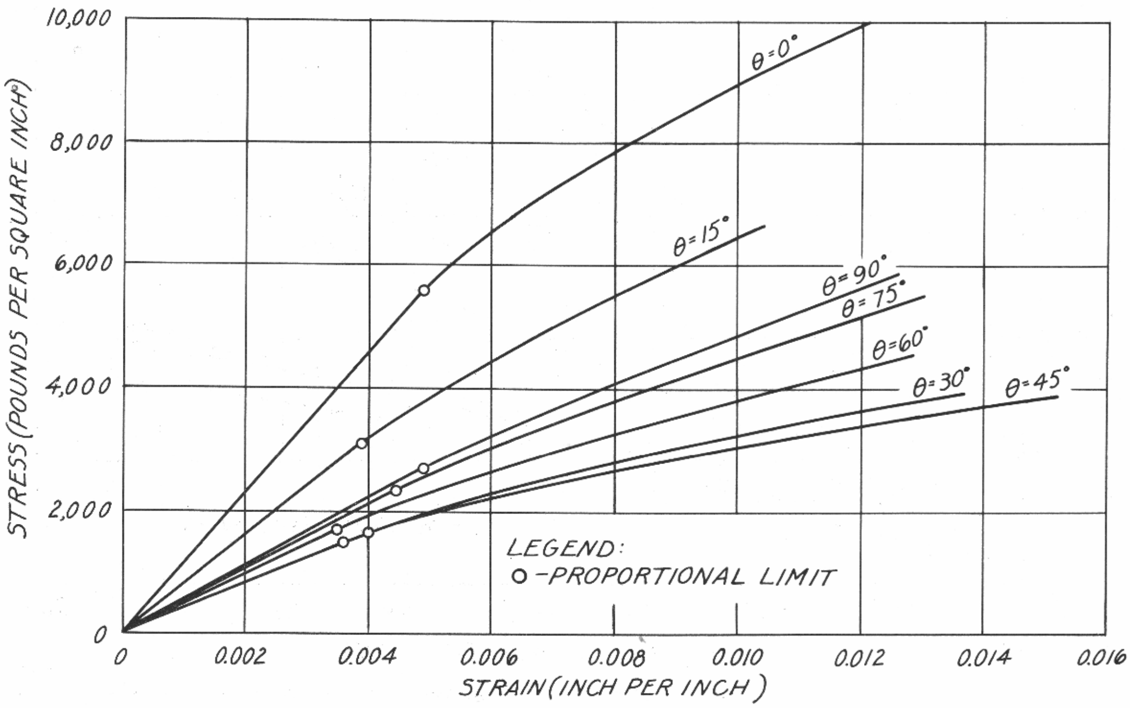


Figure 33.--Tension tests on yellow-poplar plywood at various angles to the face grain. Plywood was made of nine 1/32-inch plies. Curve for θ = 0° represents values from 48 tests, each of the remaining curves represent values from 16 tests of series B.

Z M 54246 F

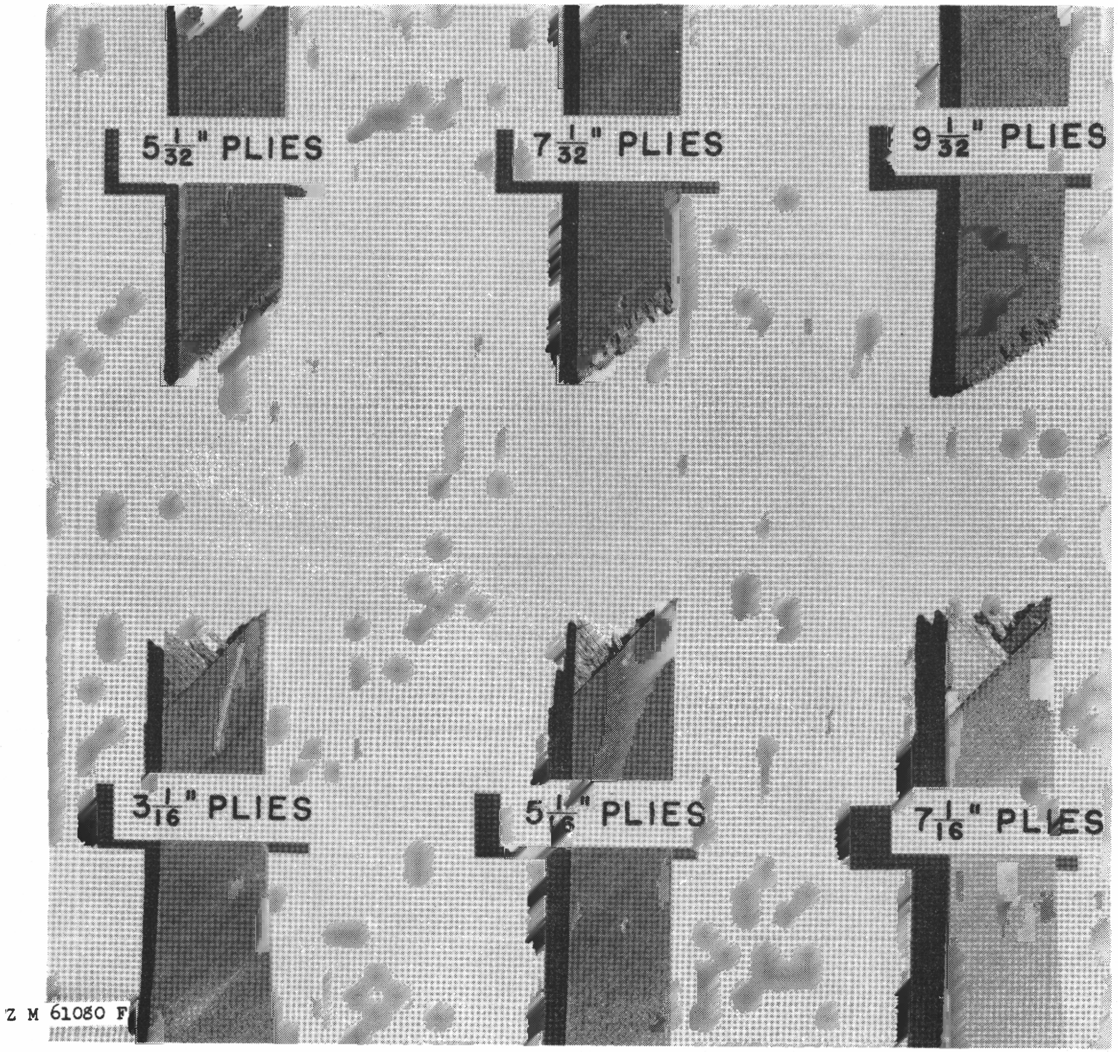


Figure 34.--Typical failures of specimens in series B showing the effect of veneer thickness on the type of failure. Angle between direction of face grain and direction of applied stress was 45°.