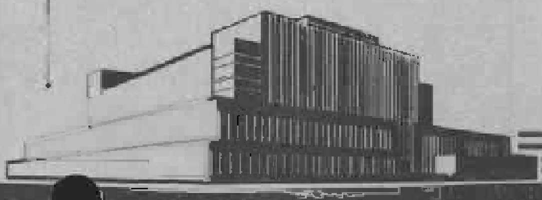
(Report) 2017 rev-

PROPERTIES OF WHITE-POCKET DOUGLAS-FIR LUMBER

Information Reviewed and Reaffirmed

October 1960

No. 2017



FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

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

Acknowledgement

Many persons have shared in the research reported here. At the Forest Products Laboratory George H. Englerth and William E. Bonser worked with the author on strength tests and grading. Nail holding tests were conducted by John A. Scholten. O. W. Torgeson and John M. McMillen did the research on drying, and Matthew E. Dunlap the work on acoustical properties. Ronald F. Luxford served as project leader.

Some of the research discussed here was done by the Pacific Northwest Forest Experiment Station and by the Oregon Forest Products Laboratory. The West Coast Lumbermen's Association furnished test material, and both it and the Douglas Fir Plywood Association gave information on grading practices. Test material was also furnished by the Pope and Talbot Lumber Co., Oakridge, Oreg.

PROPERTIES OF WHITE-POCKET DOUGLAS-FIR LUMBER

By

LYMAN W. WOOD, Engineer

Forest Products Laboratory,[1] Forest Service
U.S. Department of Agriculture

Summary and Conclusions

Results of research on Douglas-fir lumber containing white pocket can be summarized as follows:

Properties of Douglas-fir containing white pocket can be discussed only in relation to the grade or amount of white pocket present. A laboratory method for estimating the amount of white pocket has been developed. Visual grading can be related to the laboratory estimate. Common grouping systems based on visual inspection recognize incipient, light, medium, and heavy groups.

A number of strength studies on small specimens of white-pocket Douglas-fir wood have been made at the Forest Products Laboratory and elsewhere. Strength, stiffness, and shock resistance values have been obtained from bending and toughness tests. In addition, compression, shear, and hardness tests have been made. For material included in the light white-pocket group, the strength properties were reduced about one-third, stiffness about one-fourth, and shock resistance one-half to two-thirds. Reductions with larger amounts of white pocket are greater. The reduction of strength properties is greater than would be expected from the reduction of specific gravity. Where white pocket and knots occur together in structural lumber, the strength-reducing effects are cumulative. White-pocket joists are not as strong as the size of knot and the white-pocket grade would indicate.

Nails driven in white-pocket Douglas-fir were tested for withdrawal resistance and for lateral resistance. Most of the tests used the eightpenny common nail. Withdrawal resistances in material with light to medium white-pocket were about 60 percent and lateral

---

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

resistances about 75 percent of the values to be expected in clear Douglas-fir. Values with white-pocket wood reflected a normal relationship of withdrawal and of lateral resistance to the specific gravity.

Racking, static bending, and impact bending tests were made on wall panels of conventional construction studded and sheathed with white-pocket lumber. Both the No. 3 grade, and an "X" material with more white pocket were used. The tests indicated practically no loss of strength or stiffness with No. 3 but significant losses with "X" material, as compared to grades generally considered acceptable for the purpose.

Drying tests of white-pocket lumber showed that the rate of drying increases as the amount of white pocket is increased. Recommended temperature and humidity schedules for drying Douglas-fir lumber without white pocket appear to be satisfactory for white-pocket material.

Because of the increased rate of absorption of moisture, white-pocket Douglas-fir exposed to the weather is more subject to decay than is comparable wood without white pocket. The fungus causing white pocket, however, causes no important further damage after the wood is in service. Decorative effects with white-pocket wood are often pleasing, and some uses of this kind have been made. Sound-absorption tests indicate only moderate absorption effects from the open texture of wood containing a large amount of white pocket.

Introduction

A large portion of the coniferous saw timber in the United States is coast-region Douglas-fir, and nearly half of the coast-region Douglas-fir contains some white pocket. White pocket is caused by a fungus, *Fomes pini*. Although *Fomes pini* is a decay fungus, it is practically inactive in wood in service, and the important damage caused by it occurs only in the tree.

Fomes pini usually enters a tree through a dead branch stub. During its early stages, the resulting white pocket commonly has a distribution as indicated in figure 1. The pockets are circular or ellipsoidal in section, elongated in the direction of length of the trunk, generally 1/2 inch or less in length, and are often partly or largely filled with strands of white cellulose (figs. 2, 3, 4). The pockets tend to be most numerous in the summerwood bands and are often concentrated around knots. Although white pocket can occur in trees of any age, it grows very slowly and thus has its greatest extend in old-growth or over-mature trees. Geographically, white pocket may be found almost anywhere in the growth region of Douglas-fir, but it is most extensive in the State of Oregon. Logging has been delayed in large areas of timber because of white pocket.

With the depletion of much of the old-growth Douglas-fir forest, increasing attention is being paid to the utilization of white-pocket lumber. Standard grading rules of the West Coast Lumbermen's Association and the Western Pine Association recognize both "white speck" (pockets largely filled with cellulose) and "firm honeycomb" (pockets empty), and admit them in limited amount in some grades. There is much interest in the utilization of those grades for construction of all kinds. Lumber may be used in buildings, wood boxes or pallets, furniture cores, or for other purposes.

This report discusses the research on white-pocket lumber. Much of that research has been carried on at the Forest Products Laboratory, but notable work has also been done by the Pacific Northwest Forest Experiment Station at Portland, Oreg., and the Oregon Forest Products Laboratory at Corvallis. This report deals with the strength and nail-holding power of white-pocket Douglas-fir, structural tests of walls fabricated of white-pocket lumber, its drying characteristics, and a few miscellaneous properties. Each of these subjects is related to the grade or amount of white pocket.

Grading of White-Pocket Douglas-Fir

Properties of Douglas-fir containing white pocket can be discussed only in relation to the grade or amount of white pocket present. Grading or classification is thus an important part of a white-pocket study. Although grading is necessarily visual, laboratory methods of classification have also been studied.

Laboratory Grading

Several methods of laboratory grading have been explored. Since white pocket means a loss of wood substance, one possibility is to measure the reduction of specific gravity. Unaffected Douglas-fir, however, exhibits such a wide gravity range that such observations may be meaningless in the absence of directly matched pocket-free wood. Attempts to measure the specific gravity of the wood between and around the pockets have thus far been unsuccessful. Photometric methods have been considered, but appear to offer little promise.

The best results in the laboratory have been obtained by measuring the amount of a fine grit received into the surface pockets of the affected wood. The grit may be of a kind used in abrasive work; a size passing an 80-mesh and retained on a 100-mesh sieve was used in studies at the Forest Products Laboratory. By considering the surface area of the specimen and the average size of pocket, the amount of grit was translated to an apparent pocket percentage. Figure 5 shows typical specimens with various apparent percentages of white pocket.

A serious error in this method of estimating pocket volume arises from the white cellulose filling in many of the pockets. Such a filling may greatly reduce the reception of grit, while contributing very little to the mechanical properties. For example, a specimen containing many pockets largely filled with cellulose is considerably reduced in strength, while grit analysis shows only a small percentage of pockets. Experimental attempts to remove the cellulose by use of a suitable solvent were only partly successful. The most practical method of adjustment found so far has been to estimate visually the amount of filling and to use that estimate as a basis for adjusting the apparent volume determined from grit analysis.

Visual Grading

Visual grading has been done by many persons, acting more or less independently. The distinction by lumber graders between "white speck" and "honeycomb" has already been mentioned. "Honeycomb" is generally a later stage of white pocket, though not necessarily more severe. For instance, a piece of dimension may contain only a very few empty pockets and thus have better strength properties than another piece with many pockets largely filled with cellulose. As described in West Coast grading rules[2] Standard Joins and Plank admits "White Specks -- firm, narrow streak," and Utility Joist and Plank admits "Honeycomb -- firm" and "White Specks."

Other systems of visual grading or classification show considerable similarity. In most instances, an "incipient" stage is recognized. Stain is the principal characteristic of that stage; if white specks or pockets are present at all, they are too few to be measured. Following the incipient stage are 2 or 3 stages or amounts of white pocket that may be called "light," "medium," and "heavy," or some equivalent terms. Figures 2, 3, and 4 illustrate these three stages. "Medium" and "heavy" groups are sometimes combined, giving only "light" and "heavy." A "cull" or equivalent group has been recognized in some studies; in that group, the wood is so riddled with pockets as to have a fragile texture, and thin material has openings clear through (lacewood).

---

[2] West Coast Lumber Inspection Bureau. Rulebook No. 15, Standard Grading and Dressing Rules for Douglas-fir, West Coast Hemlock, Sitka Spruce, Western Red Cedar Lumber. Published by the West Coast Lumberman's Association, revised 1956.

Figure 6 is a graphic comparison of the methods of white-pocket grouping used in different divisions at the Forest Products Laboratory and by various other organizations. The general similarity of most of the grouping systems is apparent.

Strength of White-Pocket Douglas-Fir

Previous Studies

The effect of white pocket on the strength values in Douglas-fir has been under study for a number of years. The work of Scheffer, Wilson, Luxford, and Hartley[3] included investigations of strength and shock resistance of Douglas-fir with white pocket. They found that the ultimate strength and the modulus of elasticity in bending and the maximum crushing strength were not significantly reduced in comparison with clear wood by a later incipient stage of white pocket, but that the height of drop causing failure in impact bending was reduced as much as 20 percent. Average toughness values in affected areas were reduced by about 30 percent, while the range of variation of individual values was substantially increased.

Tests of strength of Douglas-fir with white pocket were reported by Stillinger[4] of the Oregon Forest Products Laboratory. The classification of white pocket developed in that study is indicated in figure 6. The following tabulation indicates percentage strength values in Stillinger's Class II white pocket in comparison to those in clear Douglas-fir:

---

[3] Scheffer, T. C., Wilson, T. R. C., Luxford, R. F., and Hartley, Carl. The Effect of Certain Heart Rot Fungi on the Specific Gravity and Strength of Sitka Spruce and Douglas-Fir. U.S. Dept. Agr. Tech. Bull. No. 779, 1941.

[4] Stillinger, J. R. Some Strength and Related Properties of Old-Growth Douglas-Fir Decayed by *Fomes Pini*, American Society for Testing Materials Bulletin No. 173, April 1951.

	Percent
Green Douglas-fir	
Ultimate fiber stress in bending	65
Modulus of elasticity in bending	79
Work to maximum load in bending	33
Maximum crushing strength	65
Stress at proportional limit in compression perpendicular to grain	88
Side hardness	56
End hardness	71
Douglas-fir at 12 percent moisture content	
Maximum crushing strength	50
Stress at proportional limit in compression perpendicular to grain	68
Side hardness	68
End hardness	70

Stillinger also found that the shrinkage of Douglas-fir was substantially reduced as the amount of white pocket increased.

Strength Related to Pocket Volume

Strength tests at the U.S. Forest Products Laboratory were continued with specimens from white-pocket studs and sheathing furnished by the West Coast Lumbermen's Association for test wall panels. The lumber had been dried but the specimens were resoaked to moisture contents above the fiber-saturation point (about 30 percent moisture). Specimens were classified by the method of grit analysis previously described, and strength values were related to the apparent pocket volume. Most of the pockets had little cellulose filling, and no adjustment of the apparent volume for cellulose filling was made. Figure 5 illustrates typical specimens with various apparent percentages of pocket volume. Table 1 summarizes the strength test results. Figure 7 shows the relation of bending strength (modulus of rupture) to specific gravity in the various pocket-volume classes, and figure 8 shows a similar relation for stiffness (bending modulus of elasticity).

Table 1 clearly indicates the progressive reduction of bending strength and stiffness as the percentage of white pocket is increased. Figures 7 and 8 show how the values in white-pocket material fall below the curve representing an average relation in clear Douglas-fir; in other words, the reduction of strength or stiffness is more than would be expected from the reduction of specific gravity.

The amount of white pocket in the No. 3 (now Utility) grade[5] of studs and sheathing used in these tests corresponded approximately to the 10-percent group in table 1. Figures 7 and 8 show that this material had about 55 percent of the bending strength and 70 percent of the stiffness of the species average.

Strength by Pocket Groups

Average strength values from somewhat larger groups in later tests of green material are tabulated in table 2 and shown graphically in figures 9, 10, and 11. In this instance, the specimens were taken from short logs furnished by the Pope and Talbot Lumber Co., Oakridge, Ore. The pockets showed a wide range in the amount of cellulose filling, and the apparent pocket percentage from grit analysis was adjusted by visual estimates of the amount of filling. From the adjusted percentages, the material was divided into incipient, light, medium, and heavy groups. The incipient group was characterized principally by stain or discoloration. The light group had 1 to 15 percent adjusted pocket volume, the medium group 16 to 30 percent, and the heavy group 31 to 62 percent. Average adjusted volumes in those groups are shown in table 2.

Table 2 and figures 9, 10, and 11 show the progressive reduction of strength properties with increased amounts of white pocket. The light group in table 2 corresponds approximately to the 5-percent group in the earlier tests, and the corresponding test values in table and table 2 are similar. Reductions of strength for any particular group are shown to vary among the various properties. Stiffness was generally reduced less than strength. Total work in bending and toughness, both measures of shock resistance, suffered the greatest reductions.

Figures 9 and 10 show the relation of some of the mechanical properties to specific gravity in the white-pocket groups of table 2. Curves representing an average relationship in clear Douglas-fir are shown for comparison. It is apparent that the reduction of strength properties is more than would be expected from the reduction of specific gravity. The loss of shock resistance indicated by the values for total work (fig. 10) is especially severe. White pocket in this respect exhibits effects that are similar to those from other decay fungi.[6]

Figure 11 indicates the range of values of bending strength in the various white-pocket groups. The average values are those given in table 2. A frequency distribution of clear Douglas-fir from a

---

[5] West Coast Lumber Grade.

[6] Scheffer, et al. U.S. Dept. Agr. Tech. Bull. No. 779.

previous study of variability[7] is included for comparison. The chart shows the overlapping of values, while averages decrease with an increase in the amount of white pocket. The curve for clear Douglas-fir represents a much larger group (791 specimens), and its increased range compared to that in the white-pocket groups thus does not necessarily indicate an increased variability. Studies of standard deviation in the various groups showed comparable values except in the heavy group, where the standard deviation was greater.

Strength of Structural Joists

Tests were also made on green structural joists 1-5/8 by 5-5/8 inches in cross section (nominal 2 by 6 inches) and 8 feet long. Each contained a knot of typical size located in the center third of the length and near the lower edge. Joists were tested over a span of 7 feet 6 inches, with third-point loading. They were classified in white-pocket groups by the same method used with the small wood specimens. Most of the joists were in the light or medium pocket group and none was in the heavy group. Table 3 summarizes the results of the tests.

Each joist was given a "strength ratio" representing the estimated effect on strength from knots or other strength-reducing characteristics other than white pocket. Strength ratios were determined from a visual inspection of the surface characteristics, related to the established principles of strength grading. Average strength values from 2 small specimens matching each joist according to the zone of growth in the log and to the amount of white pocket, are shown in table 3. Multiplication of that average strength by the strength ratio gave the estimated strength of each joist (averaged in line 10 of table 3).

The most important information from table 3 is the comparison of actual (line 7) with estimated (line 10) strength values. Most of the joists failed to realize their estimated strength values, the deficiency being greatest in the groups with the most white pocket. Reasons for this deficiency in strength are not entirely clear. One possibility is the tendency observed in some joists for white pocket to be concentrated around the knots, thus making the white-pocket effect in the critical zone more serious than the white-pocket rating based on the joist as a whole. Because white pocket tends to develop in dead branches, it is generally concentrated around knots (fig. 1).

Table 3 also shows the progressive reduction of strength and stiffness of the joists with increasing white pocket. Shock resistance, measured by the value of total work, was most severely decreased.

---

[7] Wood, Lyman W. Variation of Strength Properties in Wood Used for Structural Purposes, Forest Products Laboratory Report No. R 1780. 1950.

Nail-Holding Power

Withdrawal Resistance

Stillinger[8] reported withdrawal tests on nails of various types in white-pocket Douglas-fir. His results showed reductions of withdrawal resistance with increasing amounts of white pocket with all types of nails and under a number of different driving conditions. In some instances of withdrawal after a period of drying following the driving of the nails, nearly all of the withdrawal resistance was lost.

Tests of withdrawal resistance were made at the Forest Products Laboratory on eightpenny common nails driven into the side grain of 2- by 4-inch white-pocket studs furnished by the West Coast Lumbermen's Assocation for test wall panels. The studs were graded in two classes, No. 3 (West Coast Lumber Grade) and a so-called "X" material containing more white pocket than was admitted in No. 3. Nails were driven and withdrawn with the wood at the same moisture content, about 12 percent. Test values were compared with those on No. 1 studs with equivalent specific gravity values. The results are summarized in table 4. They show about the same resistance in the No. 3 as in the No. 1 grade of equivalent specific gravity, but substantially reduced resistance in "X" material compared to the No. 1 grade matching it in specific gravity.

Withdrawal tests were also made using eightpenny common nails driven to a depth of 1-1/2 inches into the side grain of 1-5/8- by 2-inch sticks cut from the strength test specimens. Nails were driven and withdrawn with the wood at about 11 percent moisture content. Average withdrawal values grouped by specific gravity are given in table 5. The relation of load to specific gravity is shown graphically in figure 12.

Both table 5 and figure 12 show the reduction of holding power with reduced specific gravity. Pocket volumes in table 5 are approximately in inverse order to the specific gravities; since the pocket percentages are not adjusted for cellulose filling, there are some exceptions to this general rule.

The withdrawal resistance of plain nails from wood that does not contain white pocket normally varies as the 2-1/2 power of the specific gravity. It was found in these tests of white-pocket Douglas-fir that the load also varied as the 2-1/2 power of specific gravity (fig. 12). The relationship between load and specific therefore appears to be the same whether the variation of specific gravity is

---

[8] Stillinger. ASTM Bulletin No. 173.

caused by white pocket or by differences not related to white pocket. The average for all white-pocket material, 187 pounds, is about 60 percent of the value of 323 pounds to be expected in clear Douglas-fir of average specific gravity, 0.48 (fig. 12).

The results of nail withdrawal tests were usually very erratic. Figure 12 shows the range of 92 to 296 pounds in the average loads from 4 tests. Average loads on 40 nails driven into 10 specimens ranged from 106 pounds in specimens with the lowest specific gravity to 249 pounds in specimens with the highest specific gravity (table 5).

Lateral Resistance

The same material used for the withdrawal test was also used for lateral-resistance tests with the eightpenny common wire nail. A block and a cleat of matched white-pocket material were nailed with one nail as shown in figures 13 and 14 and tested for lateral resistance in the direction parallel to their length. Nails were driven and tested with the wood at a moisture content of about 11 percent. The results are given in table 5 and figures 13 and 14.

The behavior of white-pocket Douglas-fir under lateral nail loads is similar to that of other Douglas-fir except that the loads are lower. As shown in figure 13, the lateral load varies as the 3/2 power of the specific gravity. Averages for 80 specimens shown in figure 13 are about 75 percent of the values indicated by extending the curves to a specific gravity of 0.48, the average for clear Douglas-fir. That percentage may be compared to a corrrsponding value of 60 percent in withdrawal tests with the same material. Since withdrawal loads are related to the 2-1/2 power and lateral loads to the 1-1/2 power of specific gravity, the reduction of load for the same reduction of specific gravity is less in the latter than in the former.

The relationship between lateral resistance load and slip is shown in figure 14. The spread between the lowest and highest values is considerable but is not as large as in the withdrawal resistance. The curves show that after a slip of 0.01 inch, the amount of slip increases very rapidly with relatively small increases in load and that at the maximum load the slip is very large. The average loads at slips of 0.01, 0.10, and 0.89 inch were 71, 164, and 311 pounds, respectively, indicating that each time the load was doubled the slip increased nearly 10 times.

Stud Walls of White-Pocket Lumber

To study the effect of white pocket on the utility of Douglas-fir lumber for house construction, tests were made on wall panels with studs and sheathing containing white pocket. Test material was furnished by the West Coast Lumbermen's Association and was graded by the West Coast Bureau of Grades. Some of the studs and sheathing were graded as No. 3, (now Utility) and the remainder was designated as "X" material, containing more white pocket than was admissible in the No. 3 grade. A few tests for comparison were also made on similar panels fabricated with No. 1 (now Construction) Douglas-fir.

Racking Tests

Much of the resistance of house framing to distortion from wind or other horizontal forces is in the strength and stiffness of the walls. The racking test affords a measure of that resistance. In the racking test, a full-size wall panel is placed in a vertical position and a horizontal force is applied to one corner with restraint at the opposite corner as indicated in figure 15. The loading simulates the thrust on the end wall caused by wind or other horizontal forces acting on the side wall. Resistance to racking is partly in the framing and bracing of the wall and partly in the sheathing and its fastening to the frame. Racking tests are therefore commonly made on framed, braced, and sheathed wall panels.

The panels in these tests were framed with 2- by 4-inch studs and plates and 1- by 4-inch diagonal braces, horizontally sheathed with 1- by 8-inch shiplap. The arrangement of framing members is shown in figure 16. Sheathing boards were attached by two eightpenny nails at each stud crossing. Each course of boards had one end-butt joint, the joints being staggered in adjacent cources.

Table 6 summarizes the results of the racking tests. The results are related to the performance requirements of the Housing and Home Finance Agency.[9] Those requirements specify a design load of 100 pounds per foot of length, with not more than 1/8-inch displacement at design load, no failure at 2-1/4 times design load, and not more than 25 percent residual displacement after removal of 2-1/4 times design load. Results are shown both for panels fabricated green (about 30 percent moisture content) and tested dry and for panels fabricated and tested dry. The larger displacements and lower strength values in the former condition reflect the loosening of nails driven into green

---

[9] Housing and Home Finance Agency. Performance Standards; Structural and Insulation Requirements for Houses. U.S. Government Printing Office, 1947.

wood that is later allowed to season. Panels fabricated green and tested dry did not meet the requirements of not more than 1/8-inch displacement under design load (column 4 of table 6). Panels fabricated of dry lumber of all grades and tested dry met the requirement. Panels under both moisture conditions failed to meet the requirement of not more than 25 percent residual displacement after removal of 2-1/4 times design load (columns 5 and 6 of table 6). This was true for the No. 1 grade of Douglas-fir as well as for the material containing white pocket. With small deflections a requirement of 25 percent residual displacement may not be very important. All panels sustained considerably more than 2-1/4 times design load before first failure.

No. 3 Douglas-fir gave results comparable to No. 1 material, but "X" material showed some reductions of strength and stiffness.

Static-Bending Tests

Sections of wall frames as shown in figure 16 and sheathed with shiplap in the same manner as the racking test panels were tested flatwise in transverse bending with quarter-point loading on a span of 7 feet 6 inches. The panels were fabricated green (about 30 percent moisture content) and tested dry. Table 7 summarizes the results of the tests.

HHFA performance requirements provide that deflection in static bending under design live load shall not exceed 1/360 of the span for plastered or 1/240 of the span for unplastered walls. Panels are also required to sustain 2-1/4 times design load and to have not more than 25 percent residual deflection after removal of 2-1/4 times design load. Design live load results from wind and thus varies geographically, but a load of 20 pounds per square foot was chosen in table 7 as being representative of most areas in the United States. Deflections in table 7 have been converted from the actual values observed under quarter-point loading in test to their equivalents under uniform loading. Quarter-point loading and uniform loading give the same stresses at the center of the span.

All panels of No. 3 Douglas-fir met all of the performance requirements. Panels of "X" material met the requirements for residual deflection, but did not meet requirements for deflection under design load for plastered walls. They barely sustained 2-1/4 times design load at failure. The difference in performance of these two groups emphasizes the need for limiting the amount of white pocket in Douglas-fir lumber.

Impact-Bending Tests

Sections of wall similar to those in the static-bending tests were tested flatwise by impact bending with a 60-pound sandbag dropped on the center of the panel from heights of 1-1/2 and 3 feet. The results are summarized in table 8.

HHFA performance standards require that there shall be no residal deflection in impact bending after a drop from a height of 1-1/2 feet, and that there shall be not more than 25 percent residual deflection after a 3-foot drop.

Only 2 of the 6 panels had no residual deflection after the 1-1/2 foot drop. Other tests of material without white pocket showed residual deflection after the 1-1/2-foot drop, indicating that failure to meet this requirement is not a matter of the grade of the lumber. All panels of white-pocket material met the requirement on residual deflection after the 3-foot drop. Here, as in the static-bending tests, the advantage of the No. 3 grade over "X" material was shown.

Kiln-Drying Studies of White-Pocket Lumber

Kiln-drying studies were made on boards 10 inches wide and 30 inches long in two thicknesses, 1-1/16 and 2-1/8 inches, and on 1-by 1- and 2-by 2-inch squares of the same length. The material was classified into a clear group, two groups with slight white pocket, a group with moderate white pocket, and a group with severe white pocket (see fig. 6). It was dried in a kiln with a temperature of 150° F., 62 percent relative humidity, and air flow around the material at about 300 feet per minute.

It was found that white pocket opened up the wood and produced faster drying. Table 9 gives the average time of drying from 32 to 18 percent moisture content as observed in this experiment. It clearly shows how much the drying time was reduced as white pocket was increased. The squares, having more surface exposed, dried faster than the 10-inch boards of equivalent thickness.

Under the drying conditions used in this test, the 1-inch material dried without surface checking. The 2-inch material was checked, indicating that this low a humidity condition might be considered too severe for commercial drying of 2-inch white-pocket Douglas-fir for some purposes. Some preliminary drying tests showed that 150° F. initial temperature was satisfactory and that no checking occurred when initial relative humidity was 80 percent for 1-inch or 85 percent for 2-inch material. Below 20 percent moisture content, kiln conditions of 180° F. and 50 percent relative humidity were satisfactory.

The studies indicated that temperatures and humidities in the Forest Products Laboratory moisture content schedules[10] for Douglas-fir without white pocket should be satisfactory for Douglas-fir with white pocket. Where there is a uniform distribution of white pocket, stock with moderate or severe white pocket can be separated out for faster drying. In many instances, however, all degrees of white pocket may be present in different parts of the same board. Where this is the case, drying times for pocket-free Douglas-fir will be required. White-pocket zones will be overdried, but this is less objectionable than to underdry the clear zones.

Miscellaneous Properties

Susceptibility to Decay

White-pocket Douglas-fir not only loses but also takes on moisture more rapidly than clear wood. Because of this property, it may decay more readily under conditions favorable to the growth of decay fungi. To test this belief, small specimens of wood with 10, 20, and 30 percent of apparent pocket volume were exposed for 3 months to various brown-rot fungi growing on feeder blocks and soil in closed bottles. Douglas-fir without white pocket from Oregon and from Montana was exposed in the same way for comparison. A susceptibility rating was indicated by the loss in weight of the specimen due to decay. Table 10 gives the results. It shows that wood containing white pocket generally decays more rapidly than clear wood, and that the resistance to decay is reduced as the amount of white pocket is increased.

Further evidence of the moisture grain in white-pocket Douglas-fir may be seen in the moisture content values tabulated in table 1. That material was dried and later resoaked to bring the moisture content above the fiber-saturation point. The higher moisture content values associated with the greater amounts of white pocket are apparent. The soaking that brought clear Douglas-fir up to about 33 percent moisture brought material with 30 percent or more pockets up to 100 percent or more moisture.

Fomes pini causing white pocket does not continue to grow after the tree is cut and converted into lumber. No visual evidence of further growth of that fungus was noted in a pile of solidly stacked green white-pocket lumber that had been covered with canvas for more than a year, although other fungi had infected the wood and had caused some

---

[10] U.S. Forest Products Laboratory Kiln Schedules and Drying Time. Forest Products Laboratory Report No. 1900-5. 1960.

decay. Douglas-fir lumber containing white pocket is not subject to further development of Fomes pini or other form of decay if it remains dry in use.

Decorative Properties

The interesting texture and surface appearance of Douglas-fir containing white pocket have favored its use for decorative purposes, either as lumber or as veneer. One large lumber manufacturer has marketed white-pocket material for that purpose. Experiments at the Forest Products Laboratory show that it has a pleasing appearance either with transparent or with pigmented natural finishes. Figure 17 shows a section of sandwich panel faced with white-pocket veneer applied with satisfactory results to an office ceiling. The panels were given a pigmented natural finish.

One difficulty with the utilization of white pocket for decorative purposes is that a fairly uniform distribution of pockets is desirable, while the natural occurrence is often streaked. One study at the Forest Products Laboratory gave only 6 percent of the yield of rotary-cut veneer from white-pocket logs that was classified as "decorative."

Acoustical Properties

Sound-absorption tests were made on panels composed of three 1-foot squares of plain 3/4-inch Douglas-fir without white pocket, 3/4-inch Douglas-fir with grooves 1/4 inch deep, 3/4-inch Douglas-fir with a large amount of white pocket, a sandwich of 1/16-inch white-pocket veneer over an insulation-board core, and a sandwich of 1/16-inch white-pocket veneer over a paper honeycomb core. Figure 18 shows the three 3/4-inch solid materials first named. Tests were made by the National Bureau of Standards using the "box test" method. In that method, the test panel is used as one wall of a sound box and its absorption coefficient at 512 cycles per second is obtained by comparison with samples of other materials previously tested by the more elaborate reverberation-chamber method.

Sound-absorption coefficients determined in this way are given in table 11. The clear solid Douglas-fir and the grooved Douglas-fir showed very little sound-absorbing qualities. Douglas-fir lumber with a large amount of white pocket, and thin white-pocket veneer over an insulation-board core indicated only moderate absorption, not sufficient to be considered acoustical materials. The best absorption was obtained with white-pocket veneer over a paper honeycomb core. While the value of 0.62 for this combination is somewhat lower than that for many manufactured acoustical materials, it is still appreciable. There are many purposes where white-pocket veneer over paper honeycomb core would be acceptable as acoustical material.

Table 1.--Average strength in relation to apparent pocket volume in white-pocket Douglas-fir

Pocket-volume class	Number of tests	Apparent pocket volume	Moisture content	Specific gravity[1]	Modulus of rupture	Modulus of elasticity
		Percent	Percent		P.s.i.	1,000 p.s.i.
3/4- BY 2-INCH SPECIMENS						
Clear wood	5	0	32.3	0.502	7,960	1,471
Incipient	5	0	35.7	.455	7,480	1,531
5 percent	5	5.4	47.7	.401	5,130	1,183
10 percent	5	9.7	65.0	.422	4,310	1,034
20 percent	7	20.8	122.7	.368	3,900	981
30 percent	5	29.1	141.5	.336	2,700	634
40 percent	5	39.9	166.5	.293	2,170	608
50 percent	2	48.5	150.9	.258	1,970	538
2- BY 4-INCH SPECIMENS						
Clear wood	6	0	33.8	.444	6,200	1,514
Incipient	5	0	34.1	.493	6,840	1,481
5 percent	8	5.1	60.6	.415	5,350	1,465
10 percent	9	10.8	61.0	.405	4,350	1,183
20 percent	9	18.5	72.0	.391	3,780	1,214
30 percent	7	29.8	104.0	.365	3,420	1,056
40 percent	2	37.9	88.6	.375	2,910	943
50 percent	3	52.8	110.0	.320	2,330	733

[1] Based on ovendry weight and green volume.

Table 2.--Properties of green Douglas-fir with and without white-pocket

Item	Units	Clear Douglas-fir[1]	White-pocket group[2]			
			Incipient	Light	Medium	Heavy
Tests	Number	....	33	47	70	30
Volume of pockets[3]	Percent	....	0	8	24	41
Rings per inch	Number	....	28	21	19	20
Summerwood	Percent	....	38	35	35	33
Moisture content	......do.....	38	35	31	32	34
Specific gravity[4]	....	.45	.40	.39	.36	.35
Transverse bending						
Stress at proportional limit	P.s.i.	4,500	3,150	2,730	1,930	1,700
Modulus of rupture	......do.....	7,600	6,220	5,210	3,950	3,420
Modulus of elasticity	1,000 p.s.i.	1,570	1,406	1,265	1,035	892
Work to proportional limit	In.-lb. per cu. in.	.75	.41	.35	.21	.18
Work to maximum load	......do.....	7.6	6.62	3.77	1.93	1.59
Total work[5]	......do.....	18.3	11.81	5.64	2.70	1.95
Compression						
Maximum crushing strength	P.s.i.	3,860	3,170	2,870	2,190	2,090
Modulus of elasticity	1,000 p.s.i.	2,020	1,627	1,538	1,162	1,088
Maximum shearing strength	P.s.i.	930	825	753	602	539
Toughness[6]	In.-lb.	....	143	91	64	57

[1] Values are from results of standard strength tests at the Forest Products Laboratory, reported in the Wood Handbook.

[2] White-pocket groups are described more fully in the text.

[3] Total volume, adjusted for the amount of cellulose filling in the pockets.

[4] Based on ovendry weight and green volume.

[5] To one-half maximum load.

[6] Load applied to the radial face.

Table 3.--Properties of green Douglas-fir joists containing white pocket, by white-pocket group

Line	Item	Units	White-pocket group: Incipient	Light	Medium	Cull
	TESTS OF JOISTS					
1	Joists	Number	4	22	12	3
2	Summerwood	Percent	30	33	34	27
3	Rings per inch	Number	28	14	16	15
4	Moisture content	Percent	31.3	31.7	32.2	29.5
5	Specific gravity[1]	....	.415	.389	.377	.363
6	Adjusted pocket volume[2]	Percent	0	8	20	38
7	Modulus of rupture	P.s.i.	2,300	2,140	1,900	570
8	Modulus of elasticity	1,000 p.s.i.	1,041	1,089	959	595
9	Total work	In.-lb. per cu. in.	....	1.33	.97	.16
10	Estimated modulus of rupture[3]	P.s.i.	3,640	3,020	2,770	1,510
	TESTS OF MATCHED SMALL WHITE-POCKET SPECIMENS[4]					
11	Specific gravity[1]	....	.400	.379	.367	.308
12	Modulus of rupture	P.s.i.	6,140	4,490	4,080	2,680
13	Modulus of elasticity	1,000 p.s.i.	1,411	1,152	1,102	765
14	Total work	In.-lb. per cu. in.	12.88	4.00	2.97	2.04

[1] Based on ovendry weight and green volume.

[2] Apparent pocket volume from grit analysis adjusted for the estimated amount of cellulose filling.

[3] Modulus of rupture of matched small white-pocket specimens (line 12) multiplied by the strength ratio from knots or cross grain.

[4] Average of 2 small specimens side matched to each joist and free of strength-reducing characteristics other than white pocket.

Table 4.--Average withdrawal resistance of eightpenny common nails driven in Douglas-fir studs with and without white pocket[1]

Grade group	Moisture content	Specific gravity[2]	Number of nails	Withdrawal load
	Percent			Lb.
No. 1 grade	12.1	0.511	54	303
No. 3 grade	12.5	.509	54	314
No. 1 grade	12.3	.443	72	280
"X" material	12.2	.436	72	200

[1] No. 1 (now Construction) grade groups were free of white pocket, the No. 3 (now Utility) grade group had a limited amount, and the "X" material more than that amount of white pocket.

[2] Based on weight and volume when ovendry.

Table 5.--Summary of nail holding in white-pocket Douglas-fir[1]

Specific gravity[2]	Moisture content	Apparent volume of white pocket[3]	Maximum withdrawal load	Lateral resistance: Load at slip of -- 0.01 inch	0.015 inch	0.05 inch	0.1 inch	0.2 inch	0.3 inch	0.5 inch	Maximum: Load	Maximum: Slip
	Percent	Percent	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	Lb.	In.
0.31	11.1	14.6	106	47	57	95	120	153	179	207	229	1.0
.35	11.3	14.9	150	54	66	108	136	172	196	222	246	1.0
.38	11.2	14.0	168	74	88	137	168	211	243	273	300	.8
.39	11.3	10.2	213	72	88	145	181	228	283	322	343	.9
.40	11.4	8.1	208	86	102	151	184	226	274	318	337	.8
.41	11.2	13.8	198	70	84	132	166	216	256	300	323	.8
.43	11.5	5.1	206	84	99	148	178	222	269	315	348	1.0
.44	11.4	4.2	249	82	99	151	184	230	280	333	363	.9
Average .39	11.3	10.6	187	71	85	133	165	207	248	286	311	.9

[1] Withdrawal values are averages of 40 tests, 4 nails in each of 10 specimens. Lateral-resistance values are averages of a single test on each of 10 specimens.

[2] Based on ovendry weight and volume at test.

[3] Estimated by grit analysis.

Table 6.--Average racking strength and stiffness of Douglas-fir wall panels with and without white pocket[1,2]

Lumber grade	Moisture content	Weight of panel	Displacement			Load	
			At 1,200 pounds load	At 2,700 pounds load	Residual after 2,700 pounds	At first failure	Maximum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Percent	Lb.	In.	In.	In.	Lb.	Lb.
PANELS FABRICATED GREEN AND TESTED DRY							
No. 3 grade	12.4	354	0.24	0.62	0.39	5,270	5,270
"X" material	15.1	325	.33	.72	.48	4,880	5,320
PANELS FABRICATED AND TESTED DRY							
No. 1 grade	12.3	367	.06	.18	.06	8,300	10,100
No. 3 grade	12.1	360	.05	.16	.06	8,410	9,350
"X" material	11.6	353	.08	.26	.09	6,200	7,470

[1] All panels were 8 by 12 feet, with 2- by 4-inch framing, studs 16 inches on center, single top and bottom plates, 3 let-in diagonal braces, no openings, horizontally board sheathed. Each value is the average of 3 test panels.

[2] The No. 1 (now Construction) grade was free of white pocket. The No. 3 (now Utility) grade contained a limited amount and the "X" material a greater amount of white pocket.

Table 7.--Average transverse bending strength of Douglas-fir wall panels containing white pocket[1]

Lumber grade	Moisture content	Weight of panel	Deflection with design load[2]	Deflection-span ratio with design load	Residual deflection with 2-1/4 times design load[2]	Uniform load equivalents[3] At first failure	Uniform load equivalents[3] Maximum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Percent	Lb.	In.		Percent of deflection under load	Lbs. per sq. ft.	Lbs. per sq. ft.
No. 3 grade	10.5	103	0.19	1/473	2.1	48	70
"X" material[4]	10.8	96	.26	1/338	12.9	41	45

[1] All panels were 4 by 8 feet, and 2- by 4-inch framing, studs 16 inches on center, single top and bottom plates, 1 let-in diagonal brace, no openings, horizontally board sheathed. Each value is the average of 3 test panels. Panels were fabricated green and tested dry.

[2] Design live load equivalent of 20 pounds per square foot. Deflections were adjusted to that for uniform load.

[3] Uniform load that would produce the same moment at the center of the span as that produced by the quarter-point loadings used in the tests.

[4] Lumber containing more white pocket than is permitted in the No. 3 grade.

Table 8.--Average impact bending strength of Douglas-fir wall panels containing white pocket[1]

Lumber grade	Moisture content	Weight of panel	With 1-1/2-foot drop: Deflection	With 1-1/2-foot drop: Residual deflection	With 3-foot drop: Deflection	With 3-foot drop: Residual deflection	Height of drop at first failure
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Percent	Lb.	In.	In.	In.	In.	Ft.
No. 3 grade	11.6	102	0.95	0.05	1.82	0.2	1.5
"X" material[2]	11.3	95	1.28	.10	2.28	.3	2

[1] Impact with 60-pound sandbag on panels 4 by 8 feet, 2- by 4-inches framing, studs 16 inches on center, single top and bottom plates, one let-in diagonal brace, no openings, horizontally board sheathed, panels fabricated green and tested dry, placed horizontally and supported at the ends in test. Each value is the average of 3 test panels.

[2] Lumber containing more white pocket than is permitted in the No. 3 grade.

Table 9.--Drying times[1] for pieces of clear and white-pocket Douglas-fir

Amount of white	Average specific gravity[2]	1- by 1-inch squares		1-1/16- by 10-inch boards		2- by 2-inch squares		2-1/8- by 10-inch boards	
		Number of specimens	Drying time	Number of specimens	Drying time	Number of specimens	Drying time	Number of specimens	Drying time
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			Hr.		Hr.		Hr.		Hr.
None	0.485	16	14.5	3	28.5	8	46.0	4	80.4
Slight	.455	30	13.0	6	20.0	7	25.0	2	59.0
Slight	.410	15	11.2	3	16.0	8	22.5	3	44.5
Moderate	.380	33	11.0	6	15.0	24	20.0	6	39.7
Severe	.350	22	10.0	4	12.7	13	17.7	5	32.5

[1] Time required to kiln-dry boards and squares 30 inches long from approximately 32 to 18 percent moisture content at a temperature of 150° F., 62 percent relative humidity, and air velocity about 300 feet per minute.

[2] Based on ovendry weight and green volume.

Table 10.--Weight losses in decay tests of white-pocket and clear Douglas-fir[1]

Fungus used	Apparent volume of pockets in percent			Clear wood from --	
	10	20	30	Oregon	Montana
	Percent	Percent	Percent	Percent	Percent
Poria incrassata	43.1	51.7	55.6	47.8	48.0
Poria monticola	36.0	52.6	47.6	35.2	44.5
Lentinus lepideus	21.2	28.1	44.8	13.6	26.5
Lenzites trabea	26.5	25.2	40.6	11.7	24.8
Fomes roseus	24.0	23.5	35.6	13.0	35.5
Poria xantha	20.7	27.2	25.1	14.7	20.4
Average for all fungi	28.6	34.7	41.6	22.7	33.3

[1] Each value is an average of two replicate samples.

Table 11.--Sound absorption coefficients for Douglas-fir with and without white pockets

Panel	Description	Sound absorption coefficient[1]
1	Clear Douglas-fir lumber	0.04
2	Clear grooved Douglas-fir lumber	.04
3	Douglas-fir lumber with white pocket	.23
4	1/16-inch white-pocket Douglas-fir veneer facing over insulation-board core	.21
5	1/16-inch white-pocket Douglas-fir veneer facing over honeycomb core	.62

[1] At 512 cycles per second.

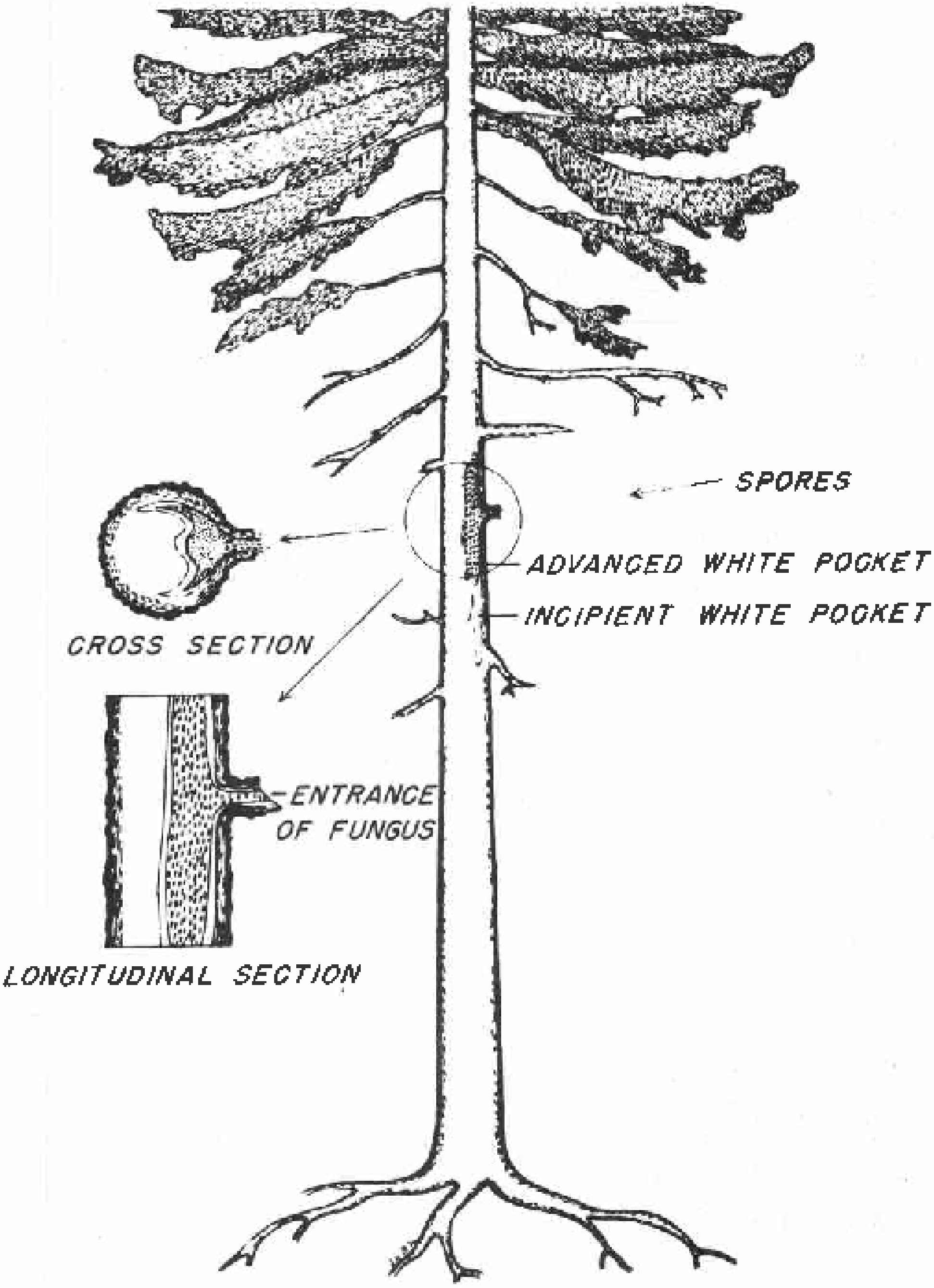


Figure 1.--Distribution of white pocket in a tree from its point of entrance at a dead branch.

ZM 97094 F

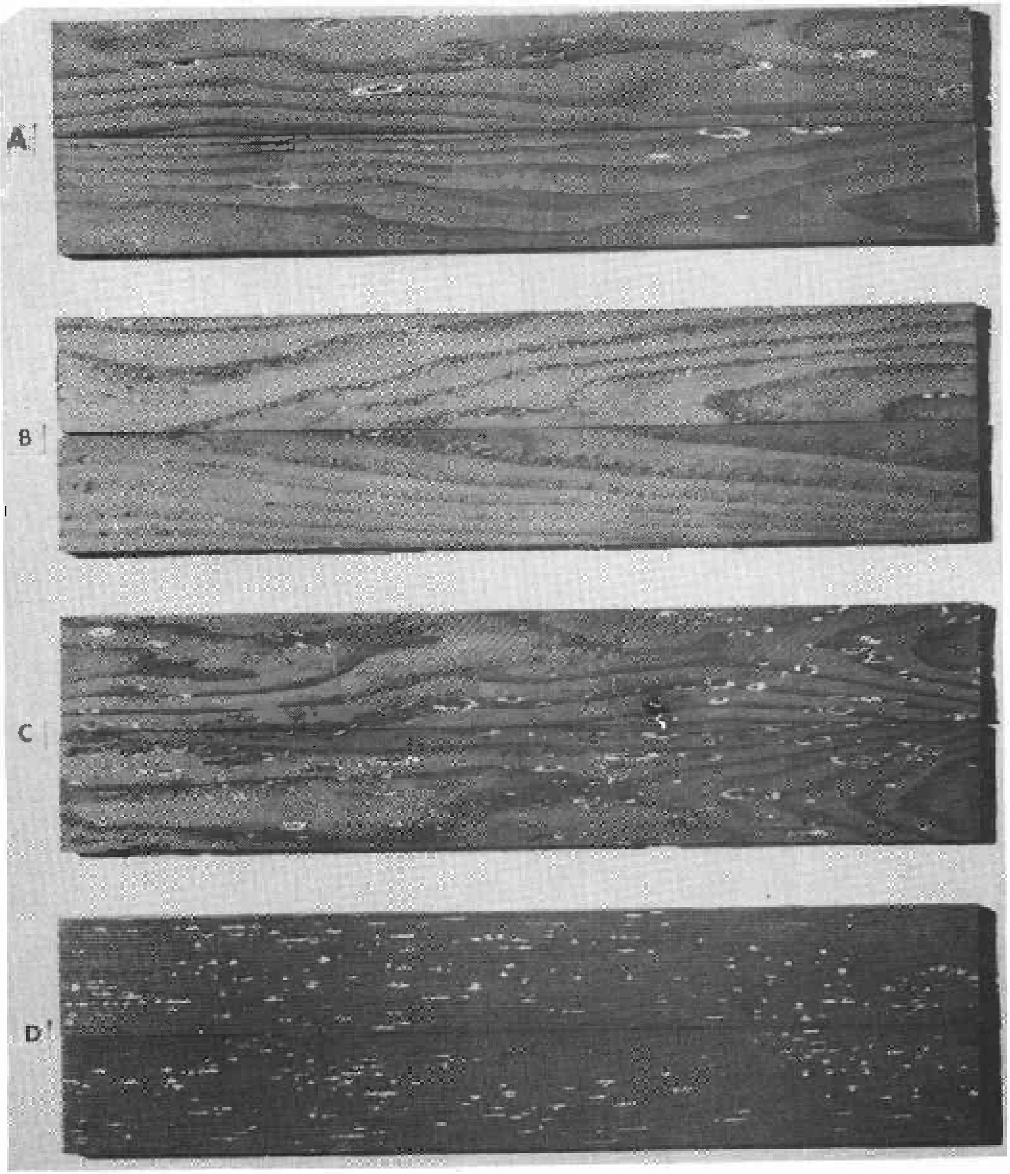


Figure 2.--Douglas-fir wood of light white-pocket classification.

ZM 95830 F

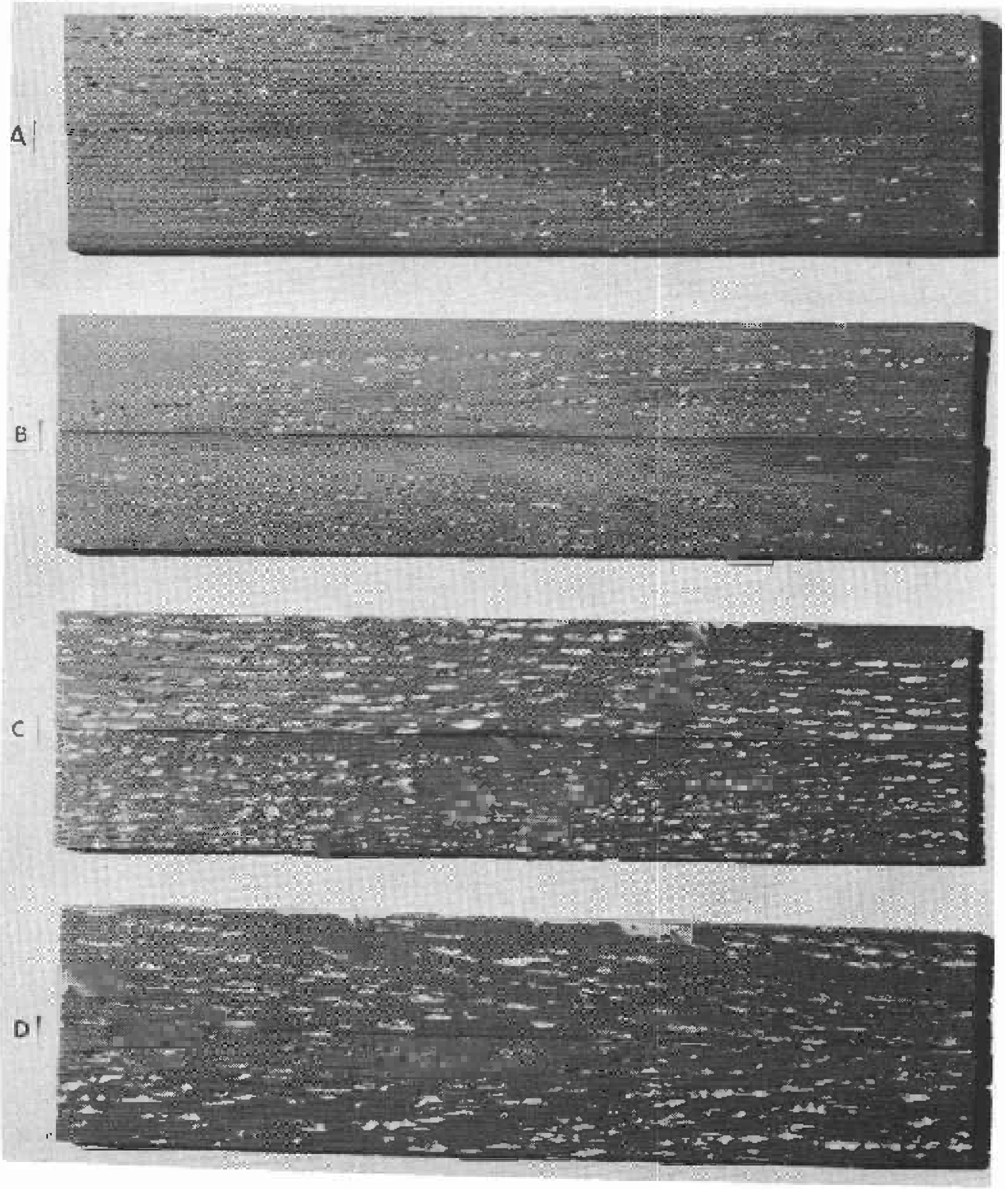


Figure 3.--Douglas-fir wood of medium white-pocket classification.

ZM 95828 F

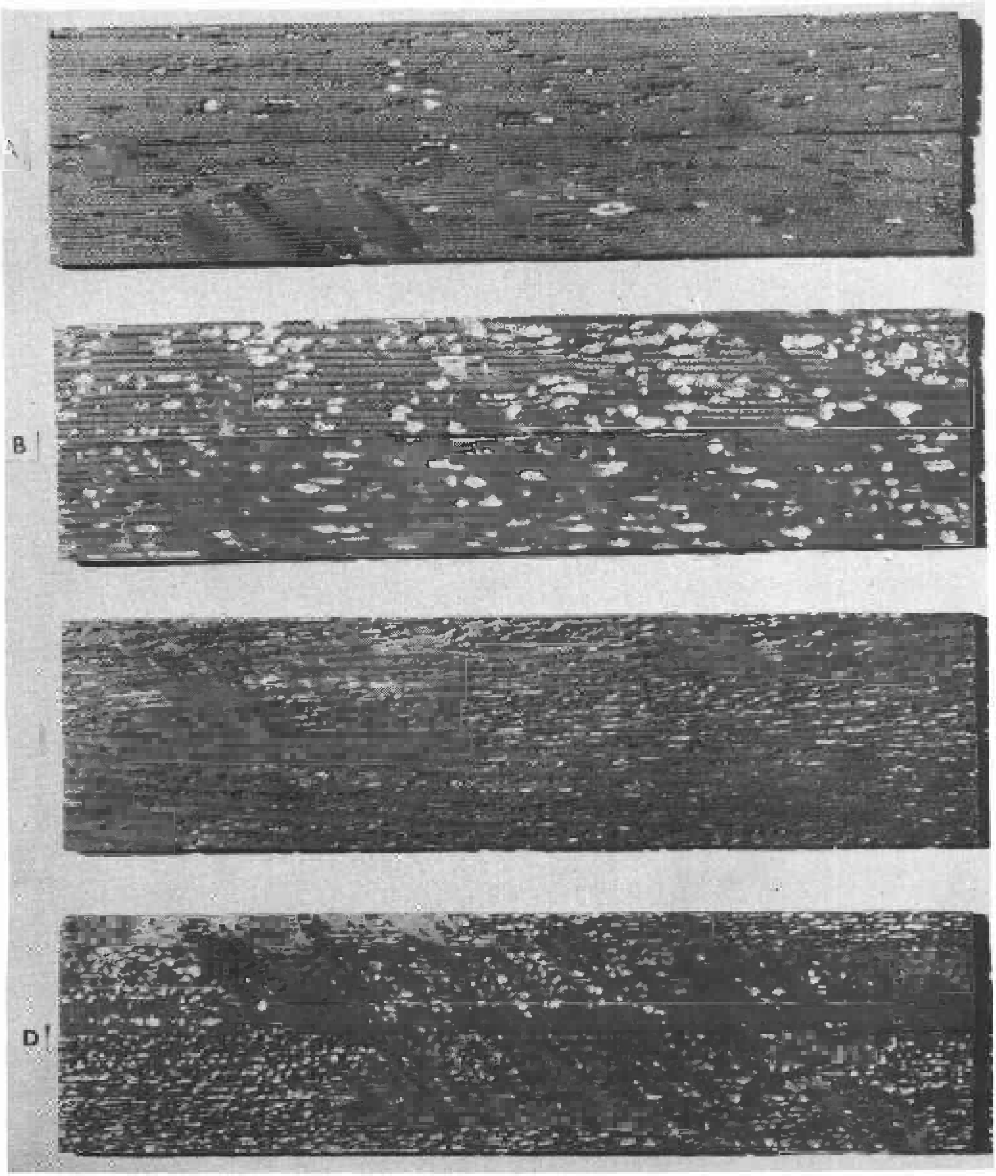


Figure 4.--Douglas-fir wood of heavy white-pocket classification.

M 95629 F

Figure 5.--Douglas-fir wood with various percentages of white pocket as determined from grit analysis. The percentages have not been adjusted for cellulose filling in the pockets.

ZM 81224 F

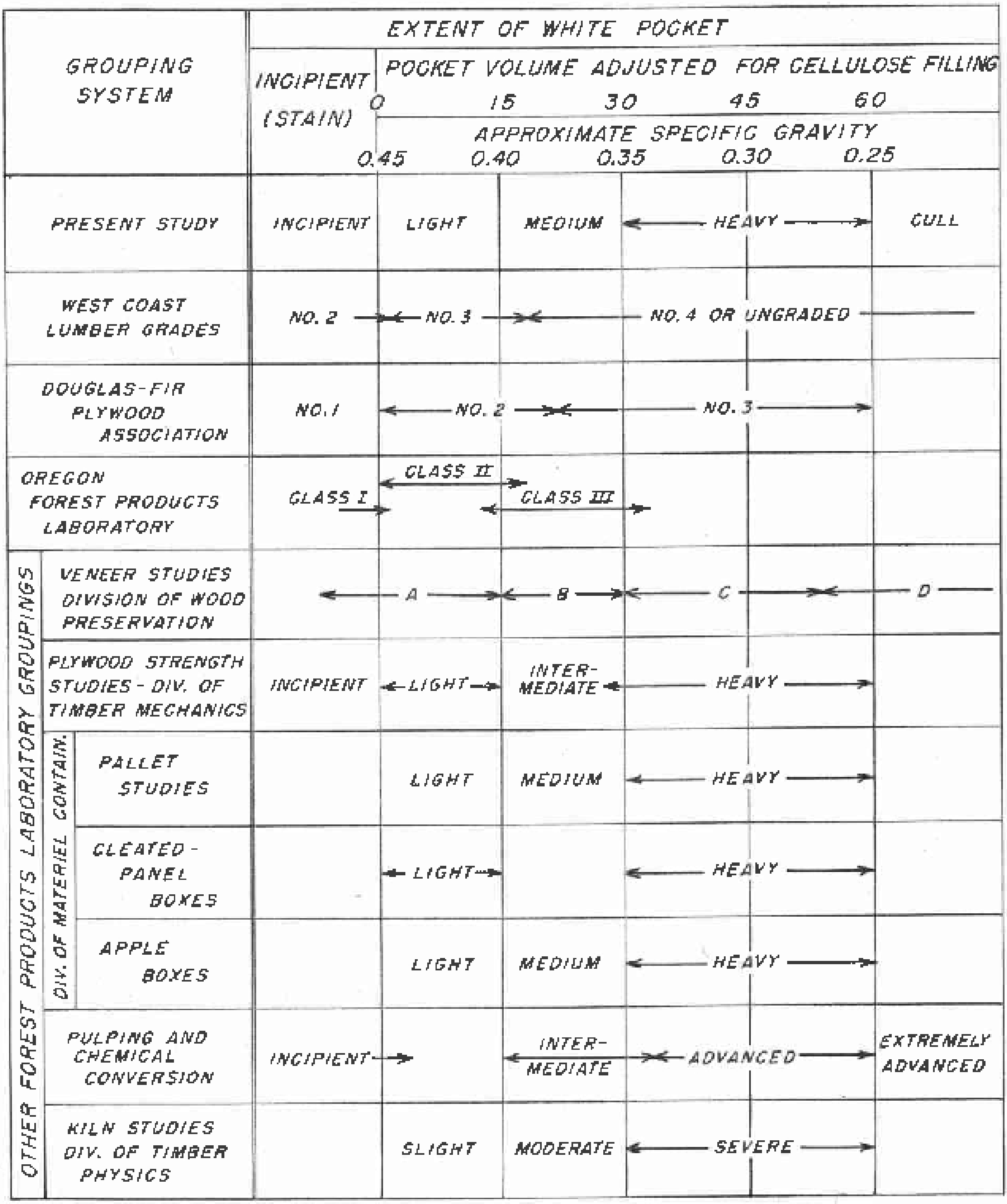


Figure 6.--Graphic comparison of white-pocket grouping systems.

ZM 96767 F

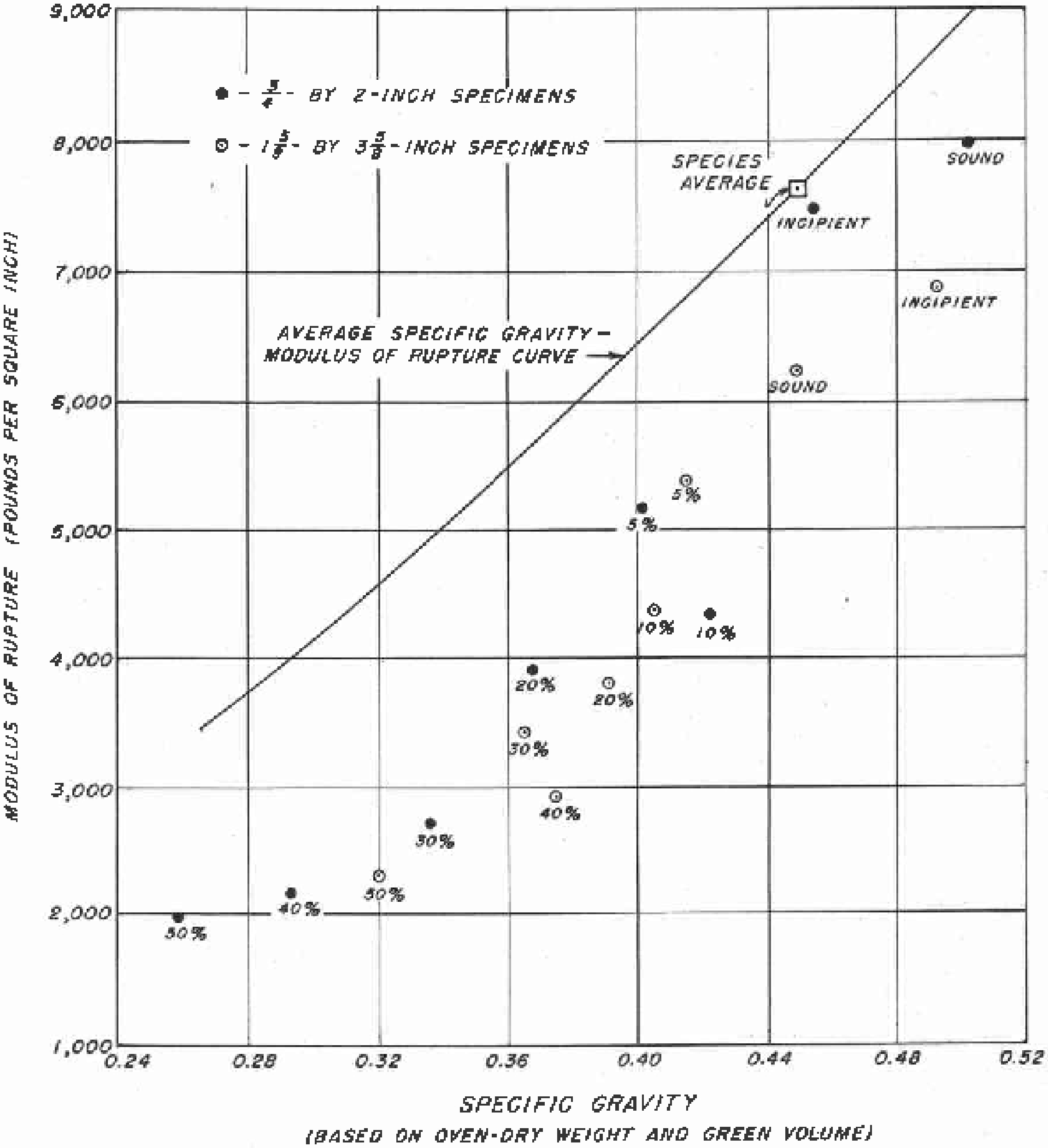


Figure 7.--Relation of bending strength (modulus of rupture) to specific gravity in various pocket-volume classes of Douglas-fir. A specific gravity-modulus of rupture curve based on the species average from the Wood Handbook is shown for comparison.

ZM 85160 F

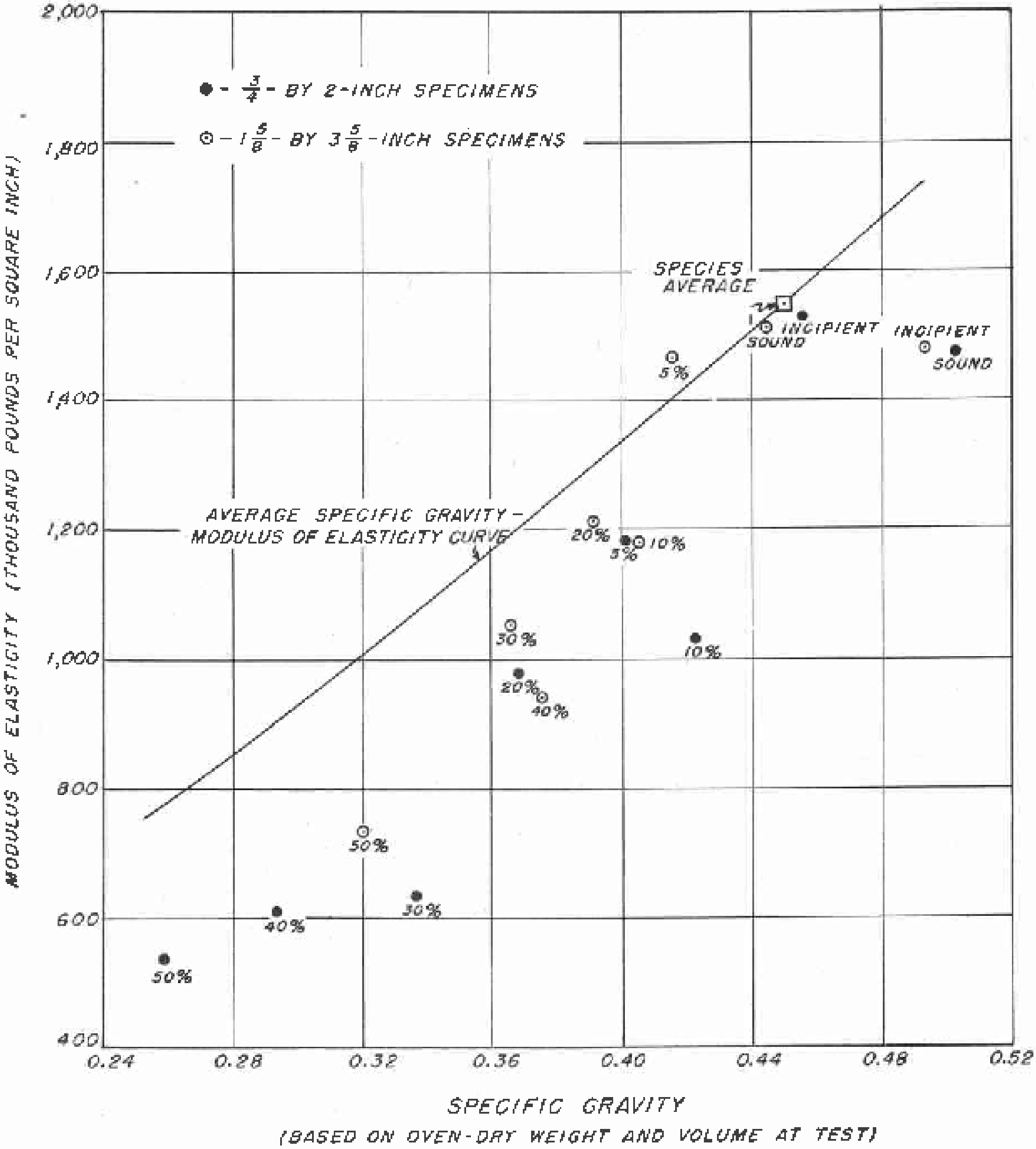


Figure 8.--Relation of bending stiffness (modulus of elasticity) to specific gravity in various pocket-volume classes of Douglas-fir. A specific gravity-modulus of elasticity curve based on the species average from the Wood Handbook is shown for comparison.

ZM 85161 F

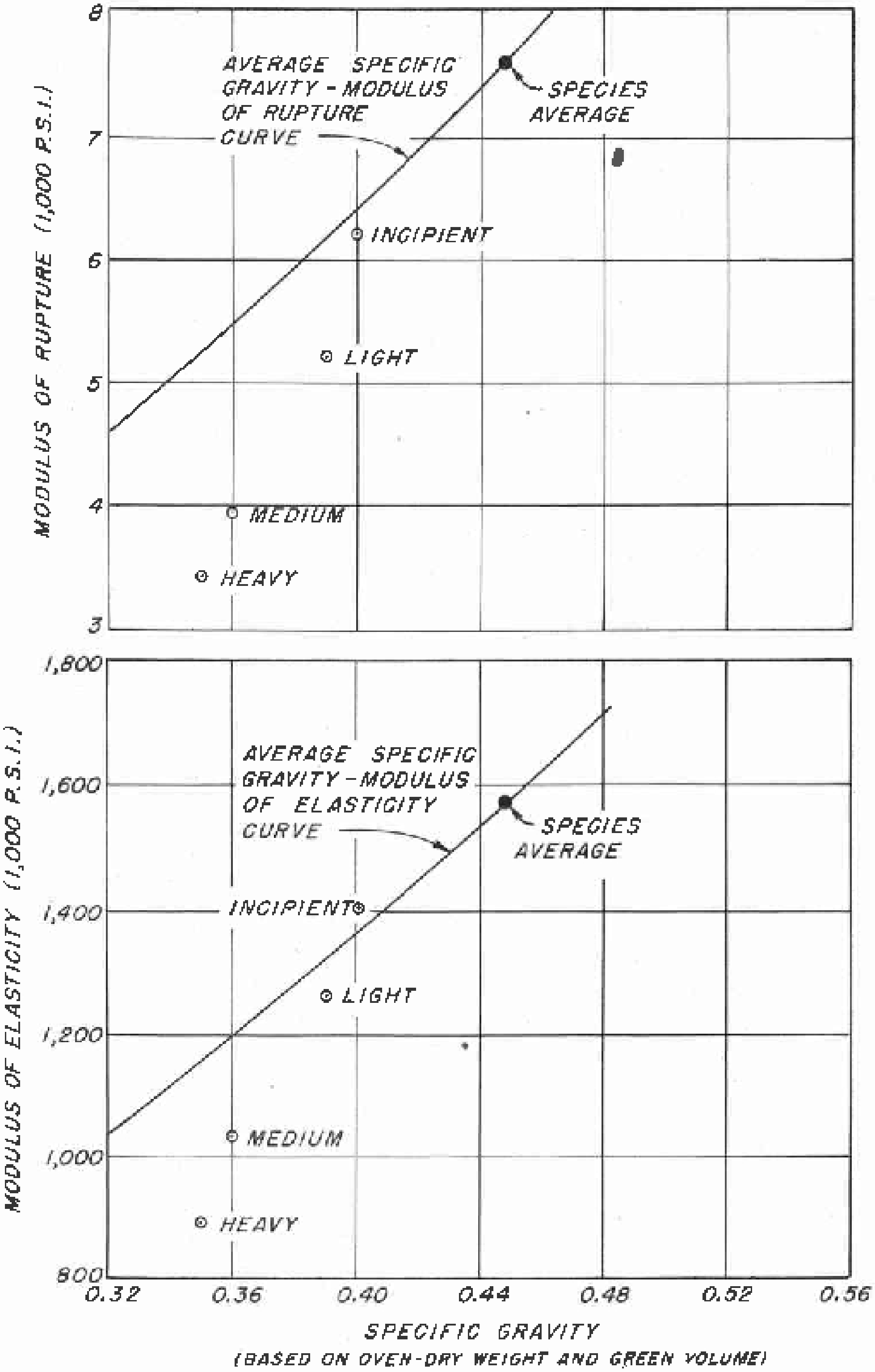


Figure 9.--Relation of modulus of rupture (above) and modulus of elasticity (below) in bending to specific gravity in groups of white-pocket Douglas-fir specimens. Curves based on species averages from the Wood Handbook are shown for comparison.

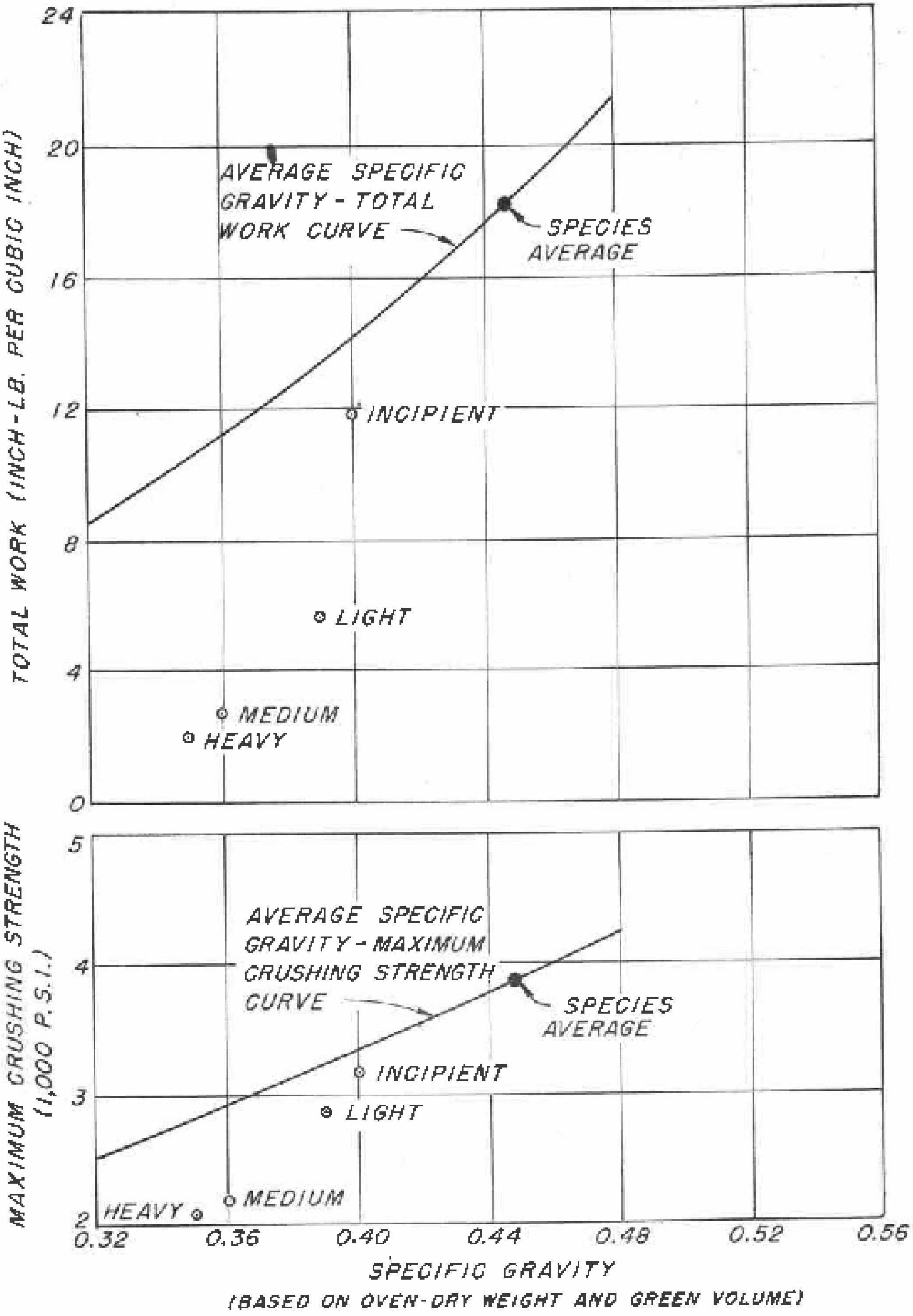


Figure 10.--Relation of total work in bending (above) and maximum crushing strength (below) to specific gravity in groups of white-pocket Douglas-fir Specimens. Curves based on species averages from the Wood Handbook are shown for comparison.

ZM 96766 F

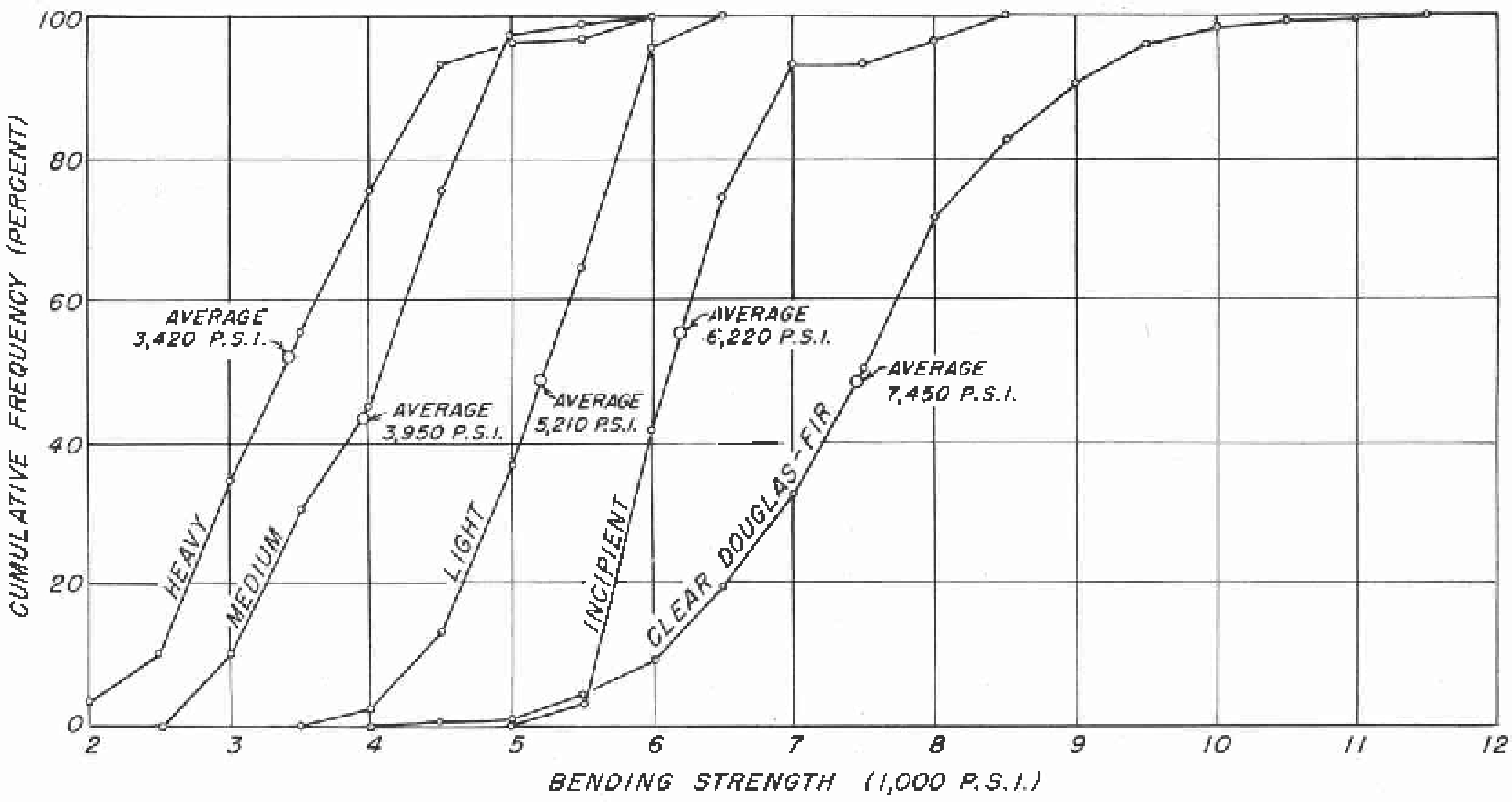


Figure 11.--Frequency distributions of bending strength values in groups of white-pocket and clear Douglas-fir specimens. The distribution for clear Douglas-fir is from a study of variability in structural woods.

ZM 96756 F

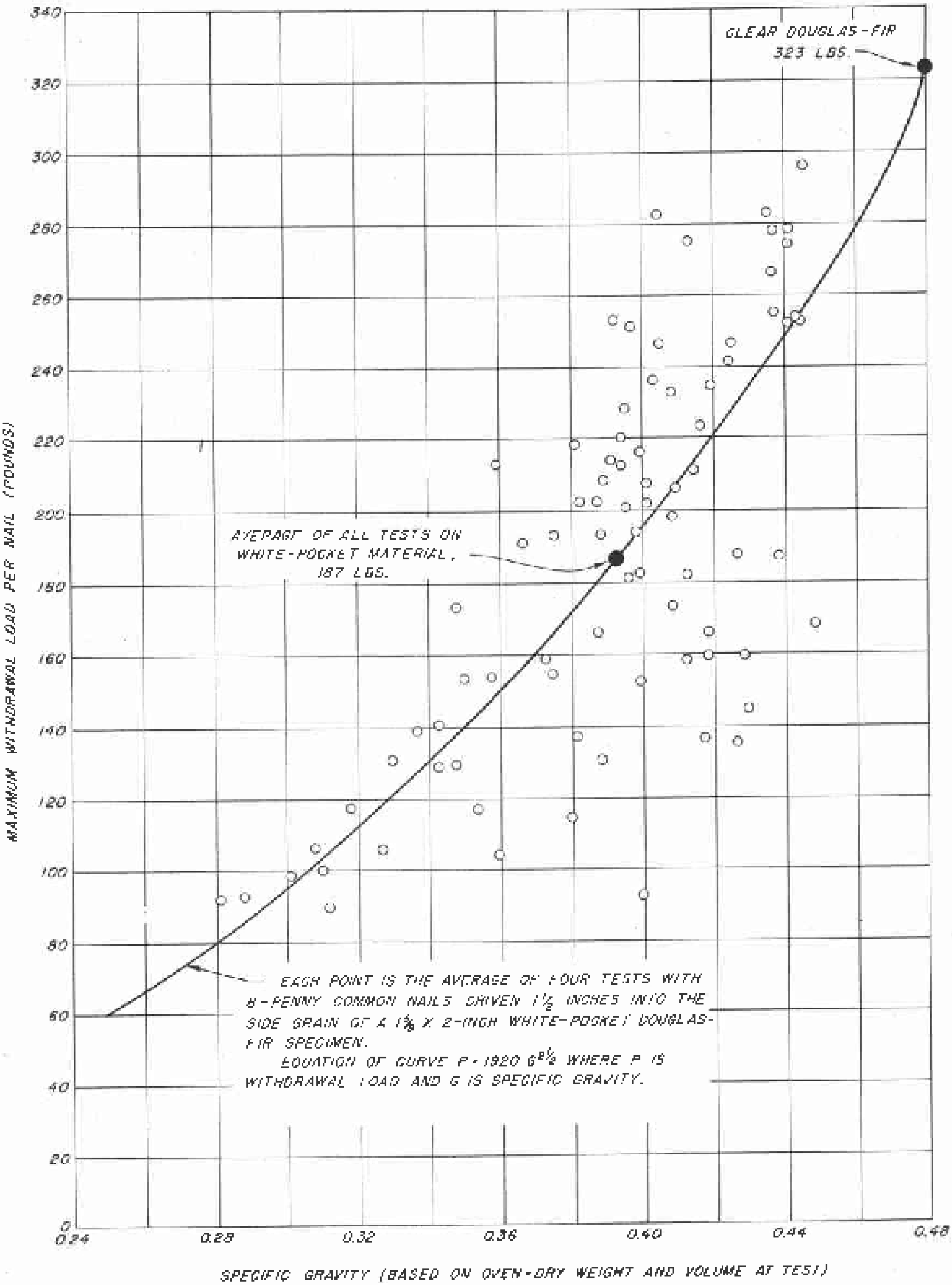


Figure 12.--Relation of withdrawal load to the specific gravity of the wood with eightpenny common nails driven into the side grain of white-pocket Douglas-fir.

Z M 97893 F

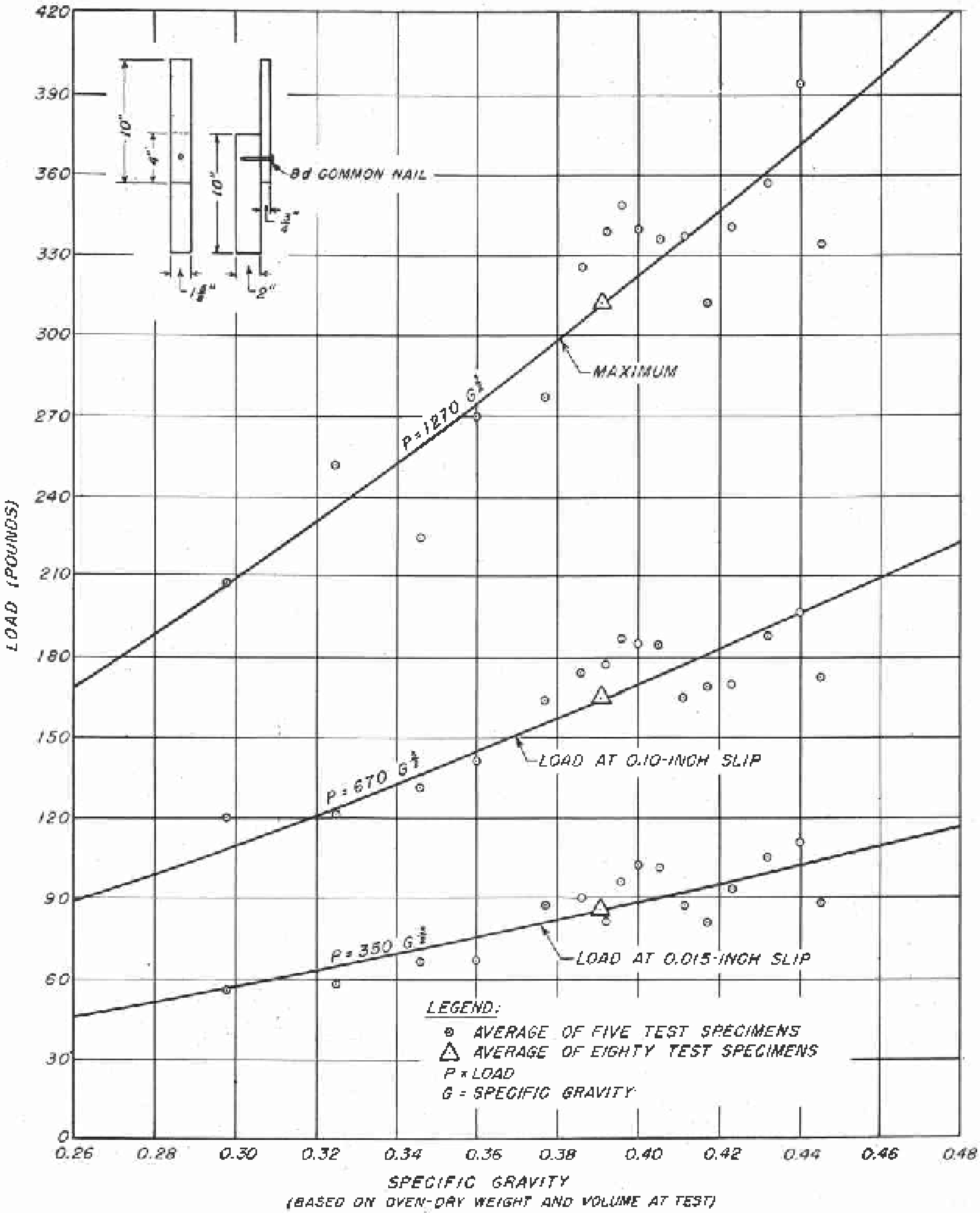


Figure 13.--Relation of load at various amounts of slip to specific gravity in lateral-resistance tests of eightpenny common nails in white-pocket Douglas-fir.

ZM 94277 F

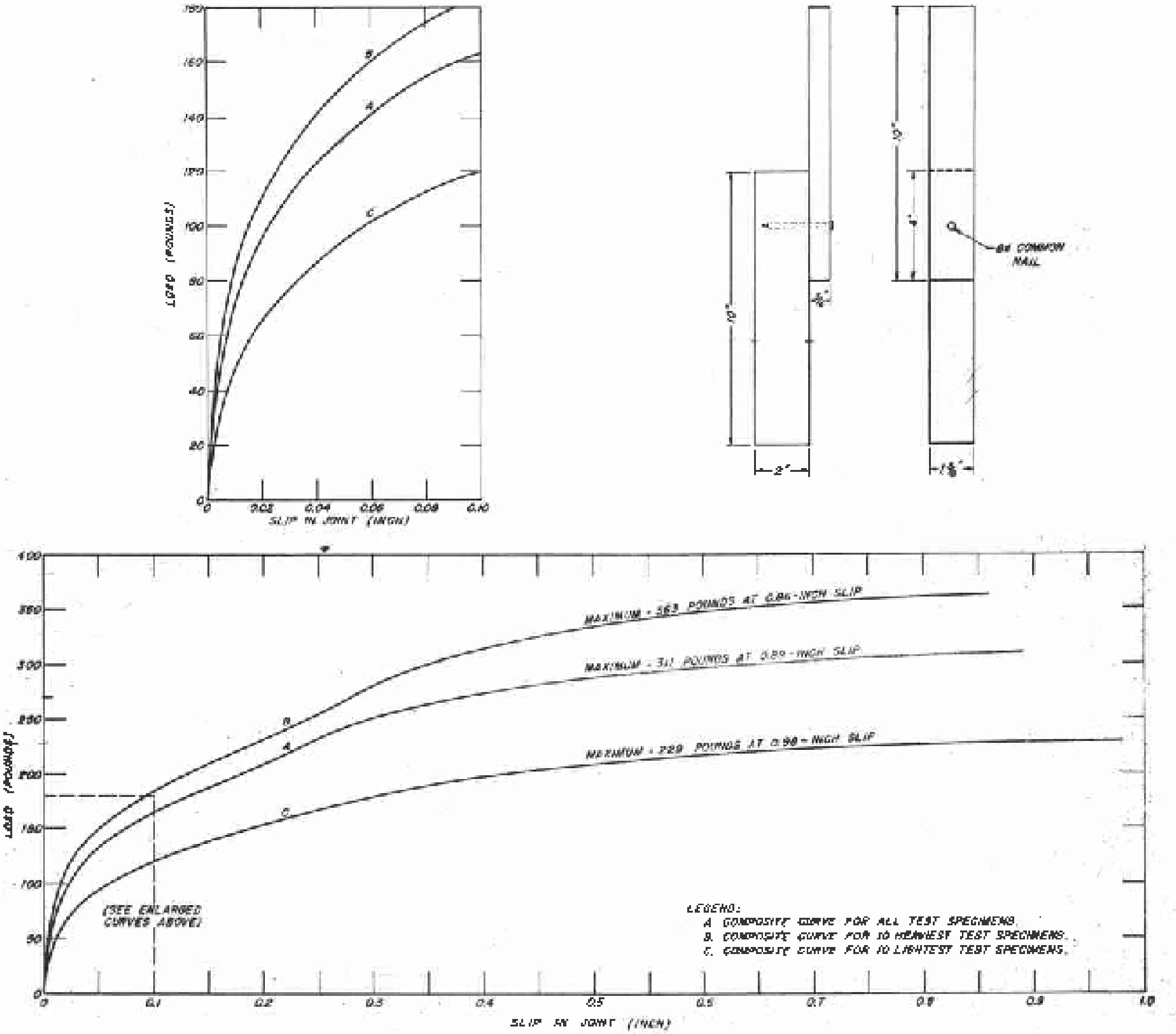


Figure 14.--Relation of load to slip in lateral-resistance tests of eightpenny common nails in white-pocket Douglas-fir.

ZM 94276 F

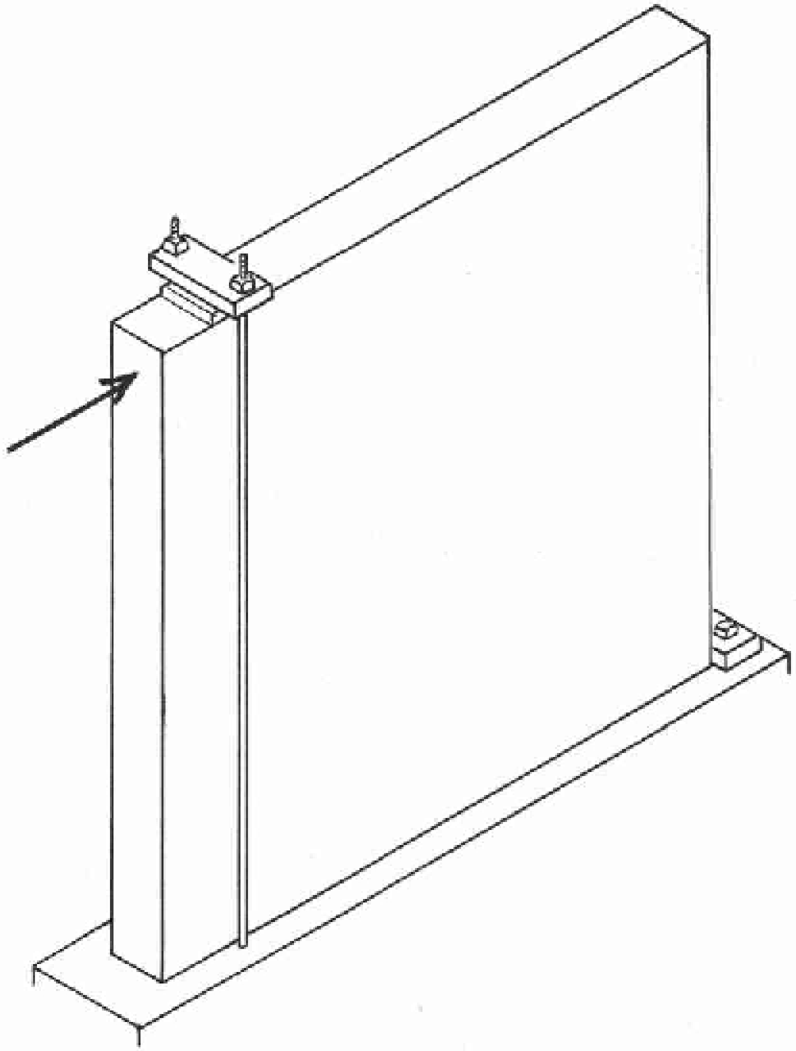
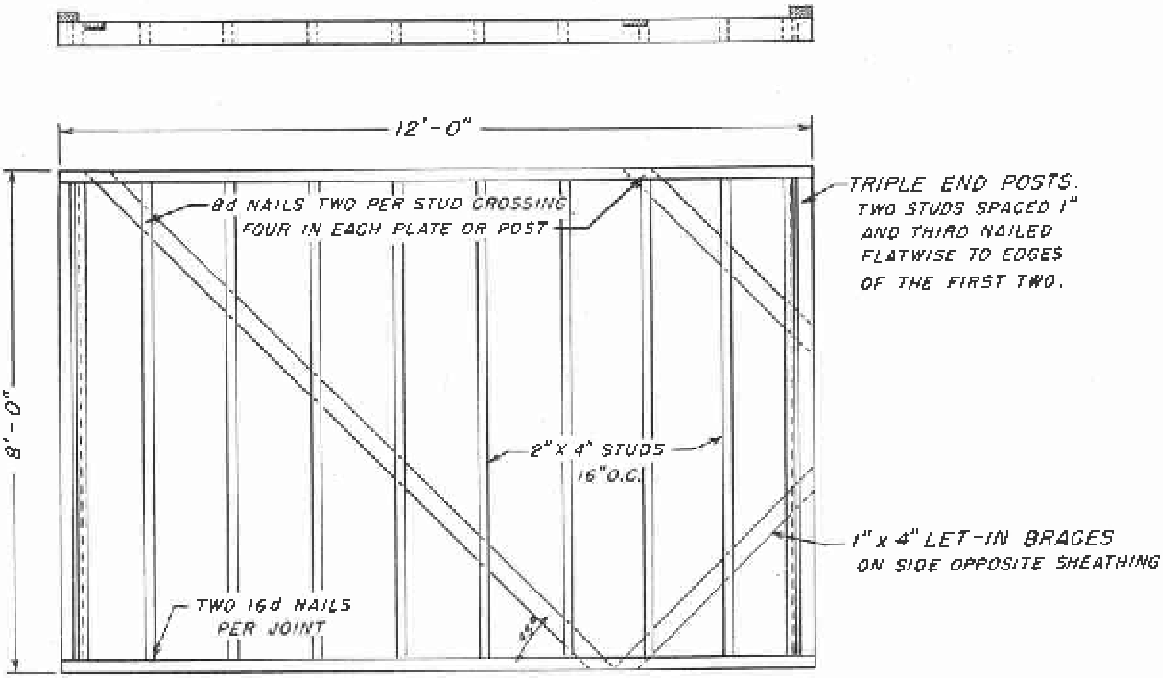
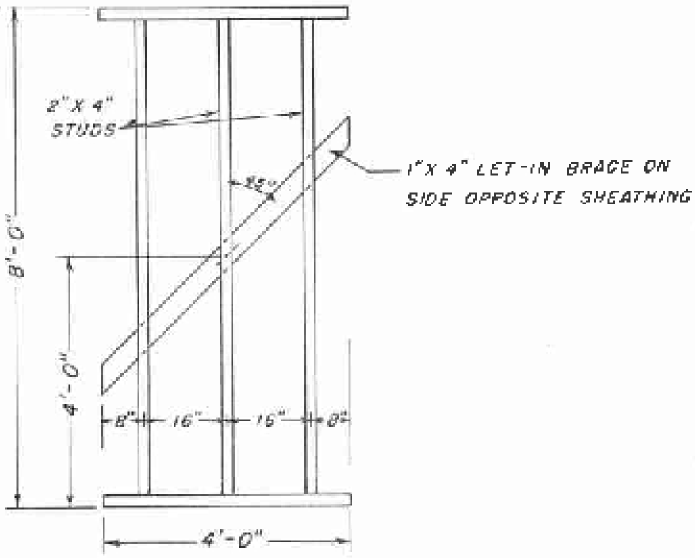


Figure 15.--Sketch of the racking test on a wall panel.

Z M 97892 F



PANEL CONSTRUCTION FOR RACKING TESTS



PANEL FRAME FOR STATIC AND IMPACT BENDING TESTS

Figure 16.--Arrangement of framing in wall panels used in racking and bending tests.

ZM 81309 F

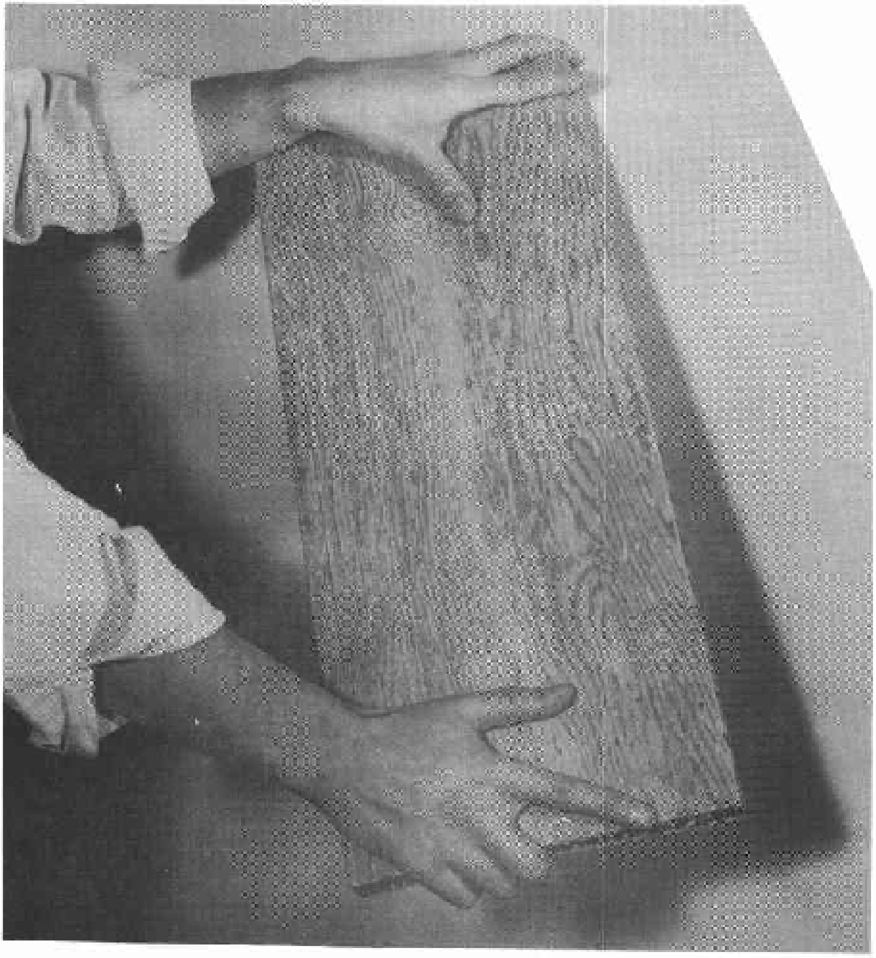


Figure 17.--Section of sandwich panel with white-pocket Douglas-fir veneer facing applied to paper honeycomb core. Used for an office ceiling.

ZM 95056 F

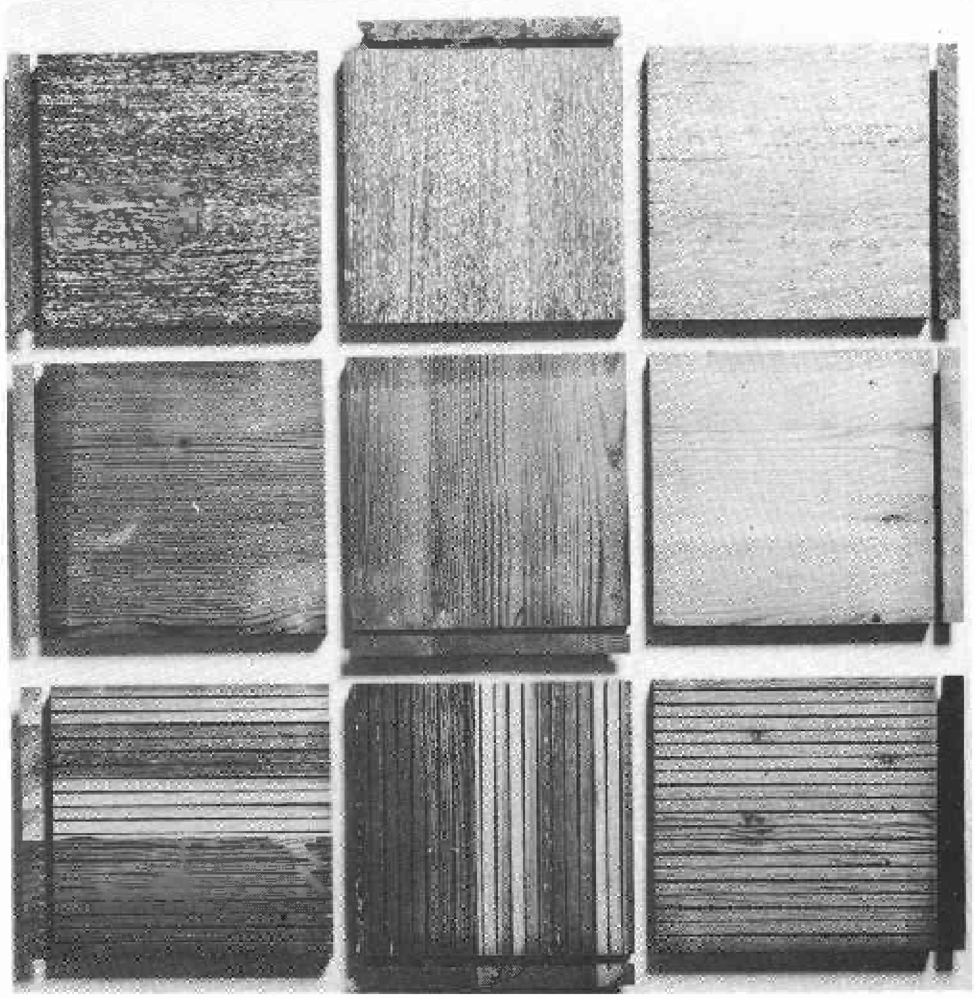


Figure 18.--Lumber materials used in sound-absorption tests. Shown are clear Douglas-fir (center), grooved Douglas-fir (below), and Douglas-fir with a large amount of white pocket (above).

ZM 88507 F