RELATIONSHIP OF LOCALITY AND RATE OF GROWTH TO DENSITY AND STRENGTH OF DOUGLAS-FIR

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RELATIONSHIP OF LOCALITY AND RATE OF GROWTH TO DENSITY AND STRENGTH OF DOUGLAS-FIR

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Summary

This report presents detailed data on the properties of Douglas-fir grown in selected parts of its range and the effect of growth rate and percentage of summerwood on density and strength properties. The data show that there are wide differences in the characteristics of Douglas-fir grown in the several areas considered. Analyses of the data show a reasonably consistent distinction between the typical Douglas-fir (*Pseudotsuga menziesii* var. *menziesii*) and the varietal form *P. menziesii* var. *glauca*. Within the latter group a secondary separation of Douglas-fir in the northern and southern Rocky Mountain areas is clearly shown. Combination of Douglas-fir grown in the Cascade and Sierra Nevada areas with the so-called Coast-type Douglas-fir has relatively little overall effect on the specific gravity and strength properties.

Introduction

Over a period of more than 40 years, the U. S. Forest Products Laboratory has investigated the basic strength properties of about 180 species of wood native to this country. Systematic research on the strength of small, clear specimens has demonstrated that the relatively large differences in properties found within a single tree and among trees within a particular area may be as large as those found among trees from widely separated areas. Hence, in general, the best estimate of the properties of a species in any location is the overall species average, which represents all the areas sampled within the natural range of the species.

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

In Douglas-fir it has been necessary to deviate from that principle. The growth range of Douglas-fir includes a tremendous variation in geographical and climatic conditions within the area west of the Great Plains. Altitudes may vary from sea level to 10,000 feet or more, rainfall from an annual average of around 18 to more than 100 inches, and soil conditions from infertile, rocky areas to the most fertile types. It is not surprising, therefore, that a decision was reached many years ago to segregate Douglas-fir into classes that corresponded to broad differences noted in the samples from certain geographical areas.

Douglas-fir timber of the western slopes of the Cascade Mountains in Washington and Oregon, and in the coastal region of northwestern California, was produced under more or less optimum growing conditions --ample rainfall, good soil, and relatively mild climatic conditions. Douglas-fir from the relatively high elevations in the northern Rocky Mountains appeared to differ from that produced under the coastal conditions. The character of the trees and tests of specific gravity and strength confirmed that difference. Trees were smaller, and were exceedingly limby as compared with those grown on the coast. Early botanists, however, differed as to whether Douglas-fir grown in the Rocky Mountains should be designated as a separate variety of the species, or as a separate species.

Nomenclature

The U. S. Forest Service accepted Pseudotsuga taxifolia (Poir.) Britton (1897) as the official botanical name for all Douglas-fir until 1944, when Douglas-fir grown in the Rocky Mountain area was recognized as a varietal form (P. taxifolia var. glauca). In 1953, a revised "Check List of Native and Naturalized Trees of the United States," Agriculture Handbook No. 41, was published. That publication recognizes the typical Douglas-fir as Pseudotsuga menziesii (Mirb.) Franco (1950) and gives its range as the "Pacific Coast region from southwestern British Columbia south through western Washington and western Oregon to central coastal California, east to the Cascade Mountains in Oregon and to the Sierra Nevada in California and western Nevada."

The remaining Douglas-fir is classified as Pseudotsuga menziesii var. glauca (Mayr) France (1950). Its range is the "Rocky Mountain region from southwestern Alberta and central British Columbia south in mountains of Montana, Idaho, eastern Washington, eastern Oregon, eastern Nevada, Utah, Wyoming, Colorado, Arizona, New Mexico, and Trans-Pecos, Texas. Also south in mountains of northern and central Mexico (Sonora, Chihuahua, Durango, Zacatecas, Coahuila, Nuevo Leon, Hidalgo, and Puebla)."

The Check List includes this explanatory note: "It seems desirable to recognize the Douglas-fir of the Rocky Mountain region as a separate geographical variety. Its differences from the Douglas-fir of the Pacific Coast region certainly are of varietal rank, and some authors regard the two as different species. The silvicultural differences were summarized by Frothingham as long ago as 1909.[2] This variation was recorded as a cultural variety in the 1927 Check List."

Sampling Considerations

Background

Early strength tests indicated a substantially lower average level of specific gravity and strength properties in material collected from the northern Rocky Mountains (Wyoming and Montana) than in that grown in western Washington, Oregon, and California. Additional tests from the Inland Empire, especially western Montana and northern Idaho, and from the Sierra Nevada in California indicated an intermediate classification. Hence, three types were designated--Coast, Intermediate, and Rocky Mountain--in the Forest Service publication of strength data.[3]

For many years commercial Douglas-fir has been separated into two classes, Coast and Rocky Mountain. The distinction is not obvious from the nomenclature, but the production practices of Douglas-fir automatically provided a basis for segregation that served quite successfully.

Until recent years, the West Coast Lumbermen's Association was made up exclusively of producers who operated in the coastal area and cut only Coast-type Douglas-fir. All other Douglas-fir, including that cut in the Rocky Mountain States, the Inland Empire, and in inland California, was produced by independent mills or mills affiliated with the Western Pine Association. Douglas-fir production was a relatively small part of their operation, and the lumber was used almost exclusively where strength requirements were not exacting. Hence, in effect, a distinction was made between Coast-type and Rocky Mountain-type Douglas-fir for structural purposes.

This system exists today, but its practicability and continued usefulness have been questioned because of a rather sudden change in production practices inspired by the increased production and use of Douglas-fir grown in inland areas and by the more exacting requirements placed on lumber by the Federal Housing Administration and structural designers.

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[2] Frothingham, E. H. Douglas-fir: A Study of the Pacific Coast and Rocky Mountain Forms. U. S. Dept. Agr., Forest Service Circular 150, 38 pp. illus., 1909.

[3] Markwardt, L. J., and Wilson, T. R. C. Strength and Related Properties of Woods Grown in the United States. U. S. Dept. Agr. Tech. Bull. No. 479, 1935.

Douglas-fir cut in certain areas now commonly enters the market as Coast type or Rocky Mountain type, depending upon the affiliation of the mill that produced the material. This practice is not logical, because basic stresses for structural material set up by this Laboratory for the clear wood of structural species are substantially lower for the Rocky Mountain type than for the Coast type. If the strength of the clear wood is high enough to merit Coast type stresses, use of lower values is inefficient. On the other hand, if the strength properties of the wood are properly represented by the lower Rocky Mountain values, grading of the material as Coast-type Douglas-fir presents a safety hazard, because such wood cannot then be expected to maintain a proper factor of safety in use.

It is recognized that the more numerous branches and the smaller size of the inland trees rigidly limit the amounts of the higher structural grades and large-sized timbers available from them. These tree characteristics could be due principally to younger ages than in the virgin Coast type. The inherent quality of the clear wood, however, also has an important bearing on permitted spans and stiffness requirements for lumber in dimension sizes now being produced in ever increasing quantity from inland areas.

In addition to these considerations, a question arose as to whether the early Forest Service data on strength representing Douglas-fir grown in inland areas could be considered fully representative of that material. Inland producers surveyed expressed a belief that the strength properties of the clear wood were better than those tests indicated.

Tests of the specific gravity of selected Rocky Mountain Douglas-fir were made over a period of years. These tests indicated that some of the inland material was of higher density than that tested for strength.

Material from six mills tested by the Western Pine Association also had higher specific gravity and strength properties than the material used in the early Forest Service tests of Rocky Mountain and Intermediate types.

In addition to the problems raised by regional classification, another important factor must be considered in a comprehensive study of Douglas-fir strength properties. Relatively young, second-growth Coast-type Douglas-fir is being cut in greater volume, and, as supplies of the large, old-growth timber decrease more and more over the years, this second-growth timber becomes increasingly important in Douglas-fir utilization.

Douglas-fir characteristically grows rapidly in its early years under favorable climatic conditions in the coastal area. Actually, the central portions of old-growth trees closely resemble the small, young trees growing today in width of growth rings. The wide-ringed wood near the center of large, old-growth trees, however, yields only a small part of the lumber cut from such trees, whereas small, second-growth trees yield a much larger proportion of wide-ringed material.

Current Procedures

It was considered essential that more complete test data be obtained on which to base a comprehensive comparison of Coast and Inland Douglas-fir. Three large shipments were therefore collected for this purpose in 1950 from the Wenatchee, Umatilla, and Trinity National Forests. The Wenatchee forest on the eastern slope of the Cascades in Washington and the Trinity forest in northern California are areas in which both Associations operate. The Umatilla, in northeastern Oregon, was typical of extensive stands of Douglas-fir that had never previously been sampled. At the same time, secondary samples were taken from additional trees at each of these major collection sites and at three other places in northern California.

In 1952, samples for limited tests were obtained from the Bridger and Teton National Forests in Wyoming. In 1953, 7 additional samples of Rocky Mountain Douglas-fir were collected in Montana, Idaho (3 samples), Colorado, Arizona, and New Mexico.

To investigate some of the properties of second-growth material, a large sample of Coast-type Douglas-fir ranging in age from 65 to 150 years was collected in Lane County, Oreg., in 1946. Growth sites classified as II and IV were represented. That sample did not contain a large proportion of wide-ringed wood; hence, in 1953, a special selection of very rapidly grown trees was made in western Oregon to permit a more complete analysis of the strength properties of wide-ringed wood.

The total data available in this study are from several sources and types of tests: (1) Forest Products Laboratory standard strength studies; (2) Forest Products Laboratory limited or special strength studies; (3) Forest Products Laboratory special specific gravity studies; (4) Western Pine Association special strength studies; and (5) Canadian Forest Products Laboratories data from standard strength studies.

Data from the Western Pine Association and Canadian Forest Products Laboratories are presented for comparative purposes and are not included in the major analyses. The Western Pine Association tested plank material procured from six member mills. The collection instructions provided that not more than one plank be taken from any one tree. There was no information as to the height from which the plank came in the tree. Presumably, butt logs were chosen in order to insure that each plank was from a separate tree. In that case, if the plank were cut from the lower portion of the butt log, its specific gravity and strength properties could be expected to be somewhat higher than if it had been taken at the height utilized in standard tests. Further, the actual origin of the trees represented by the 10 planks from each location is known only in a very general way; and, since individual test results were not available to this Laboratory, detailed analyses of variability could not be made.

Data from the nine shipments of Douglas-fir tested at the Canadian Forest Products Laboratories may be considered directly comparable in all respects to data obtained in standard tests at the U. S. Forest Products Laboratory. The same basic procedures are used in both laboratories, and conform to the selection and testing requirements of American Society for Testing Materials (ASTM) Standard D143, "Standard Methods of Testing Small Clear Specimens of Timber." However, the Canadian data were not combined with the United States data in the detailed analyses because the material tends to be segregated into well-defined groups under existing marketing conditions.

Table 1 lists the various shipments and groups of material tested at the U. S. Forest Products Laboratory, together with general information on each shipment. Table 2 gives some comparable information on the tests made at other laboratories. The approximate location of the various shipments is shown in figure 1, and the numbers correspond to the item numbers in the first column of tables 1 and 2.

For convenience in comparison and analysis, the shipments have been segregated into four broad locality groups: Coast, Interior West, Interior North, and Interior South. These do not correspond directly to the geographical segregation used in previous publications such as Technical Bulletin No. 479.[3] The group of shipments termed "Coast" in figure 1 includes the seven virgin "Coast-type" shipments listed in Technical Bulletin 479 and more recent shipments of second-growth material from the same area.

The group of shipments termed "Interior West" is intended to include the transition zone between the coastal area and the Rocky Mountains. Botanically classified, this group of shipments falls in the eastern portion of the area producing the typical Douglas-fir (*Pseudotsuga menziesii*), as defined by the Forest Service Check List. It includes the eastern slopes of the Cascade Mountains in Washington and Oregon, the Sierras in California, and the mountainous area of northern California between the Sierras and the narrow strip of so-called Coast-type Douglas-fir along the coast of northern California.

"Interior West" shipments are from the area already referred to in which mills belong to either or both marketing associations; hence, Douglas-fir produced in that general area now reaches the market both as "Coast-type" and as "Rocky Mountain-type" Douglas-fir.

"Interior North" and "Interior South" shipments are from a geographical area which produces the varietal form of Douglas-fir (*P. menziesii* var.

glauca), according to the Check List. This general area has been arbitrarily divided for purposes of analysis into a northern and southern zone. The dividing line is formed by the southern borders of eastern Oregon, Idaho, and Wyoming. Other divisions of the area might have been made; but it appeared desirable to divide the mountain-type class on the basis of a fairly logical marketing segregation, in case the analysis required such division.

Analysis of Data

Value of Specific Gravity Data

Table 3 lists a total of 43 separate samples tested at the Forest Products Laboratory for which specific gravity data are available. Column 4, however, shows that of this number a total of only 18 shipments or samples are from standard strength (ASTM) studies, and an additional 11 shipments are from special or limited studies in which some strength values were obtained. The balance of 14 samples covers only specific gravity data. These 14 shipments include 1,796 of the 5,568 specific gravity specimens listed; hence, strength data are available for only about two-thirds of the total material sampled.

Since the strength of wood is reasonably well related to specific gravity, these 14 shipments provide a basis for judging the reliability of strength test data in several of the broad geographical areas studied.

The specific gravity and related variability data in the following tabulation show the correlation between the best estimate of specific gravity (all available tests) and the specific gravity of those shipments for which strength data are available.

Class	Average specific gravity	Calculated standard deviation
Interior North, standard (strength)	0.411	0.0411
Interior North, limited (strength)	.415	.0402
Interior North, standard and limited (strength)	.412	.0408
Interior North, specific gravity only	.420	.0412
Interior North, all	.415	.0412
Coast, second growth, standard and limited (strength)	.433	.0516
Coast, second growth, specific gravity only	.413	.0407
Coast, second growth, all	.428	.0498
Interior West, standard (strength)	.450	.0529
Interior West, specific gravity only	.423	.0482
Interior West, all	.433	.0517

The best estimate of the average specific gravity of Douglas-fir from the Interior North area is 0.415, the value obtained from all the available tests. The average specific gravity from all strength tests is 0.412, almost the same value. Therefore, the six additional shipments for which only the specific gravity is available substantiate the general specific gravity level obtained in the strength tests. Furthermore, the variability, as measured by the standard deviation, is nearly the same in all groups.

For second-growth material from the coast area, the overall average specific gravity is 0.428, slightly lower than the average of 0.433 derived from strength tests of that type. This difference is not large, and the strength-specific gravity relations are not sufficiently precise to reflect so slight a difference accurately. It must be recognized, however, that the average properties and variability of samples classified as second-growth Douglas-fir in this study are related to, and substantially influenced by (1) the tree age at which the wide-ringed material was produced, and (2) its proportion in the overall sample. These may or may not be characteristic of second-growth Douglas-fir in any particular area, or in that type of material as a whole. The second-growth coastal Douglas-fir shipments were segregated to provide data relating to a younger class of material than that represented in Coast virgin shipments.

In the case of Interior West material, the observed differences are substantially greater. When all available specific gravity data are considered, an average of 0.433 is obtained, whereas the average specific gravity from strength tests is 0.450. A difference of that magnitude could well be reflected in strength properties. However, two other factors should be considered.

First, the values for specific gravity only are influenced to a considerable extent by the values from shipment 1654P. This shipment was from the Pondosa area (table 1), which apparently has a reputation for producing material of lower density than is generally found in northern California. No strength data were obtained in the Interior West area on wood of such low density. Therefore, the strength properties and associated specific gravities are higher than they would be if exceptionally low-density material were included.

Second, the values for specific gravity only may be lower than values that might have been obtained from strength tests of green material from that area. In several other cases, tests of specific gravity only yielded lower values than were obtained in matching strength tests. This discrepancy is probably related to the use of different testing techniques and procedures in the two types of studies.

Consideration of these factors leads to the conclusion that strength values representing the Interior West area probably describe the material more accurately than cursory examination of the tabular values would indicate. On the other hand, it should be kept in mind in the subsequent discussions that strength values for the Interior West area would be reduced slightly if material such as that in Shipment 1654P had been included.

Strength Properties

Table 4 summarizes strength and related data for individual shipments and groups of shipments of green Douglas-fir tested at Madison, Wis. The table includes only those strength properties that are of prime importance in the use of wood as a structural material. Modulus of rupture provides the basis for determination of allowable unit fiber stress in bending and tension parallel to grain. Modulus of elasticity provides the basis for determining stiffness in bending. Maximum crushing strength provides data for allowable values in compression parallel to grain; fiber stress at proportional limit, in compression perpendicular to grain; and maximum shearing strength, in horizontal shear.

All data are from tests of green material, as basic stresses for structural material are related primarily to such data. The only tests included are those made at a standardized height in the tree, usually 8 to 16 feet above the stump.

Table 4 also includes exclusion limit values for various groups of shipments. An exclsuion limit value is that level of the property below which the designated percentage of individual specimens lie. In this study, the 5 percent exclusion level was chosen as a comparison base.

Variability.--The data in tables 3 and 4 show that a wide range of specific gravity and strength is found in any classification. Thirteen of the 17 shipments from the northern Rocky Mountain area (Interior North) yielded an average specific gravity equal to or higher than one of the samples representing supposedly the best type of Douglas-fir.

Measurements of the relative dispersion around the mean, such as standard deviations, coefficients of variation, and exclusion limit values, give a more complete picture of a sample. Although these measurements may reflect to some extent the relative size of the samples, they indicate that, on the whole, shipments collected from the Interior West, North, and South tend to be less variable than coastal Douglas-fir shipments.

Although the Forest Products Laboratory tests involve samples from 441 trees from 9 states, this sample is only a minute fraction of the total population of Douglas-fir trees. Yet, experience has shown that the large variability that exists within individual trees and among trees in any one area makes it possible to develop from relatively few trees average values that can be considered representative of the species as a whole. Average species values for many commercially important native woods are based on tests from five trees. For species as widely distributed as Douglas-fir, however, it is obvious that more trees are required.

Because such large differences do exist within and among trees, the results of tests on two or more samples from the same area may show substantial differences. When these differences are coupled with those from variations in site, rainfall, elevation, soil, or species varieties, and possible differences in collection and testing procedures, it is perhaps remarkable that the results are as consistent as they are.

Compression perpendicular to grain.--In reviewing the results of tests in compression perpendicular to grain, special attention must be given to the effect of differences in test methods. Part of the difference between various shipments may be due to the fact that modern test equipment used in evaluating recent shipments provides a more accurate measurement of deflection in the compression perpendicular to grain test than do the earlier tests. Experience has shown that more accurate measurements of deflection result in greater uniformity in the straight line portion of load-deflection curves, which in turn tends to reduce the observed values of fiber stress at proportional limit.

Values of fiber stress at proportional limit in compression perpendicular to grain are substantially higher for the coast virgin shipments than for shipments from other areas. At least part of this difference presumably is due to testing techniques. All tests of coast virgin shipments were made with the older testing methods. In all other groups, except coast second-growth, shipments are included that represent both present and past testing techniques. A more equitable basis for comparison of all material except coast virgin is established when only modern shipments (numbers higher than 1600) are considered. In general, this results in lower average values.

These considerations imply that values of fiber stress at proportional limit in compression perpendicular to grain are higher in coast-type material than would be expected in present-day tests, but the data are not adequate to predict what values would be obtained. While values in compression perpendicular to grain may be lower in material of lower specific gravity than coastal virgin Douglas-fir, it is unlikely that the differences are as large as the data indicate.

Supplementary data.--The average specific gravity and strength of Coast-type virgin material and the range of averages for the individual shipments tested in Canada (tables 5 and 6) were almost the same as for the comparable shipments tested at this Laboratory. Similarly, values for second-growth material proved to be only slightly higher than for the same type of wood tested at the Forest Products Laboratory.

The data are somewhat different for Douglas-fir grown in inland areas. Two of the Canadian shipments had average values well within the general range of Coast-type Douglas-fir. The remaining shipment from the province of Alberta showed an average specific gravity of 0.413, only slightly lower than the lowest of the Coast-type shipments.

The Canadian Forest Products Laboratories have studied the problem intensively and have decided that there is no justification for continuing the present distinction between their shipments 1, 3, and 83 and the remaining Coast-type shipments. Canadian shipments 3 and 83, in particular, are comparable to the Interior West material in this report. Apparently there is considerable evidence that the areas represented by shipments 3 and 83 produce the typical Douglas-fir (P. menziesii). Botanical classification of Douglas-fir in the area represented by shipment 1 is apparently not so well defined.

Representatives of the Canadian Laboratories have indicated, however, that Douglas-fir grown in the extreme southeastern corner of British Columbia and the southwestern corner of Alberta can probably be considered an extension of the Douglas-fir type found in northern Idaho and Montana. No Canadian tests are available from that area.

Data from tests made in the laboratory of the Western Pine Association (WPA) are summarized in table 7. In the Interior West area, the average specific gravity of 3 shipments was 0.413, as compared with an average of 0.433 from 8 shipments tested at the Forest Products Laboratory. The averages from the Western Pine Association shipments ranged from 0.401 to 0.430 while those from the Forest Products Laboratory ranged from 0.382 to 0.477.

In the Interior North area, the 17 Forest Products Laboratory shipments averaged 0.415, ranging from 0.377 to 0.441, while 3 shipments tested by the Western Pine Association averaged 0.458 and ranged from 0.447 to 0.464. The Forest Products Laboratory shipments that yielded the minimum and maximum average values were from recent collections.

It is not surprising that the relatively limited number of WPA shipments do not show as large a range in average or individual values as did the FPL shipments. It is surprising, however, to find the average values of 3 shipments tested by the WPA from the Interior North area higher than any of the 17 shipments representing that area that were tested by the Forest Products Laboratory. Figure 1 shows the areas that were tested by both WPA and the Forest Products Laboratory. It is possible that equally high values might have been obtained in some further tests at the Forest Products Laboratory, but it is equally certain that further tests by the Western Pine Association would include the kind of material represented by the Forest Products Laboratory tests.

Although the data of the Western Pine Association were useful as supplementary information, they could not be used in the detailed analyses included in this report because of basic differences in the methods of collection and sample representation.

Specific Gravity-Strength Relations

Strength values for individual specimens were plotted against their specific gravity for all properties except shear, for which no individual specific gravity values are available. The principal interest in such plots was in the relationships exhibited in the major data groups--that is, the interior areas as compared to the coastal region, and the virgin and second-growth coastal types.

The relationship between groups of data can best be seen when all points are plotted on a single figure. The ovals in figure 2 show the approximate envelope of points representing each of the 5 principal types or areas. About 5 percent of the points fell outside the envelopes shown for modulus of rupture and modulus of elasticity, and about 2 percent of the points fell outside for maximum crushing strength.

Extensive studies on many species have shown that strength properties tend to increase with specific gravity.[3] The generally accepted relationship is a power function in which strength is presumed to vary in relation to some power of the specific gravity. Such relations were developed and can be applied quite successfully to broad differences such as those that occur among species. It has also been considered that the relationship of pieces within a species can usually be represented by a power of specific gravity slightly higher than that representing average values from different species.[3] This study, representing different areas and other variables, provides excellent data for obtaining by regression analyses more exact information on these relations, but such studies are logically outside the scope of this report.

In modulus of rupture and maximum crushing strength, the envelopes in figure 2 fall in a rather regular pattern. Coast virgin, Coast second-growth, and Interior West ovals cover essentially the same area. In the Interior North and Interior South groups, the upper part of the envelopes fall short of the maximums obtained in the other groups, showing that a concentration of unusually high values of specific gravity and the corresponding properties is lacking in these Interior groups. The lower ends of all envelopes are reasonably similar for maximum crushing strength, but for modulus of rupture, the Interior South group falls short of the minimums obtained in other groups.

In modulus of elasticity, the areas included in the coastal and Interior West groups are again quite similar, and the maximums become progressively lower in the Interior North and Interior South groups. The envelope curve for Interior South lies lower than would be anticipated within the specific gravity range represented and has a flatter slope.

While property values in figure 2 obviously increase with increases in specific gravity, the envelopes emphasize the wide range in property values that may occur at any specific gravity.

At a specific gravity of 0.45, for example, the modulus of rupture of all but a few scattered specimens ranges from about 6,150 pounds per square inch to 8,800 pounds per square inch; the maximum crushing strength from about 2,550 pounds per square inch to about 4,850 pounds per square inch; and the modulus of elasticity from about 950,000 pounds per square inch to about 1,970,000 pounds per square inch. These ranges represent respective ratios of 1.43, 1.90, and 2.08. If only the coastal virgin material were considered, the ratios would be almost as large.

The strong similarity in the strength-specific gravity relations for the Coast virgin and second-growth and the Interior West groups should be kept in mind.

Growth Rate

Differences in specific gravity-strength relations in various areas have been discussed. Whether observed differences in such relations may be related to differences in growth rate is the next question. It has been observed that in softwood species the specific gravity and properties of some wide-ringed wood may be substantially lower than in wood grown at a moderate rate. Also, very slowly grown wood has been presumed to show a somewhat similar decline in specific gravity and properties. With the increasing use of second-growth timber the problem has become more important.

Recent studies at the Forest Products Laboratory indicate that the specific gravity of wood depends not only on the width of annual rings, but also on the age of the tree at the time the wood was produced. For example, the specific gravity of an annual ring 0.2 inch wide (growth rate 5 rings per inch) is likely to be higher if grown at an age of more than about 30 years in the life of the tree than if a ring of that width is grown at an earlier age. The question is important from the standpoint of genetics and forest management of second-growth timber but, from the standpoint of structural utilization, there is no practical basis for taking age into account. In this study, most of the wide-ringed wood represented juvenile periods in the trees.

Considerable differences in specific gravity and properties exist at any particular rate of growth (figs. 3 through 10). Curves representing the Coast virgin, Coast second-growth, and Interior West areas are fairly closely grouped. The curve for Interior North falls below the three groups mentioned, and that for Interior South is consistently and decidedly lower than any other curve.

These relations indicate that wood produced in the Interior North and Interior South areas tends to have lower density and strength properties--regardless of the rate at which it grows--than is the case for wood grown in the coastal or Interior West areas. An average line representing the similar Coast virgin, Coast second-growth, and Interior West areas has been shown on figures 3 to 10.

The curves show a decided increase in specific gravity and strength properties as the growth rate decreases from the very rapidly grown material. The curves tend to level off in the vicinity of 10 to 15 annual rings per inch. For slower rates of growth, it is difficult to evaluate trends because of the relatively small number of very slowly grown specimens. Beyond the 30- to 40-ring class, the number of specimens in most groups is so small as to make the plotted points essentially meaningless; hence, little consideration can be given to the curves in the slow-growth region.

Contrary to the belief of some persons, these curves do not show a general tendency for decrease in specific gravity and strength values in slow-growth wood. In fact, current grading rules for "close grain" specify a maximum of 20 or 30 annual rings per inch for material in that category. From a practical point of view, such a limitation may be desirable and necessary, but these data do not offer consistent evidence to support the rules.

In wood having less than 10 to 15 annual rings per inch, the property-growth rate curves for the Interior North show the same general trends as those representing the coastal areas, but the curves representing the Interior South show essentially uniform property-growth rate relations. Actually, the samples indicate that the Rocky Mountain areas do not produce a substantial amount of wood with an annual growth rate faster than about 6 rings per inch. In the combined Interior North and Interior South areas, only 1 test specimen in 1,722 had less than 4 rings per inch, and 36 specimens, or 2.1 percent, had less than 6 rings per inch. In the combined test sample from the Coast and Interior West areas, a total of 5.7 percent of the specific gravity specimens had less than 4 rings per inch, and 17.1 percent had less than 6 rings per inch. It is evident, therefore, that any attempt to increase average or near minimum strength values by excluding rapidly grown wood, as in "medium" or "close" grain, can serve no useful purpose in the Rocky Mountain (Interior North and South) areas.

Figures 11 through 15 show the relationship between properties and rate of growth for the various classes of material tested by the Canadian Laboratories. In these curves, the 3 shipments listed as "Interior" in tables 5 and 6 have been further subdivided into "Interior West" and "Interior East." The objective was to bring out the general similarity of shipments 3 and 83 in the Interior West area to the Coast-type material, and to show the apparently lower level of material in shipment 1.

The Canadian data and those representing tests at the Forest Products Laboratory show similar trends in the more rapidly grown wood. The Canadian results, however, show a decline in specific gravity and in most other properties for growth rates slower than 10 to 20 rings per inch, in contrast to the United States data where no marked decline was evident.

Summerwood

It is generally known that wood with a high percentage of summerwood is denser and stronger than wood with a low percentage of summerwood. Exact relationships between summerwood percentage and specific gravity or strength have not been established, because factors other than the percentage of summerwood are always involved. Moreover, data on the percentage of summerwood are more limited than for other properties.

The differentiation between springwood and summerwood is often difficult, especially in wide-ringed wood.[4] For that reason, the percentage summerwood data in this report cannot be considered precise. Furthermore, because of the physical difficulty of measurement in narrow-ringed wood, no summerwood percentages were obtained in these studies for many such specimens. In some shipments, no measurements were made on any of the specimens.

Notwithstanding these limitations, the available data were studied to determine whether differences in the percentage summerwood were reflected in the strength-growth rate trends. Figure 16 shows the relationship between the average percentage of summerwood in the usual groups and rate of growth. The trends must be considered in relation to the number of specimens represented at each point. The percentage of summerwood tends to increase with a decrease in rate of growth in the more rapidly grown wood. That trend is consistent with the observed increase in specific gravity and strength properties in such material. However, the rate of increase in the percentage of summerwood is less pronounced, particularly in the Coast virgin material.

Differences in the material representing the various areas or types are again evident. The Coast virgin, Coast second-growth, and Interior West groups show considerably higher percentages of summerwood over the entire range of growth than do the Interior North and Interior South groups. For example, at a more or less optimum rate of growth of 15 annual rings per inch, the wood grown in the Rocky Mountains produced an average of about 24 percent summerwood, while the wood grown in the coast and adjacent regions produced about 36 percent summerwoood. Obviously, if the strength properties are associated with the percentage of summerwood present, the Rocky Mountain material will not have as high values of specific gravity or strength.

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[4] Smith, Diana M. Comparison of Methods of Estimating Summerwood Percentage in Wide-Ringed, Second-Growth Douglas-fir. Forest Products Laboratory Report No. 2035, Sept. 1955.

The question remains whether or not Douglas-fir has the same density for a given percentage of summerwood regardless of where it grows. In figure 17, the relationship between specific gravity and percentage summerwood is shown for the specimens in 3 growth classes: under 6, 6 to 20, and more than 20 annual rings per inch. Only Coast virgin and second-growth material appears in the group with less than 6 rings per inch, because for all practical purposes, no such wood was found in the samples from the Interior West, North, or South areas.

As expected, the general trend is for increase in specific gravity with increase in the percentage of summerwood. Inasmuch as the measurements of summerwood percentage are not exact, any conclusions drawn must necessarily be very general. On the other hand, the data from various areas and types should be subject to about the same limitations in accuracy of measurement and failure to obtain data for slow-growth specimens. Shipments from all areas should have a reasonable chance of being consistent with one another.

The equation $Y = 0.1717 + 0.007428 X$ in figure 17 represents the theoretical relationship between specific gravity and percentage summerwood in whole annual rings of a special sample of Douglas-fir taken from shipment 1672.[2] The sample was from second-growth, Coast Douglas-fir and represented ages up to about 45 years and mostly less than 6 annual rings per inch. The curve in figure 17A for that class of material fits the regression line fairly well from 28 percent summerwood upward, but it does not fit well for smaller percentages of summerwood. This may be partially the result of the inclusion in the second-growth coastal group of various shipments in which rather low percentages of summerwood were recorded, perhaps erroneously. As indicated in report No. 2045,[2] the summerwood percentages in the special sample were very carefully measured under a microscope, and they are doubtless much more accurate than those measured in the usual procedure.

Figure 18 shows that in the three broad growth rate groups considered, the specific gravity tends to be higher for slower grown wood at a given percentage of summerwood. Hence, it can be inferred that an analysis of the relationship between specific gravity and percentage of summerwood, based on microscopical examinations, would be likely to show quite different data in wood of different growth-rate classes, depending also upon the age of the tree at the time the wood was produced.

The data plotted in figure 17 indicates that the density of the summerwood itself varies with locality of growth. In the 6- to 20-ring class (fig. 17B), the northern Rocky Mountain wood seems to correspond with the Coast-type and Interior West material, but the southern Rocky Mountain wood is substantially below the other groups. The difference is more noticeable in the group representing the slowest growth rate, 21 rings per inch and up (fig. 17C).

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[2]Smith, Diana M. Relationship Between Specific Gravity and Percentage of Summerwood in Wide-Ringed, Second-Growth Douglas-fir. Forest Products Laboratory Report No. 2045, Dec. 1955.

Segregation by Rules for Medium Grain, Close Grain, and Density

It has been pointed out that rules intended to improve properties by elimination of rapidly grown wood (generally less than 4 rings per inch for medium grain and less than 6 rings per inch for close grain) have no real meaning for material grown in the Rocky Mountain area. The proportion of rapidly grown material in that area is so small that there is virtually nothing to eliminate. On the other hand, some of the Rocky Mountain Douglas-fir may have the necessary percentage of summerwood to qualify as dense; but if the shipments included in this study can be considered typical, the percentage of dense material is very small.

Table 8 shows the effect of growth rate and percentage summerwood classification on average values of the more important properties for various combinations of shipments. The only groups that show any substantial increase in specific gravity and strength when wide-ringed material is eliminated are Coast virgin and second-growth. Similar data calculated for wood meeting close-grain requirements were found to be a little lower, in general, than those for 6 rings and up. This is because the elimination of pieces with more than 30 annual rings per inch reduced the averages beyond the slight increases that could be expected from inclusion of pieces with 5 rings per inch and one-third or more summerwood. In the Canadian data, this condition probably would not have occurred, as property values tended to decline in the slower grown material.

Table 8 shows that rate of growth data were obtained for nearly all specimens. The ratios in columns 5, 9, 11, and 15 show that medium-grain requirements, as represented by the data for 4 rings per inch and up, are beneficial from a practical standpoint only where a substantial proportion of wide-ringed material is present. In the second-growth Coast type, where 15 to 21 percent of the sample is eliminated by the growth-rate restriction, property values increased 3 to 5 percent in the restricted group. Smaller increases accompanied the elimination of about 5 percent of the samples in the virgin coastal material. Obviously, no improvement could be shown where there was virtually nothing to eliminate in the interior areas. This is true also of material having 6 rings per inch and up, except that the increases are larger.

Table 8 shows that percentage summerwood records were available for only about 75 to 80 percent of the test pieces. Of these, about one-half of the Coast virgin specimens and about one-third of the Coast second-growth and Interior West specimens qualified as dense. In the Rocky Mountain areas (Interior North and South), only about 3.5 to 5 percent of the specimens could qualify.

The proportion of material that could qualify as dense may be greater than the figures in table 8 would indicate, because of errors in measurement and failure to obtain percentage of summerwood data for a substantial number of specimens. In the Coast virgin, second-growth, and Interior West groups, the number of specimens is sufficient to give authenticity to the recorded averages. That is decidedly not the case in the Interior North and Interior South groups--only 9 static bending specimens in 235 available tests from the Interior North and only 8 of the 175 static bending specimens from the Interior South qualify as dense. Obviously, averages based on these small numbers of specimens cannot be considered a proper representation.

Considering the limitations imposed by the very small number of specimens available, it appears Rocky Mountain Douglas-fir that qualifies as dense may have strength properties reasonably similar to those of dense material from other areas.

If data from all sources are considered as a single group, one finds that restrictions essentially comparable to medium grain eliminated about 6 percent of the specimens and increased average strength property values about 1 percent. Elimination of material with less than 6 rings per inch removed about 15 percent of the specimens and increased average strength values about 2 percent. The requirements for dense quality eliminated nearly 70 percent of the specimens, but raised average strength values 12 to 18 percent.

Average values, of course, do not give the full picture. Figures 19, 20, and 21 show the relationship between rate of growth and modulus of rupture, modulus of elasticity, and maximum crushing strength for the five basic area groups. The open squares represent specimens actually segregated in accordance with rules for close grain. This group is the same as the "all" specimen group for material with 6 to 30 rings per inch, but it also includes other specimens with 5 rings per inch or more than 30 rings per inch that meet the percentage summerwood requirements. Dense material is an entirely separate group.

In general, the figures show that specimens that meet the density rule have somewhat higher properties over a wide range of growth rates than is the case when all specimens at the various growth rates are considered. Greater improvement in properties is shown at the more rapid growth rates in coastal material and at the more moderate growth rates in the Interior North and Interior South groups.

The effect of growth rate and percentage summerwood limitations is shown also in cumulative frequency curves (figs. 22 through 28). Average values, approximated by the 50 percent frequency level, tend to increase in the Coast virgin and second-growth groups when wide-ringed specimens are excluded. No such increase occurs in the three interior groups. Curves representing dense specimens are quite consistent in all groups except Interior South, where the number of items is inadequate.

The cumulative frequency curves also emphasize the general similarity of the Coast virgin, second-growth, and Interior West groups, as contrasted to the Interior North and South groups. The lesser variability of the Interior groups, which decreases the difference between these and the coastal groups at the 5 percent frequency level, may also be noted.

For general comparison of frequency characteristics, cumulative frequency curves for all Canadian specimens are shown in figure 29 for several properties.

Conclusions

The basic data presented in this report show that the characteristics of Douglas-fir differ widely in the several areas and types under consideration. In the Rocky Mountains a very large proportion of the sampled Douglas-fir had a growth rate of 6 or more annual rings per inch; virtually all of the samples from that area grew at a rate of 4 or more rings per inch. Hence, any attempt to improve properties by eliminating wide-ringed wood cannot be expected to operate efficiently in the Rocky Mountain area.

The data show, moreover, that in the moderate and slow growth-rate classes, the specific gravity and strength properties of Douglas-fir grown in the Rocky Mountain area are lower than for wood grown in the coastal area, the Cascades, and the Sierras. The wood grown in the Rocky Mountains tended to have smaller percentages of summerwood at any growth rate than the wood grown under the more advantageous conditions in the coastal and adjacent areas.

Thus, there is evidence that Douglas-fir is not a single population that can be considered to vary more or less consistently throughout its range. On the contrary, it appears that at least 2, or possibly 3, populations are involved.

Analyses of the data show a reasonably consistent distinction between the typical Douglas-fir (P. menziesii) and the varietal form of Douglas-fir (P. menziesii var. glauca). Within the latter group, a secondary separation of the northern and southern Rocky Mountain areas appears to exist; this is probably largely due to the wide variation in growth conditions of altitude, latitude, and soil moisture.

Combination of second-growth, Cascade, and Sierra Douglas-fir with the material commonly classed as Coast-type virgin Douglas-fir has relatively little overall effect on average specific gravity and strength properties of the sample material represented. Douglas-fir from the northern Rocky Mountains (Interior North) has about the same density and strength values as the Intermediate type presently segregated in Technical Bulletin No. 479.[3] Such material, therefore, has better properties than the Rocky Mountain type listed in that publication.

On the other hand, Douglas-fir from the southern Rocky Mountains (Interior South) is generally less dense and weaker than the present Rocky Mountain type.

While these distinctions appear to be very real, the task of making combinations and presenting the data for the species as a whole is considerably more difficult than simply combining values from various sources to arrive at average values for the species. Basically, it is a question of practical utilization as against theoretical considerations.

Information presented in this report should provide a practical basis for judging the effectiveness of various possible alternatives in the development of basic stresses for structural uses of Douglas-fir. The decisions to be made will largely determine the basis for revising average values for the species.

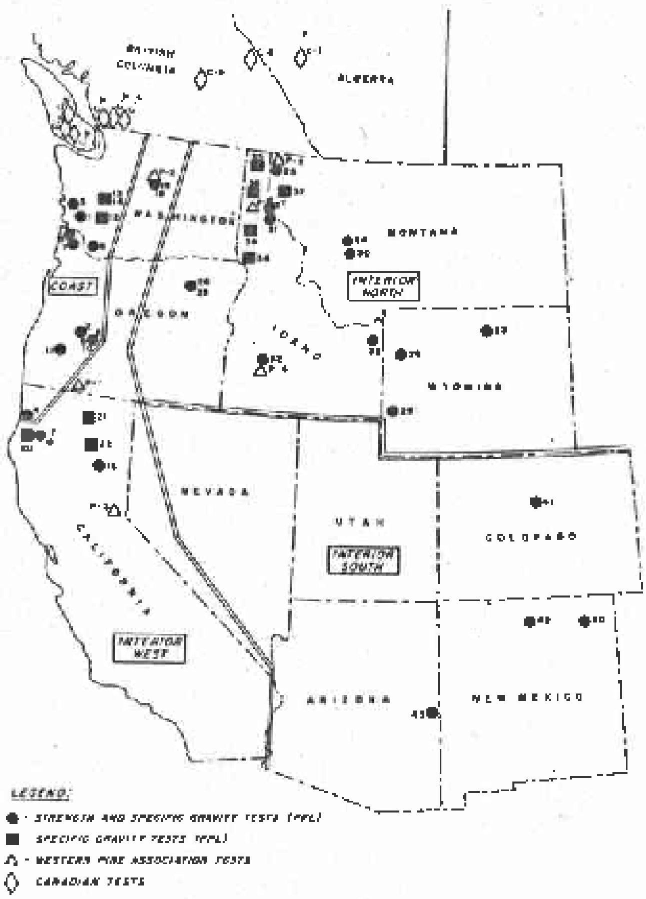

Figure 1.--Location of Douglas-fir samples tested at the United States and Canadian Forest Products Laboratories and the laboratory of the Western Pine Association.

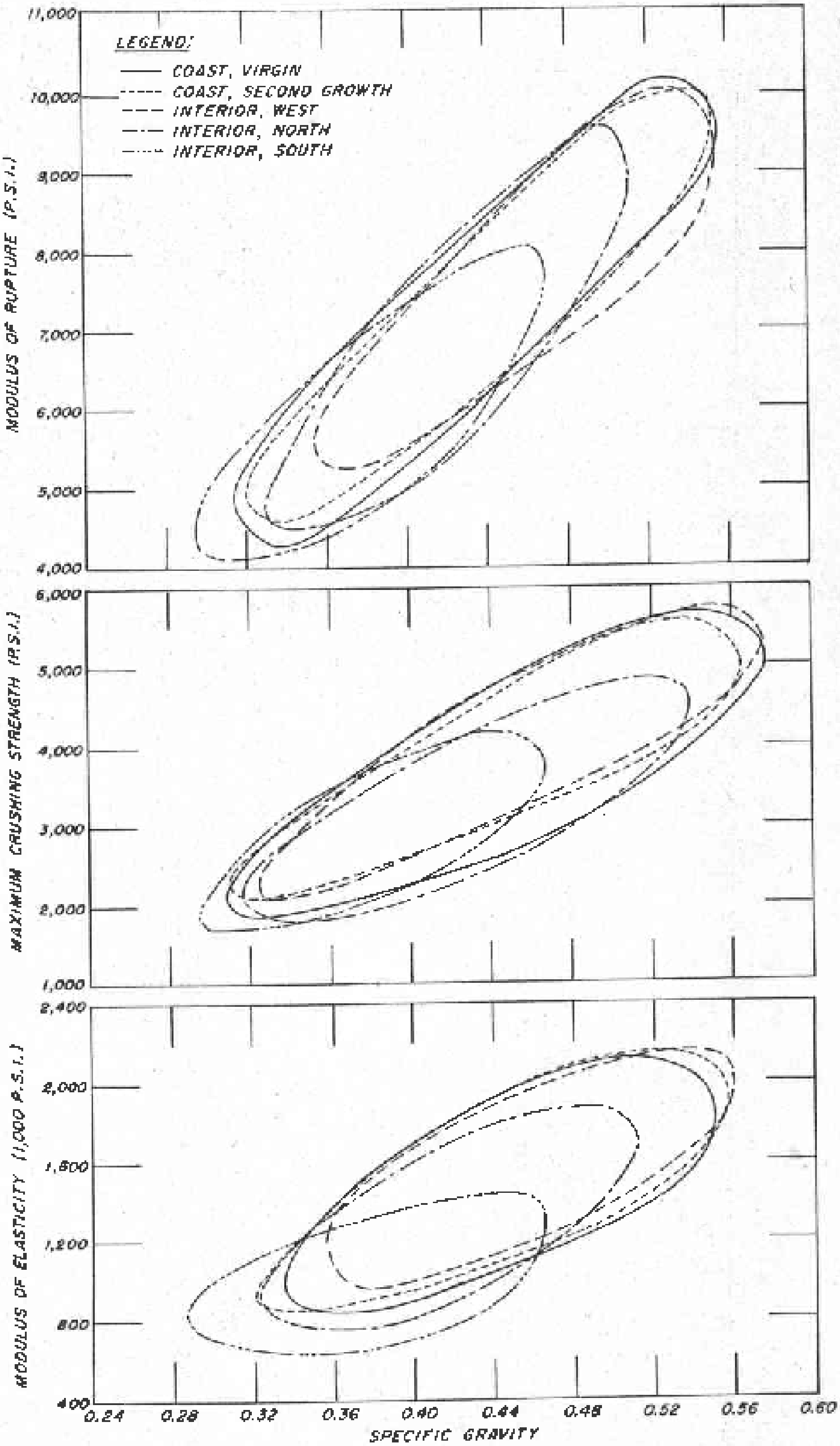

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Figure 2.--Envelope curves showing approximate concentration of points representing strength properties versus specific gravity of individual specimens tested at the U. S. Forest Products Laboratory.

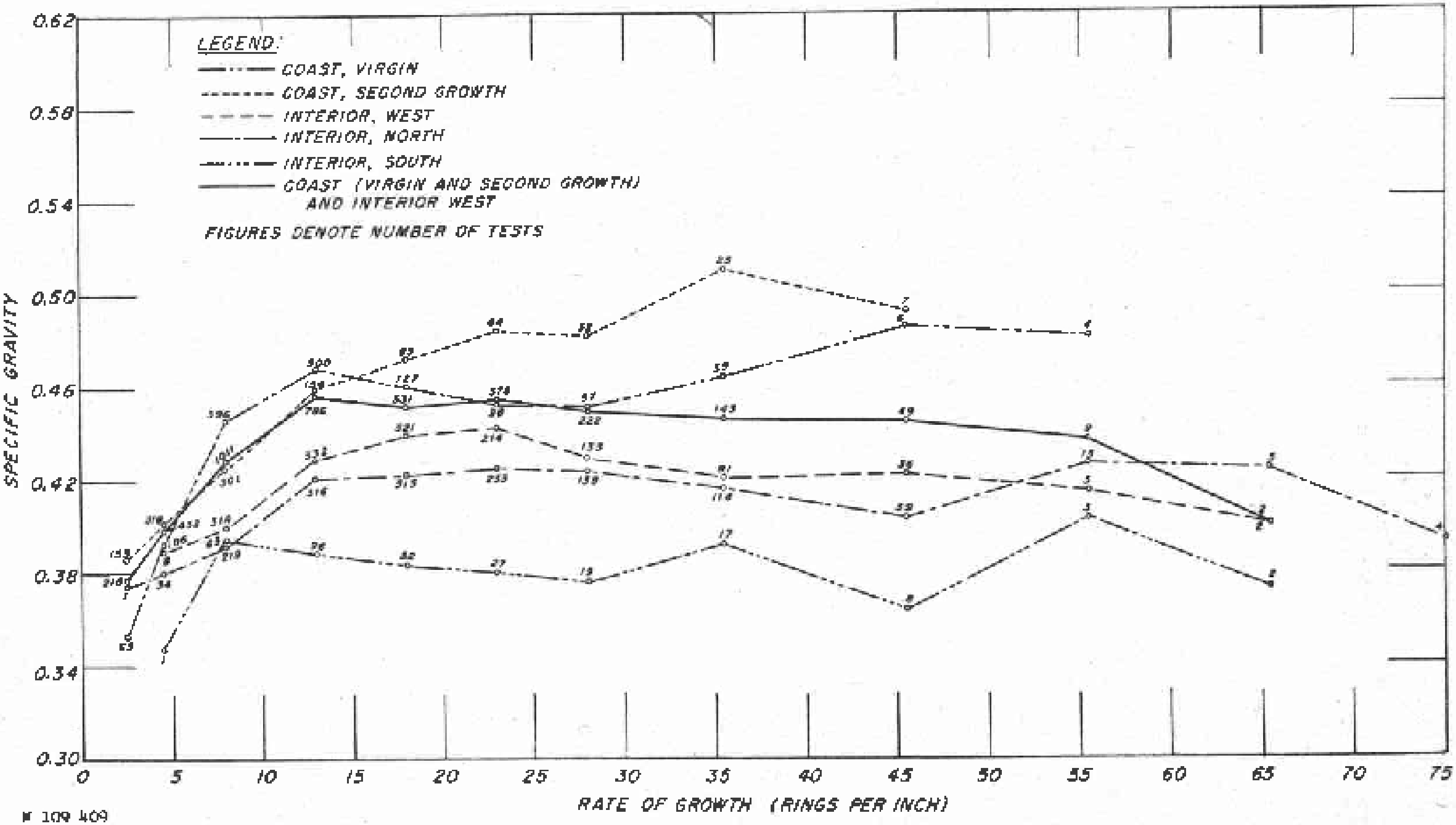

Figure 3.--Average specific gravity within growth-rate classes for all material tested at the U. S. Forest Products Laboratory. The specific gravity was based on the wood's volume when green and the weight when ovendry.

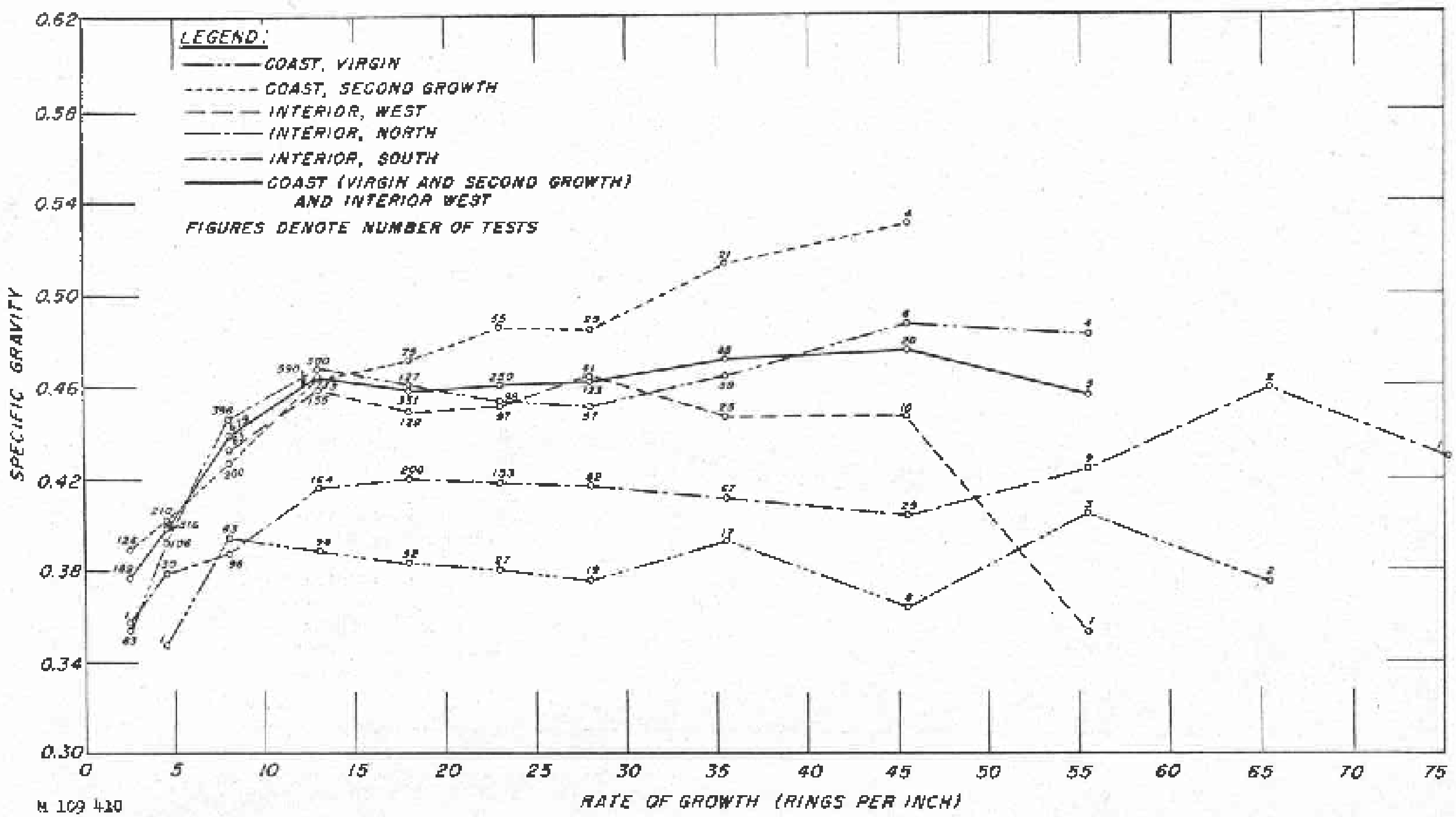

Figure 4. --Average specific gravity within growth-rate classes for only those Douglas-fir samples for which strength data are available (U. S. Forest Products Laboratory data only). The specific gravity was based on the wood's volume when green and weight when ovendry.

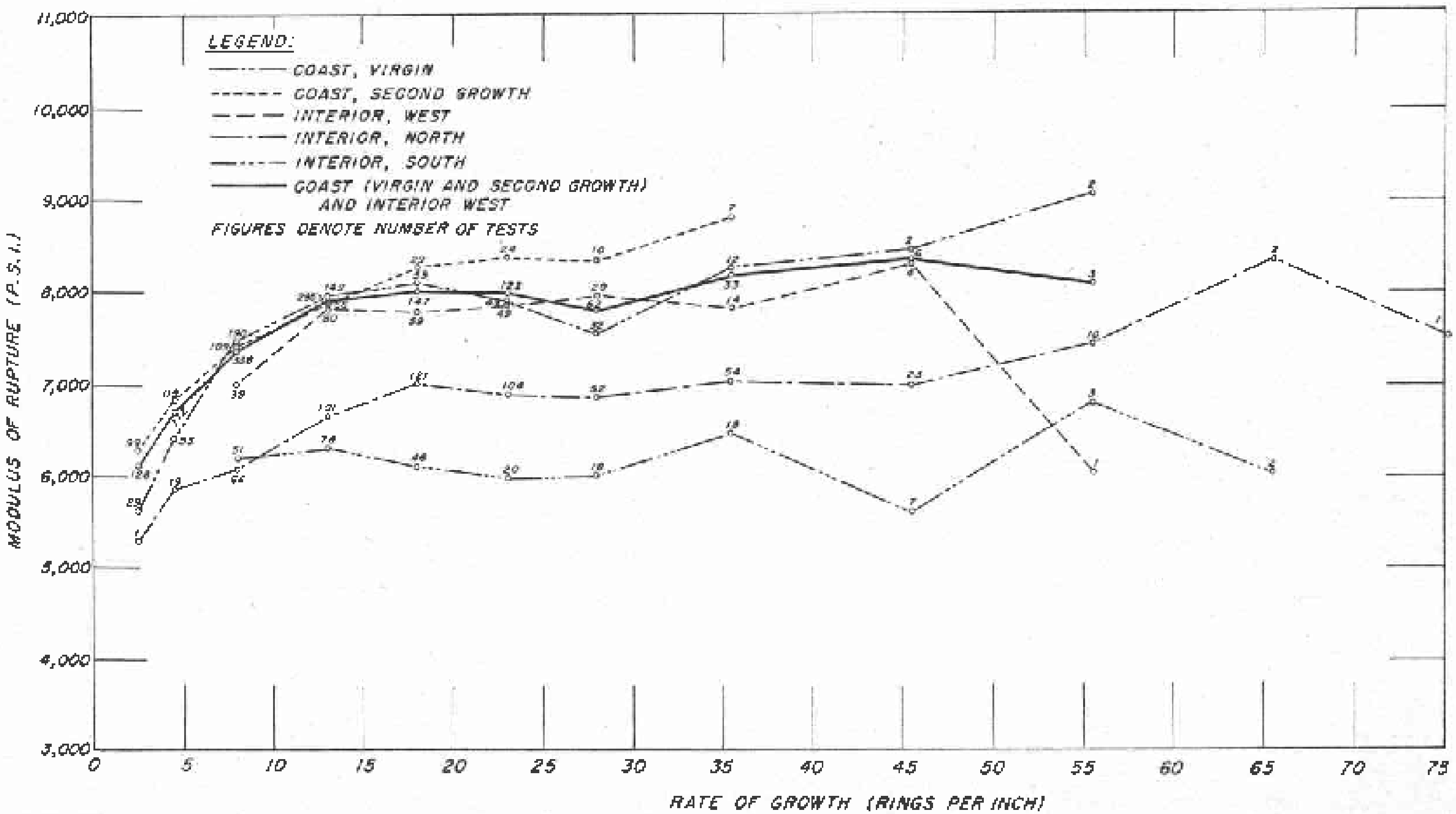

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Figure 5.--Average modulus of rupture within growth-rate classes for Douglas-fir tested at the U. S. Forest Products Laboratory.

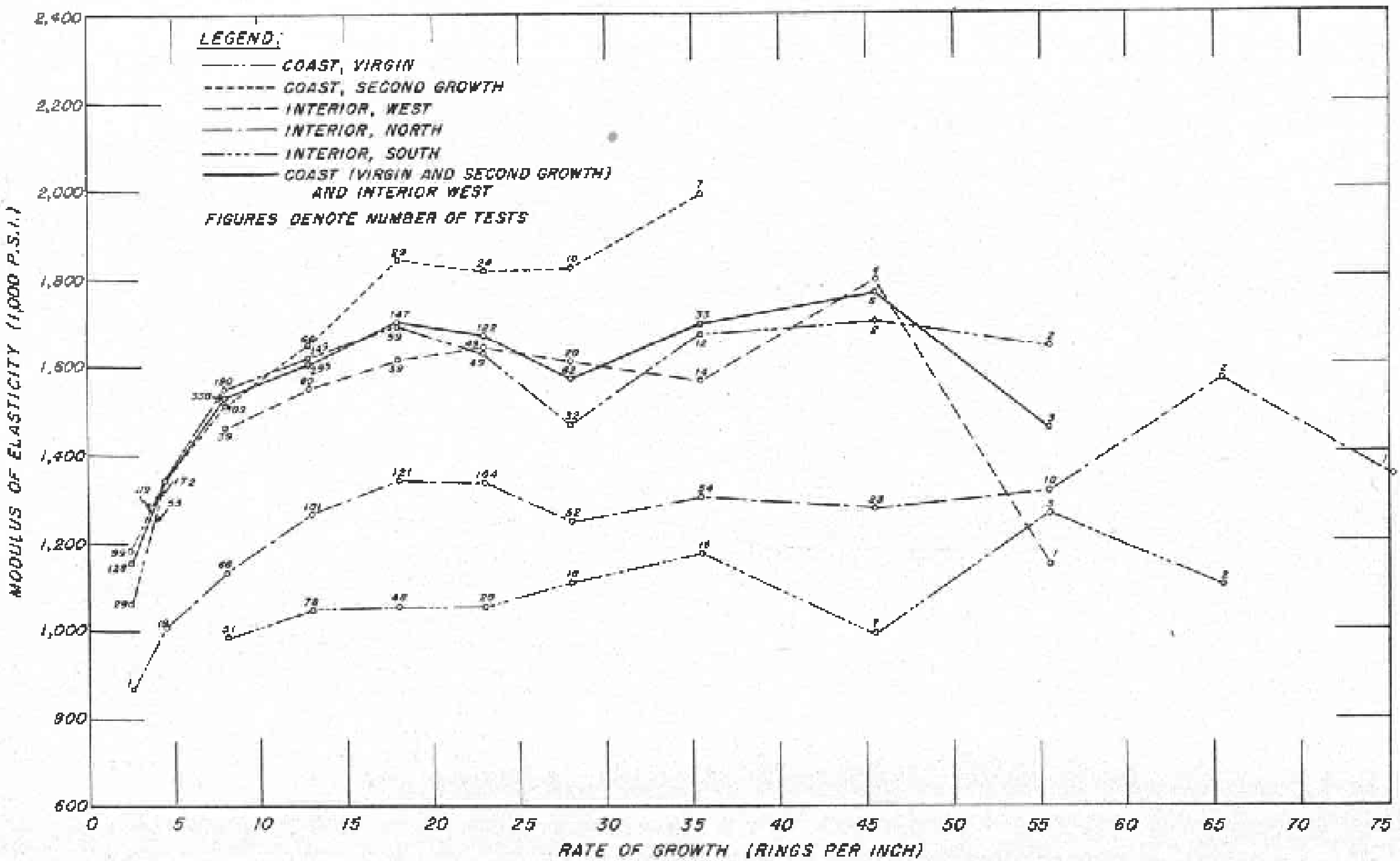

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Figure 6.--Average modulus of elasticity in static bending within growth-rate classes for Douglas-fir tested at the U. S. Forest Products Laboratory.

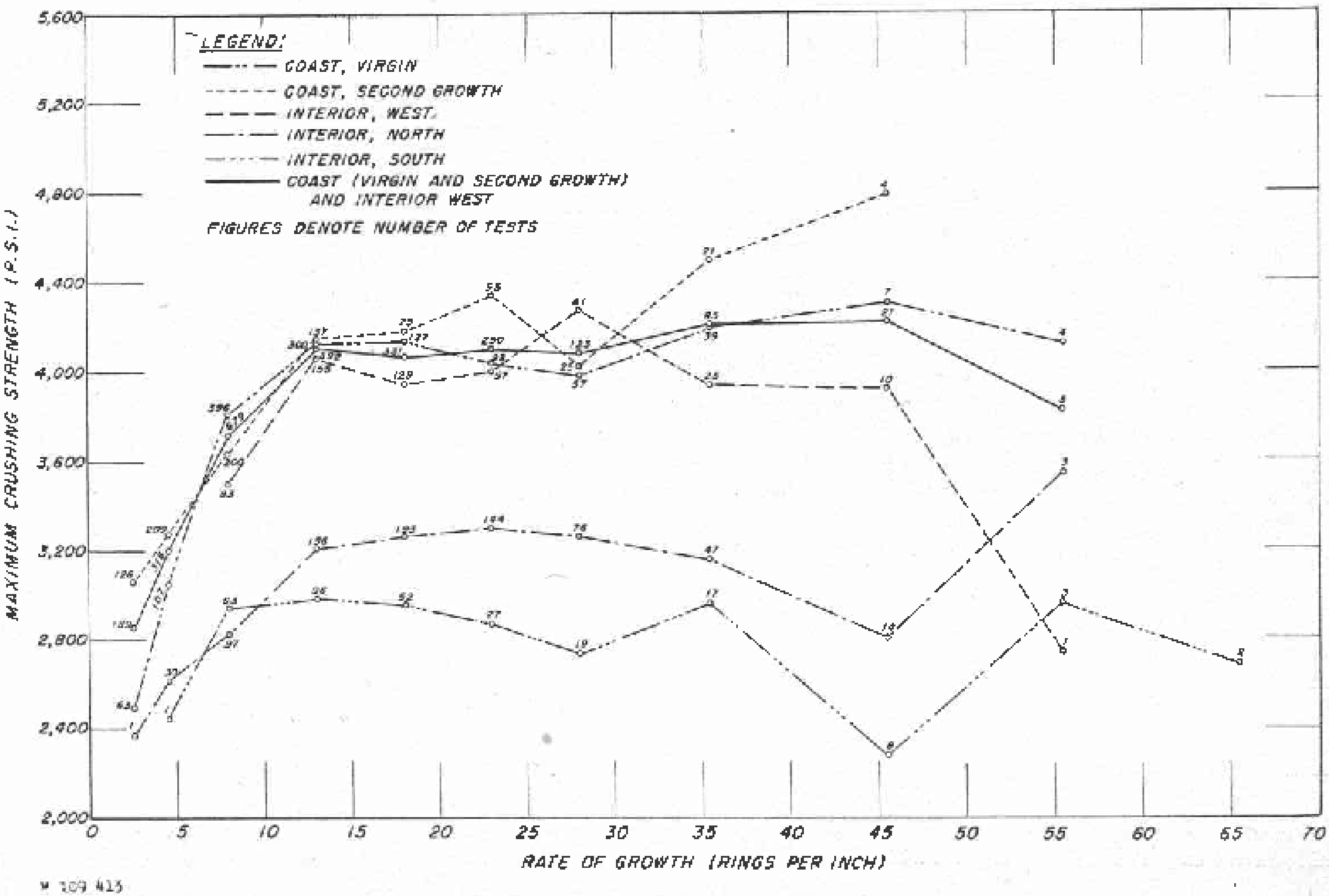

Figure 7. --Average maximum crushing strength in compression parallel to grain within growth-rate classes for Douglas-fir tested at the U. S. Forest Products Laboratory.

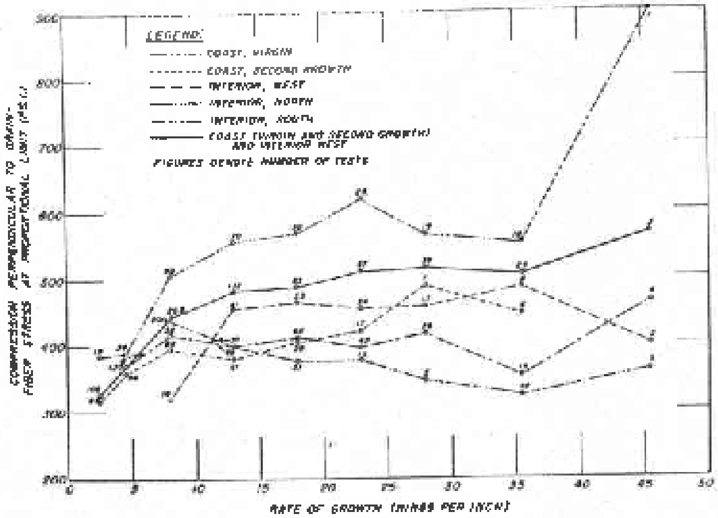

Figure 8.--Average fiber stress at proportional limit in compression perpendicular to grain within growth-rate classes for all Douglas-fir shipments tested at the U. S. Forest Products Laboratory.

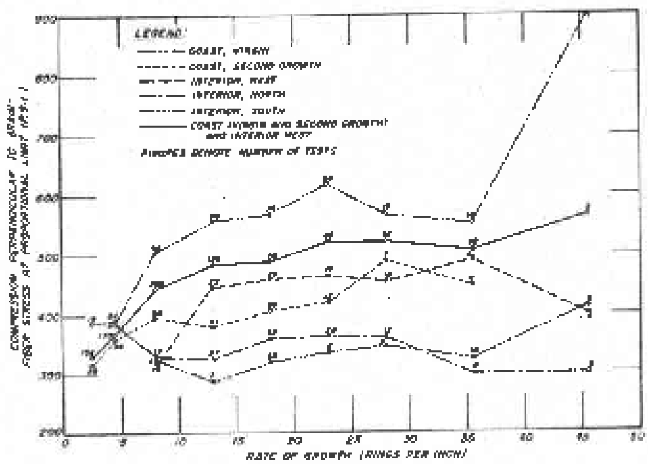

Figure 9.--Average fiber stress at proportional limit in compression perpendicular to grain within growth-rate classes for segregated Douglas-fir shipments tested at the U. S. Forest Products Laboratory.

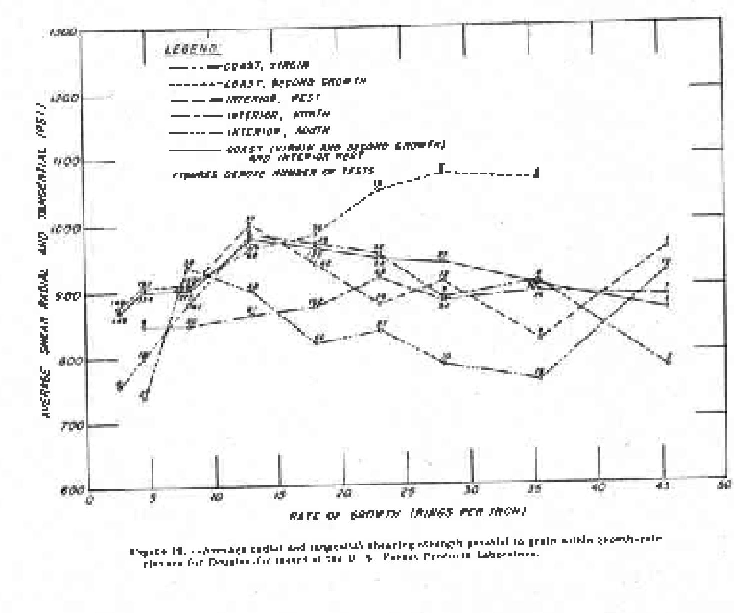

Figure 10.--Average radial and tangential shearing strength parallel to grain within growth-rate classes for Douglas-fir tested at the U. S. Forest Products Laboratory.

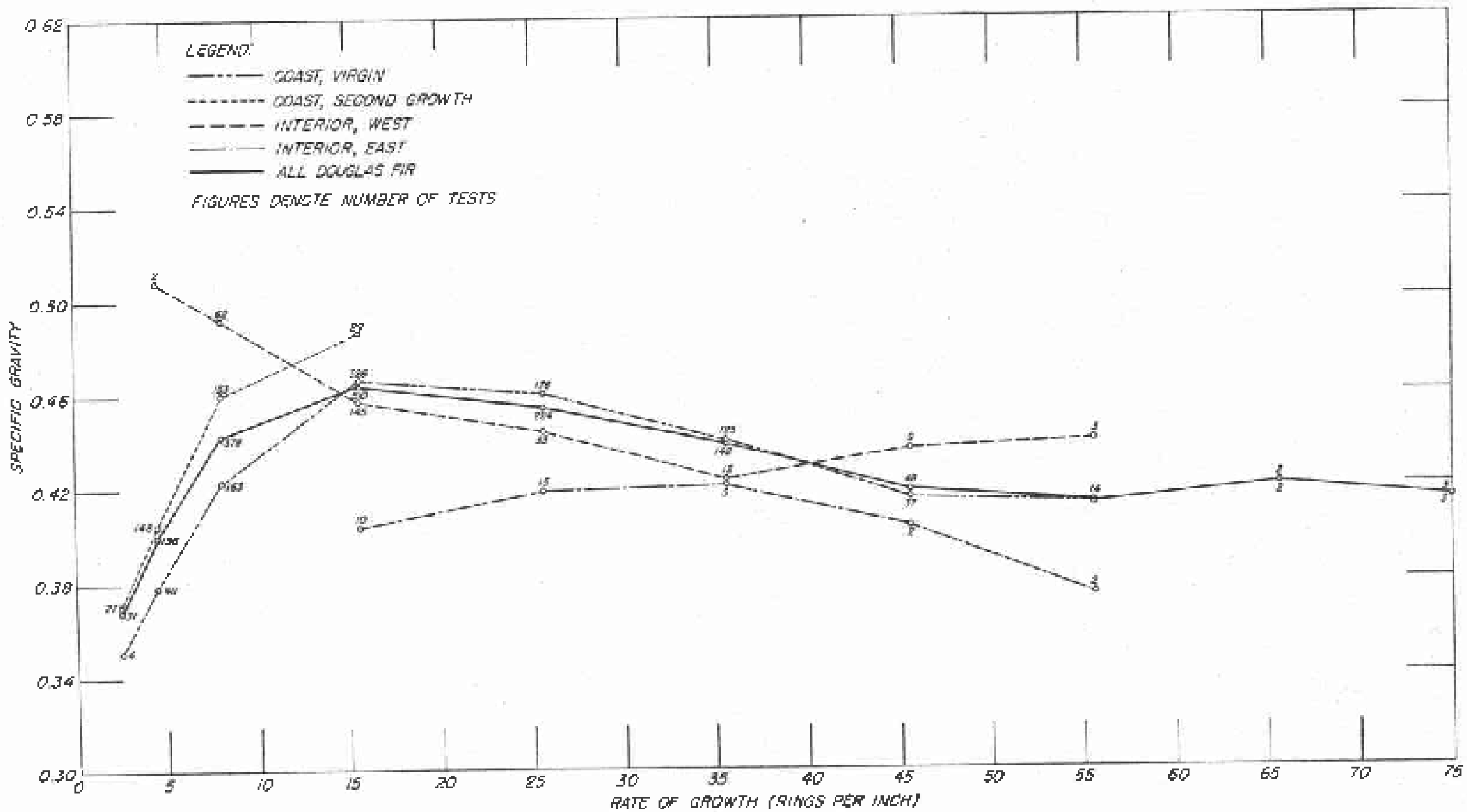

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Figure 11.--Average specific gravity within growth-rate classes for Canadian Douglas-fir tested at the Canadian Forest Products Laboratories. The specific gravity was based on the wood's volume when green and weight when ovendry.

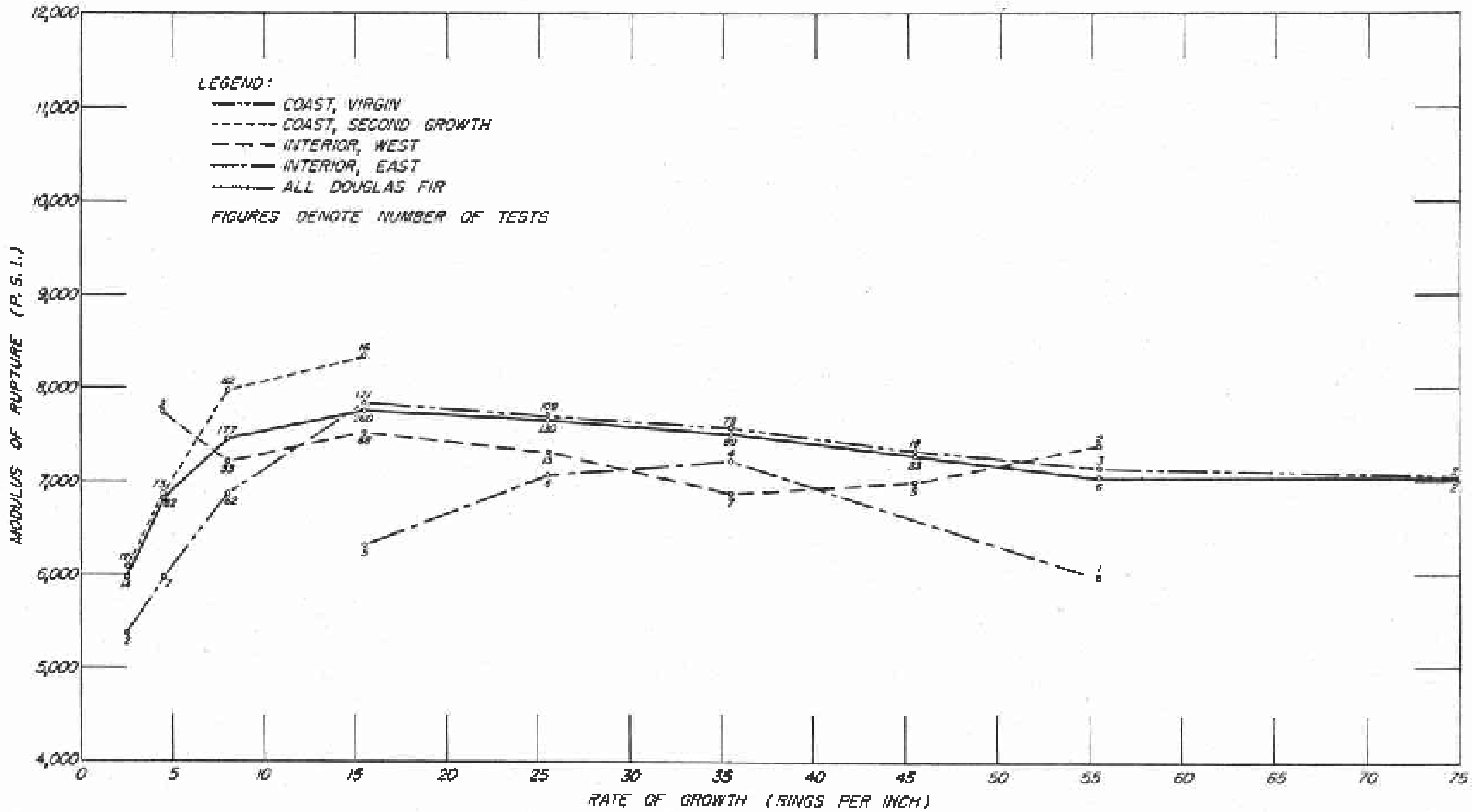

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Figure 12.--Average modulus or rupture within growth-rate classes for Canadian Douglas-fir tested at the Canadian Forest Products Laboratories.

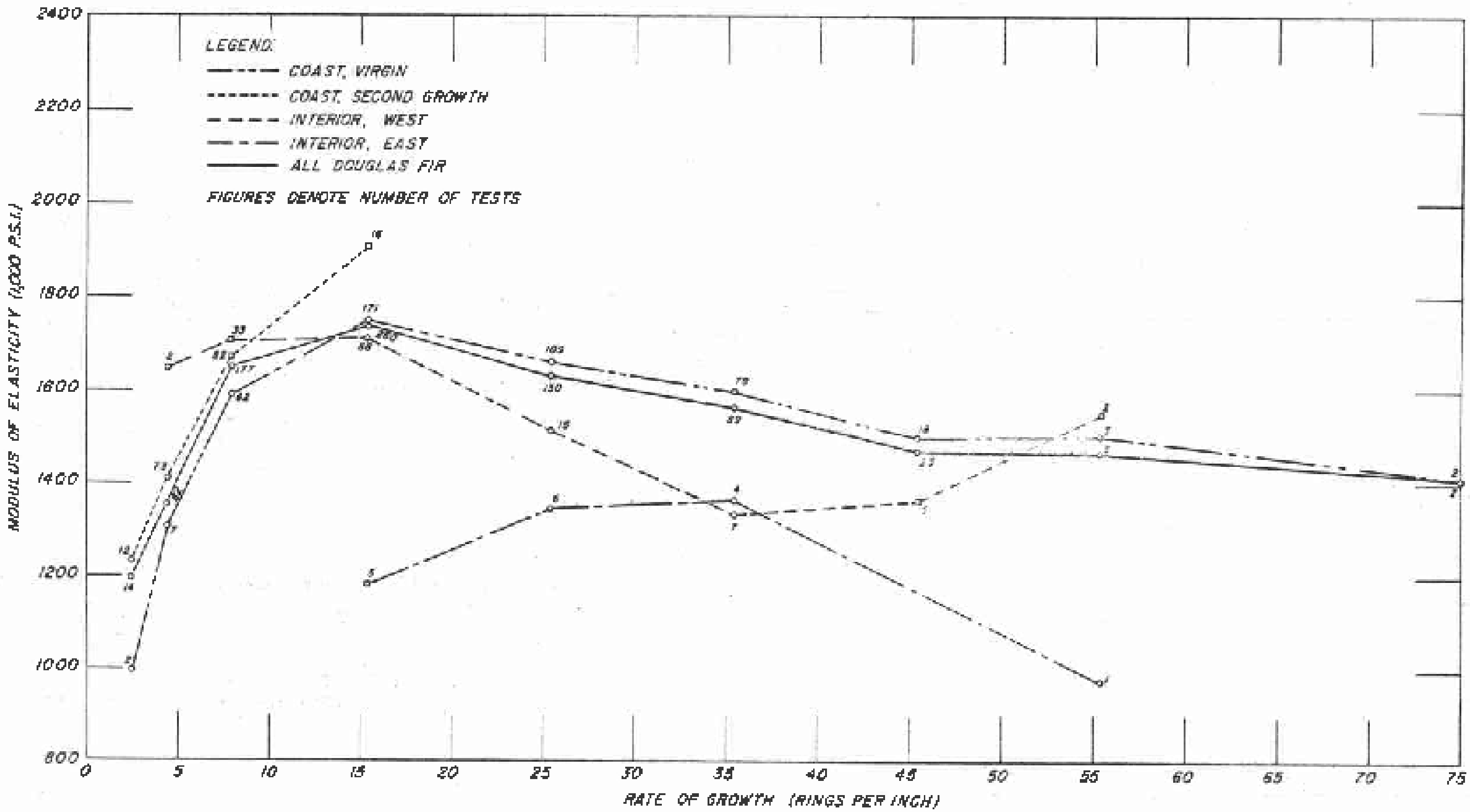

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Figure 13. --Average modulus of elasticity in static bending within growth-rate classes for Canadian Douglas-fir tested at the Canadian Forest Products Laboratories.

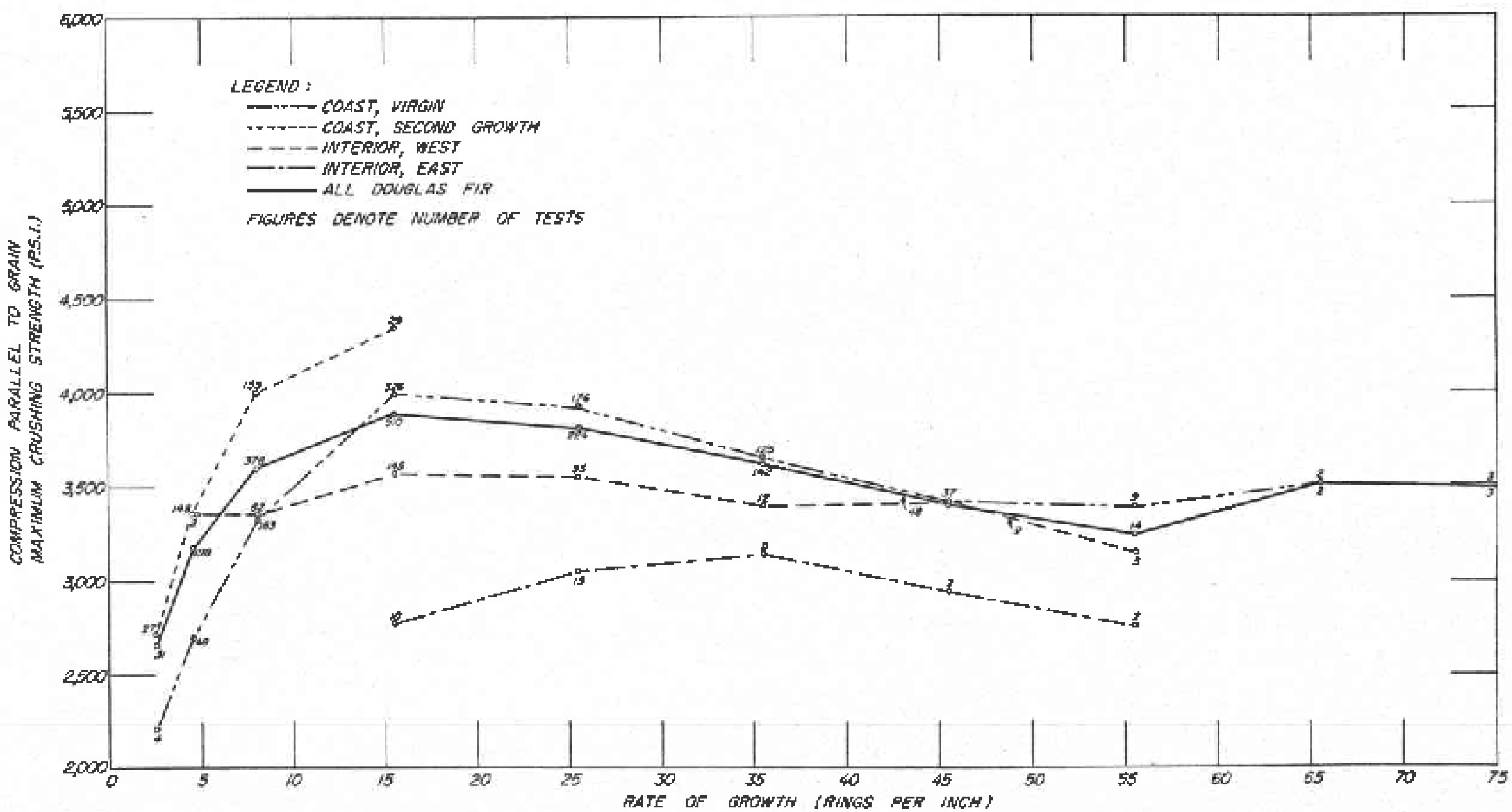

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Figure 14. --Average maximum crushing strength in compression parallel to grain within growth-rate classes for Canadian Douglas-fir tested at the Canadian Forest Products Laboratories.

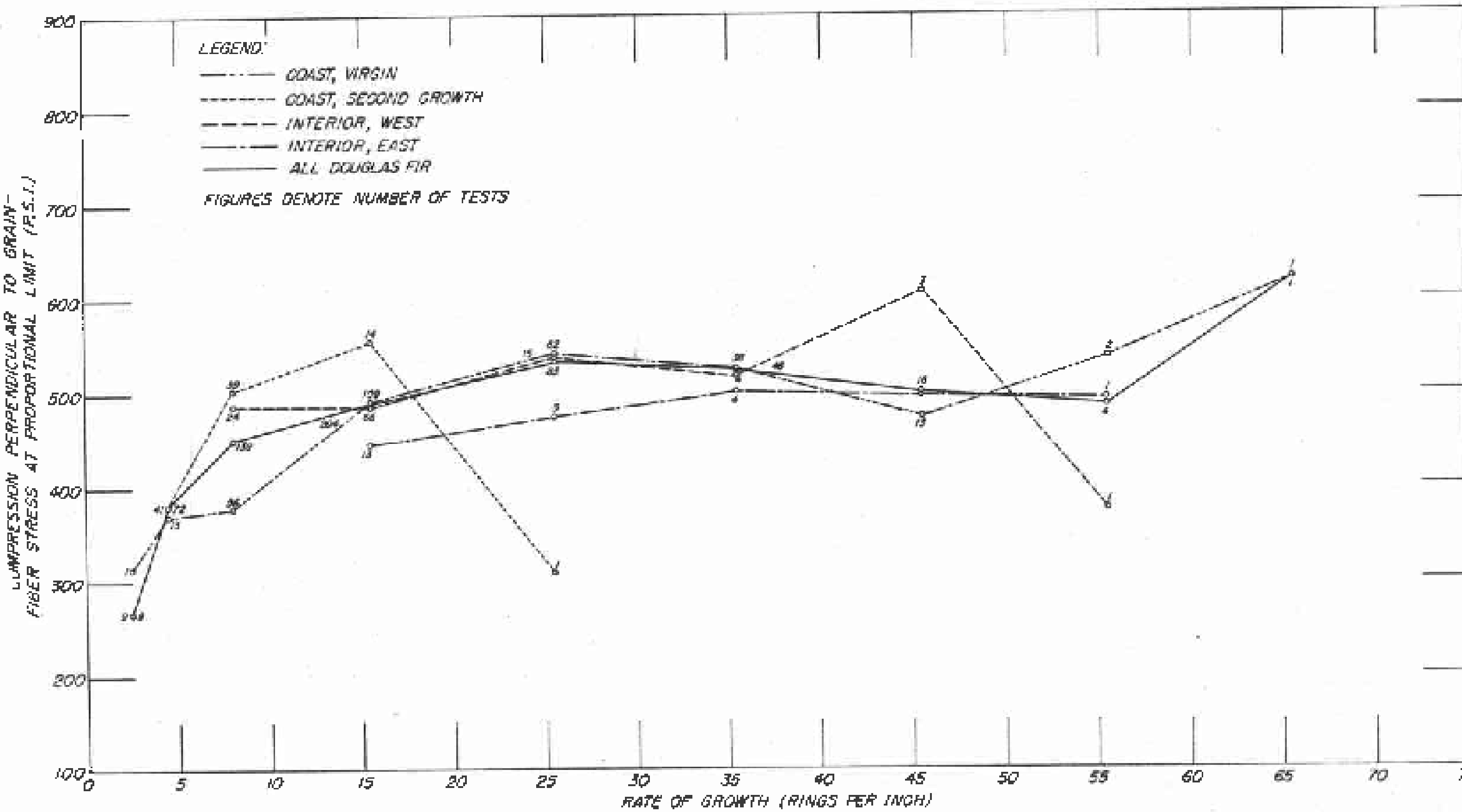

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Figure 15.--Average fiber stress at proportional limit in compression perpendicular to grain within growth-rate classes for Canadian Douglas-fir tested at the Canadian Forest Products Laboratories.

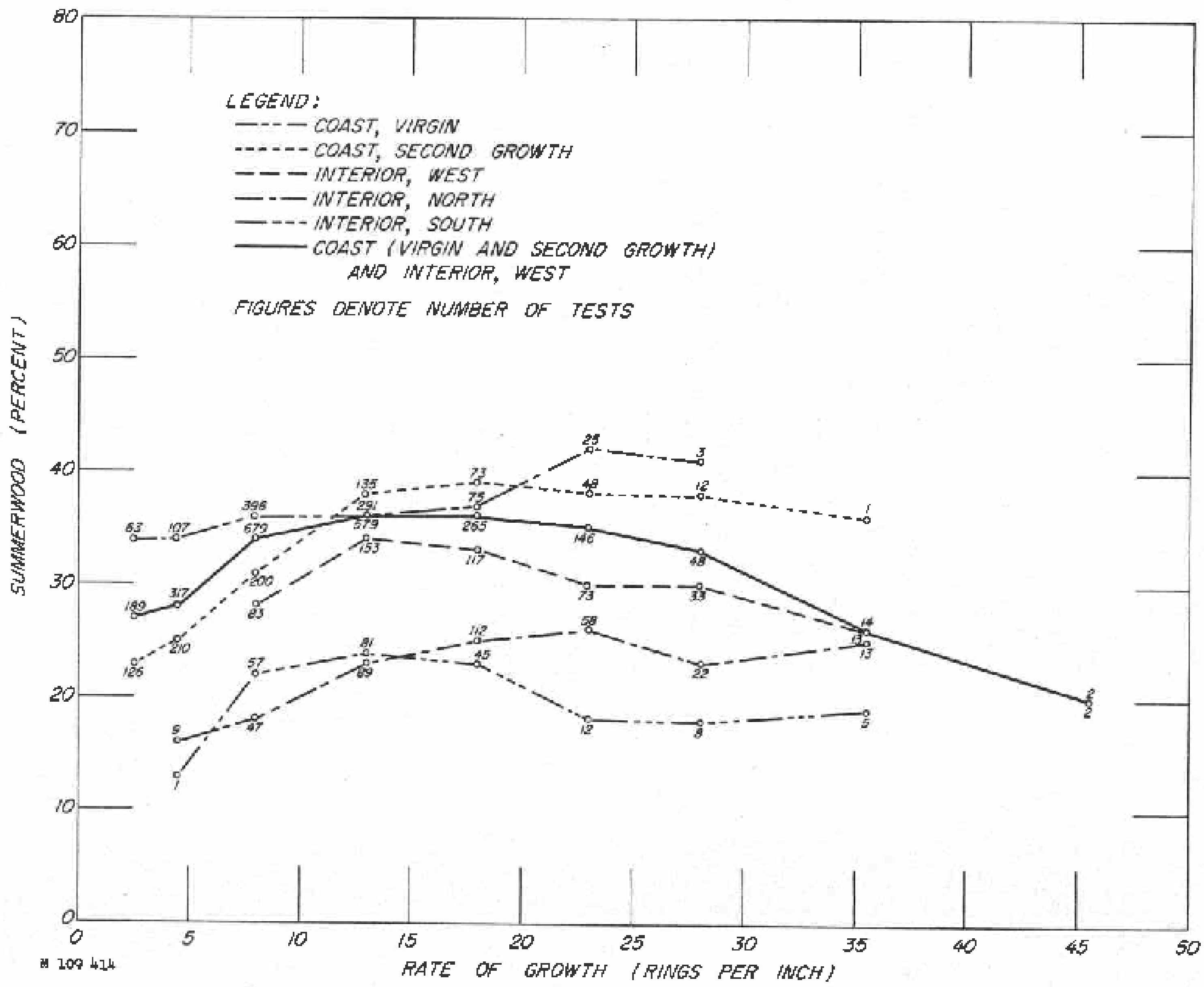

Figure 16. --Average percentage of summerwood within growth-rate classes for Douglas-fir tested at the U. S. Forest ...

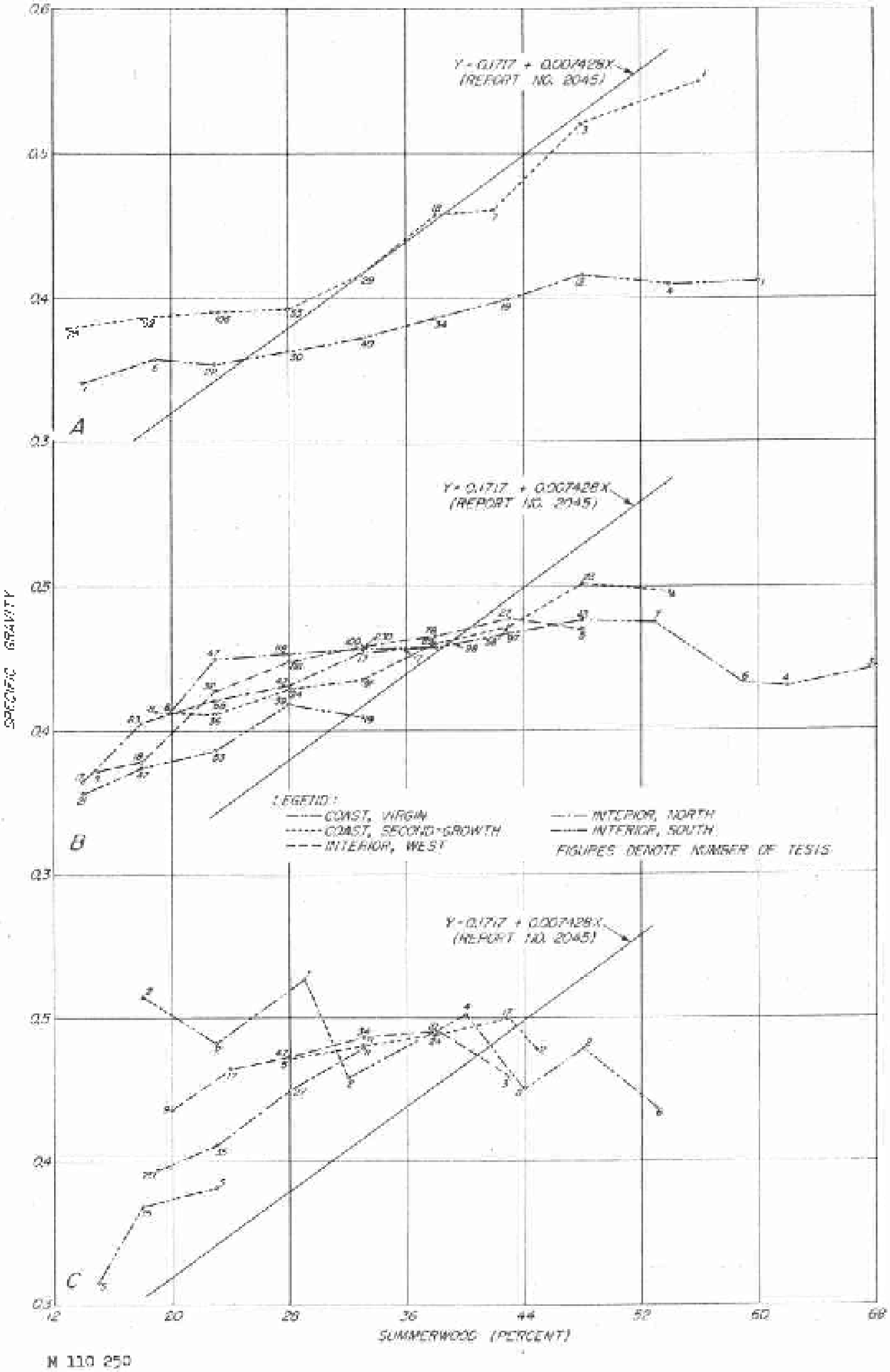

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Figure 17. --Average specific gravity within percentage summerwood classes for Douglas-fir segregated by growth rate and tested at the U. S. Forest Products Laboratory. A, Material with less than 6 annual rings per inch; B, material with 6 to 20 annual rings per inch; C, material with 21 or more annual rings per inch.

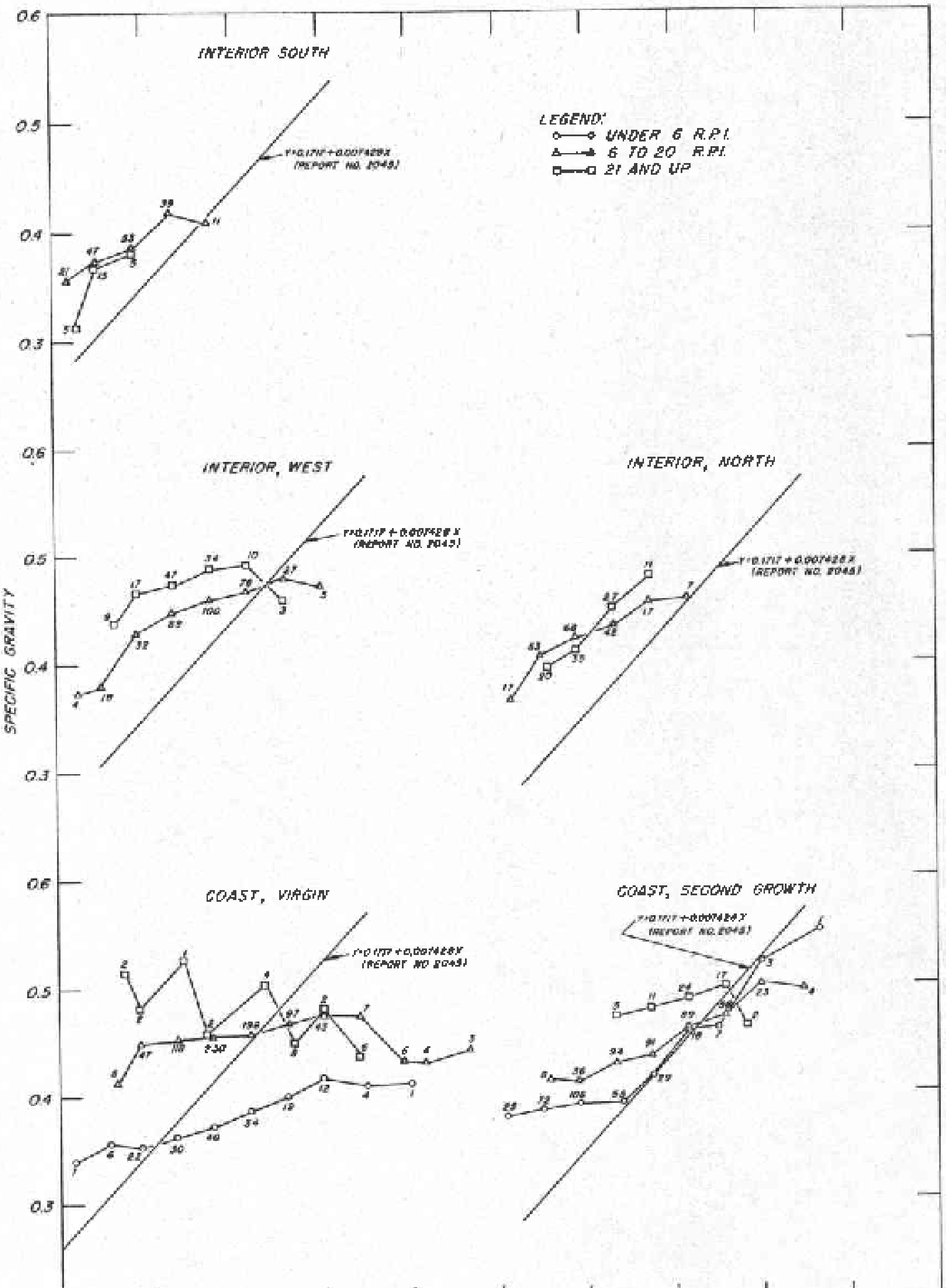

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Figure 18.--Average specific gravity within percentage summerwood classes for Douglas-fir of various growth rates, segregated by geographic areas and tested at the U. S. Forest Products Laboratory.

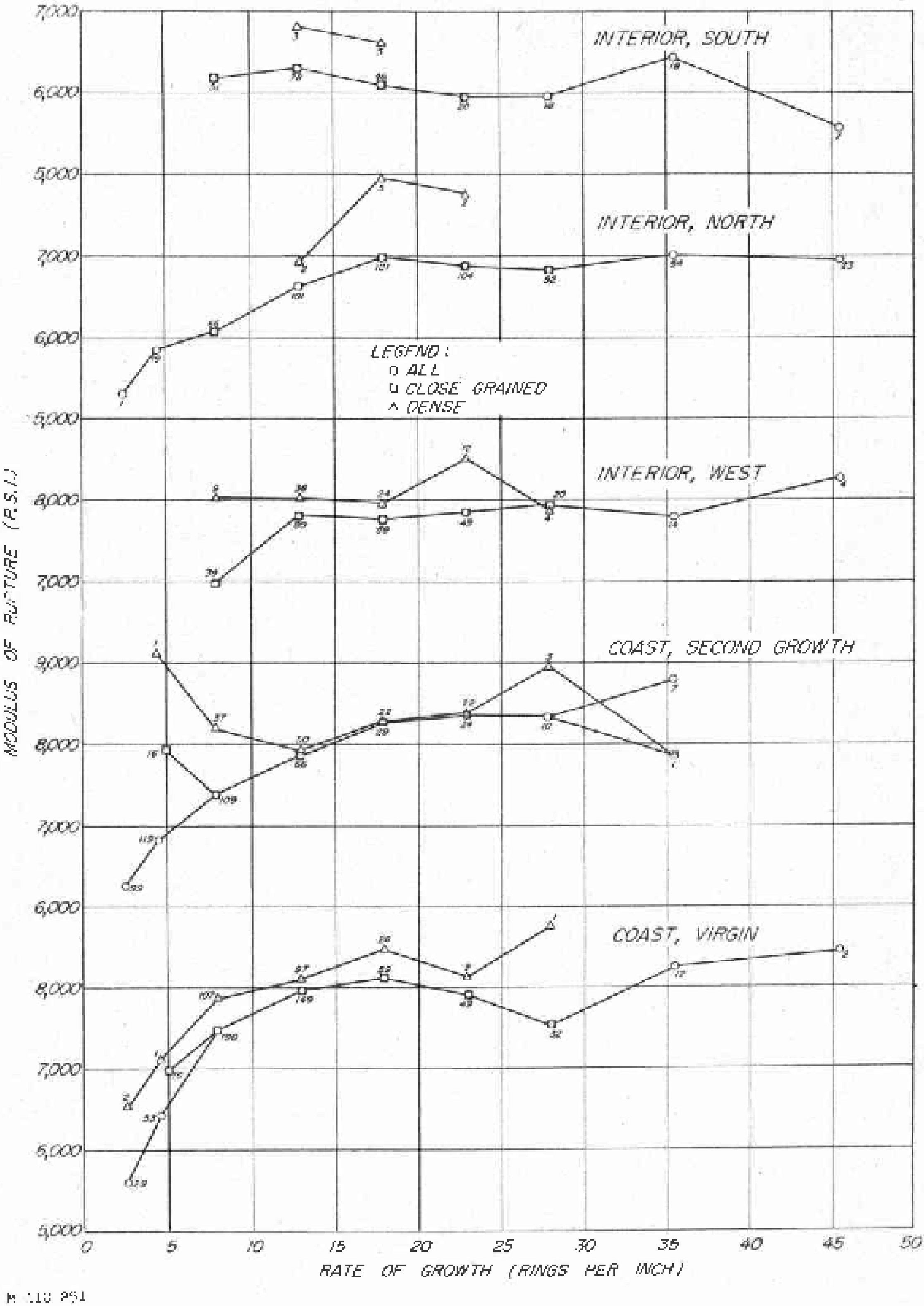

Figure 19.--Effect of rules for density and close grain on modulus of rupture of Douglas-fir within growth-rate classes, segregated by geographic areas and tested at the U. S. Forest Products Laboratory.

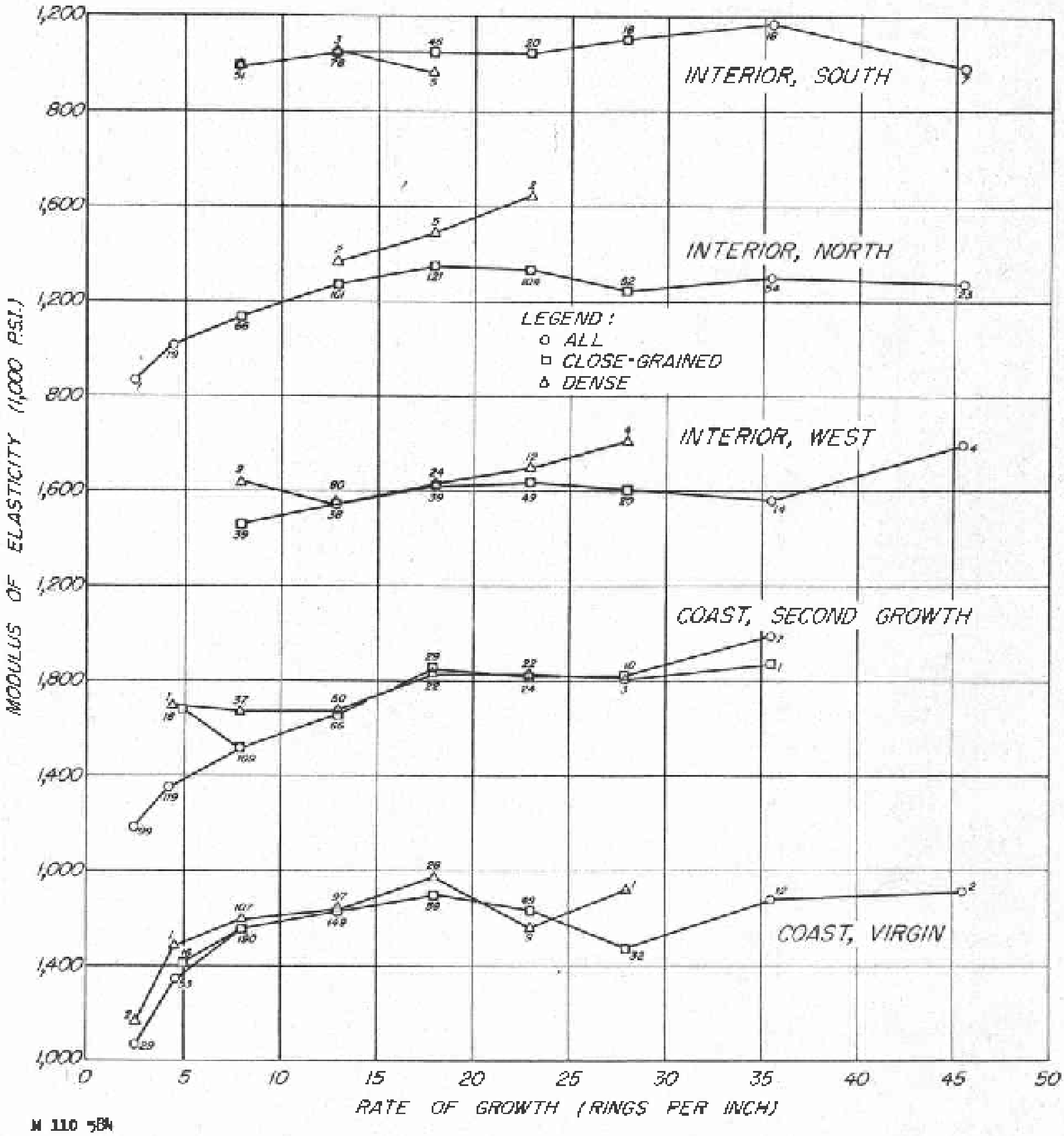

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Figure 20.--Effect of rules for density and close grain on modulus of elasticity in static bending of Douglas-fir within growth-rate classes, segregated by geographic areas and tested at the U. S. Forest Products Laboratory.

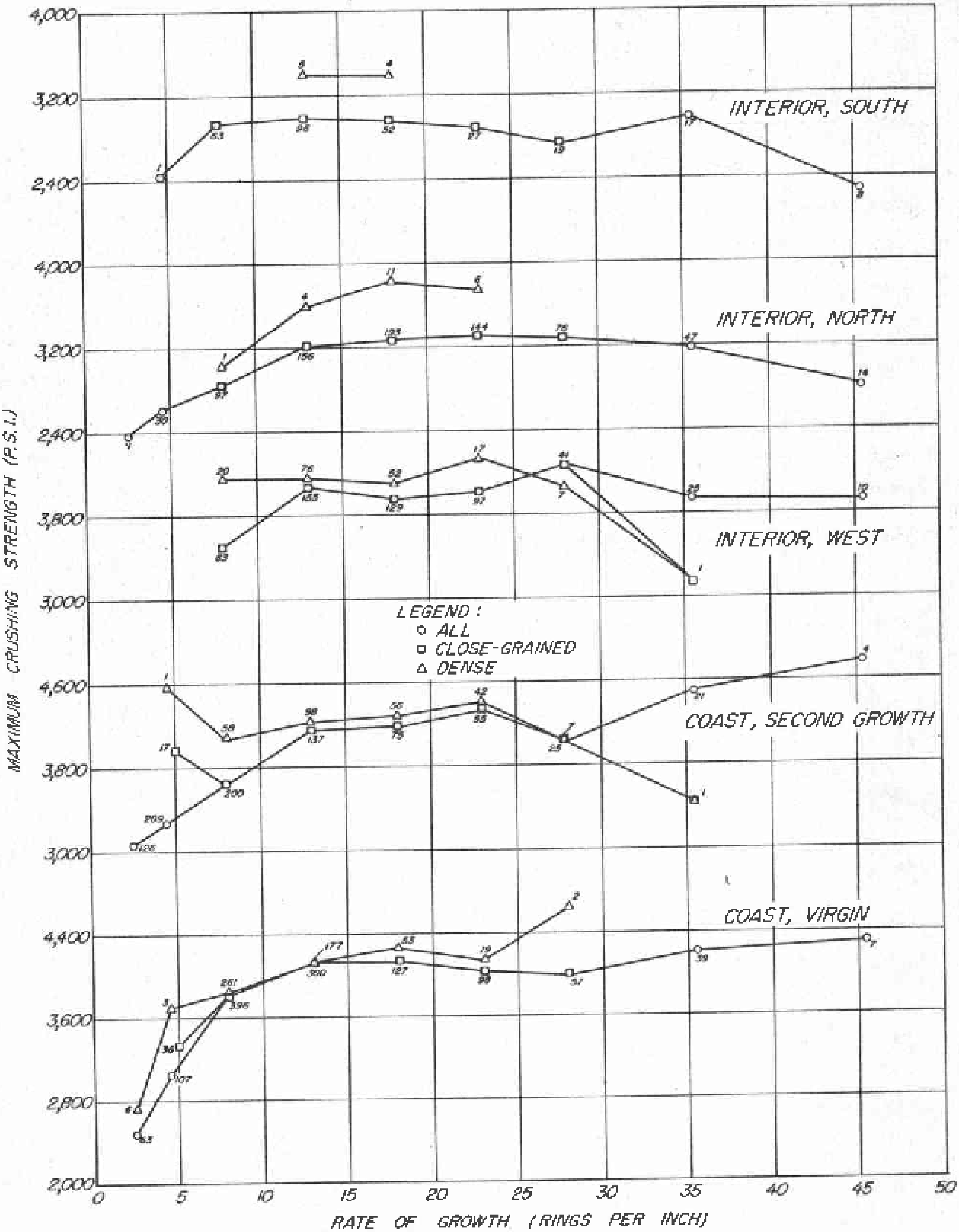

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Figure 21.--Effect of rules for density and close grain on maximum crushing strength in compression parallel to grain of Douglas-fir within growth-rate classes, segregated by geographic areas and tested at the U. S. Forest Products Laboratory.

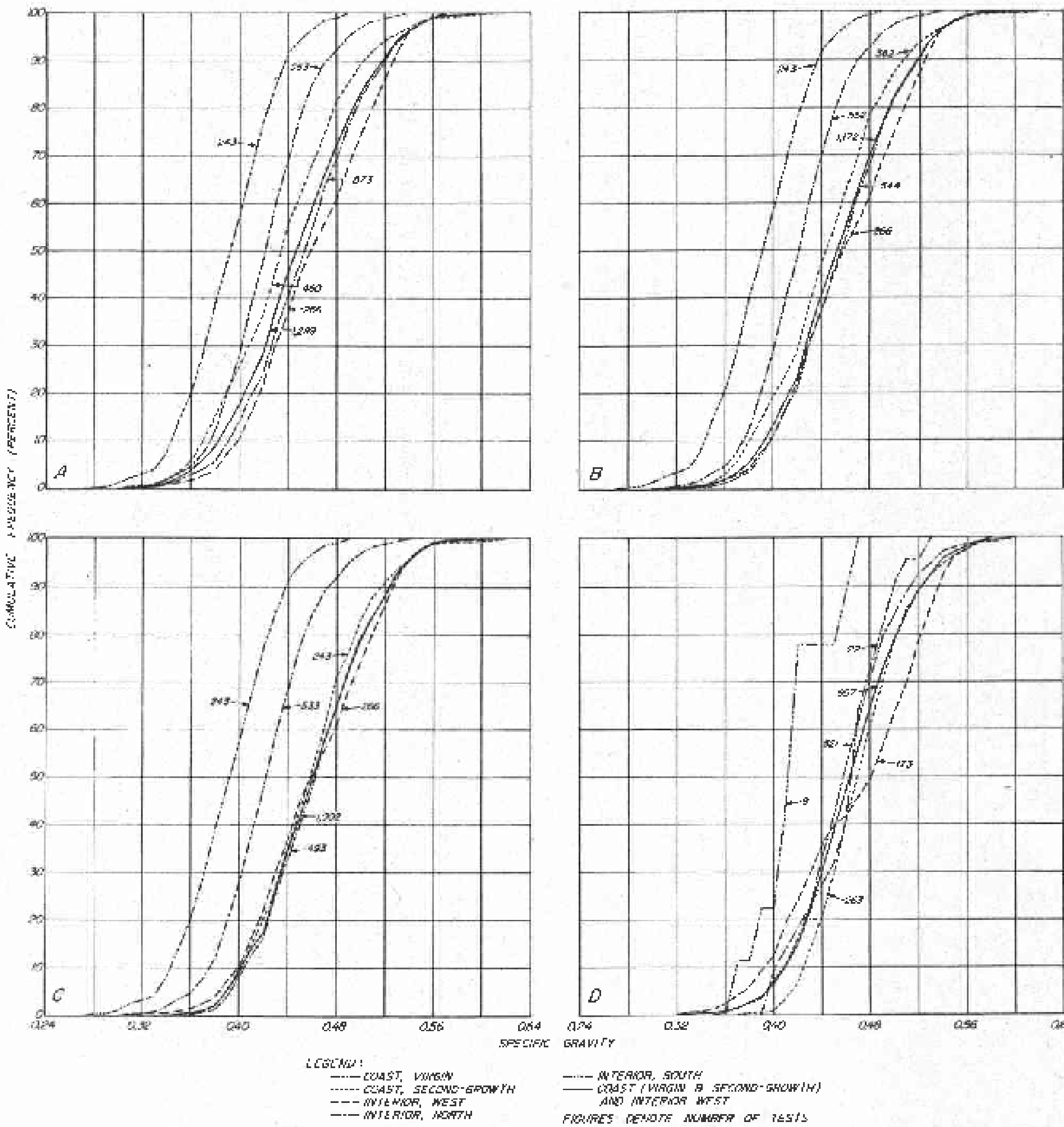

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Figure 22.--Cumulative frequency distribution curves for specific gravity of Douglas-fir static bending specimens tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and D, specimens qualifying as dense.

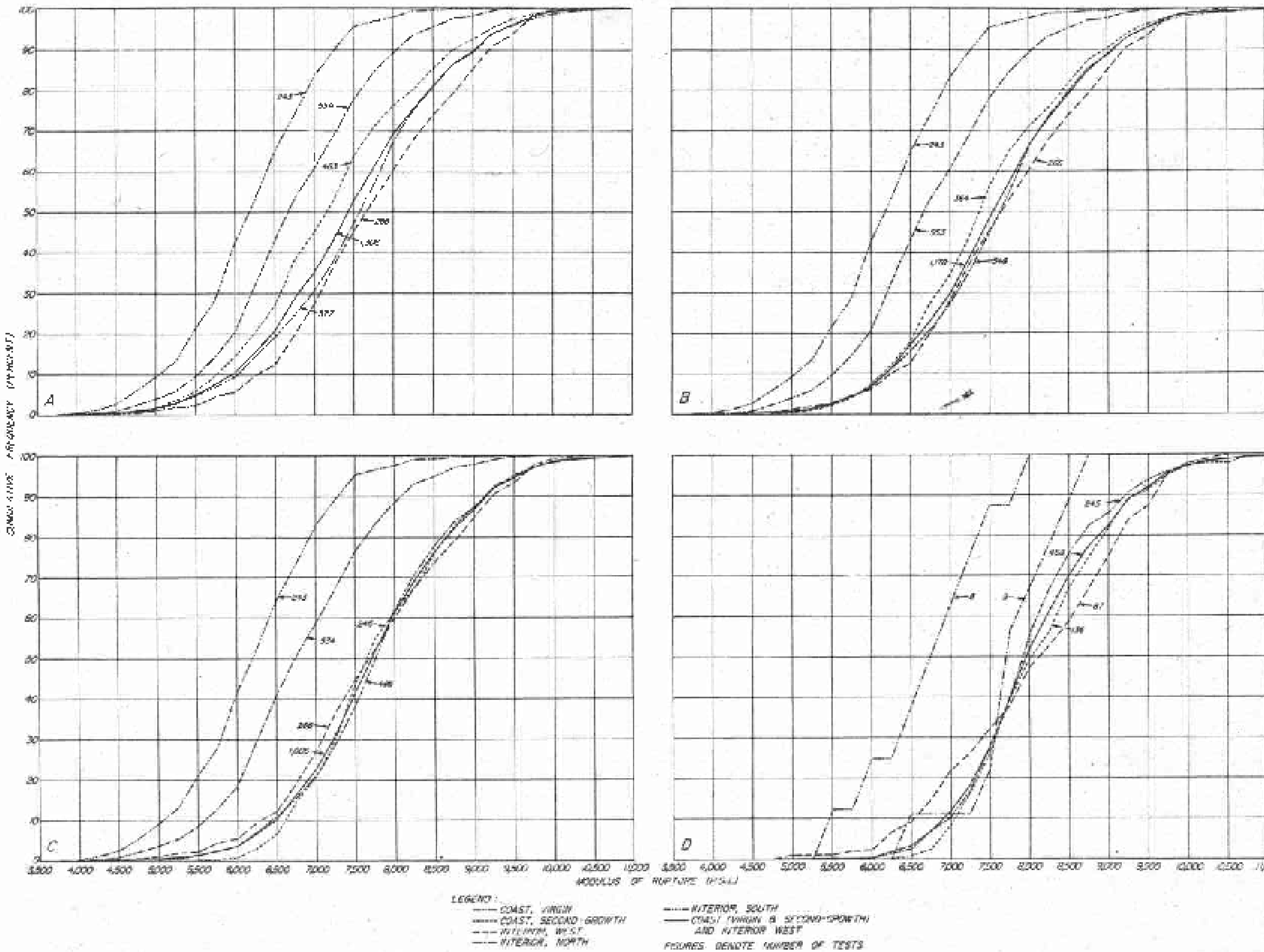

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Figure 23. --Cumulative frequency distribution curves for modulus of rupture of Douglas-fir tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and D, specimens qualifying as dense.

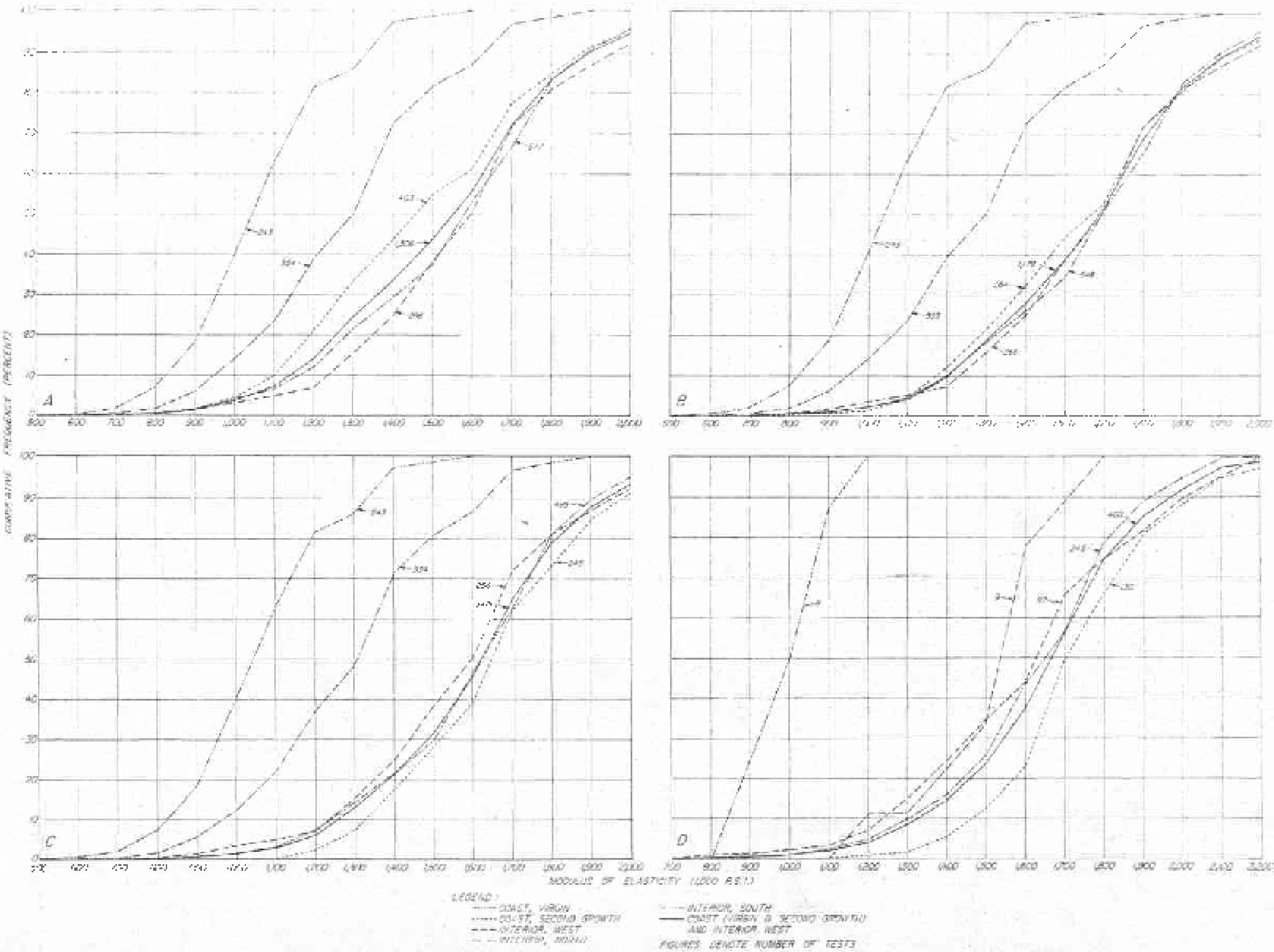

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Figure 24.--Cumulative frequency distribution curves for modulus of elasticity in static bending of Douglas-fir tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and

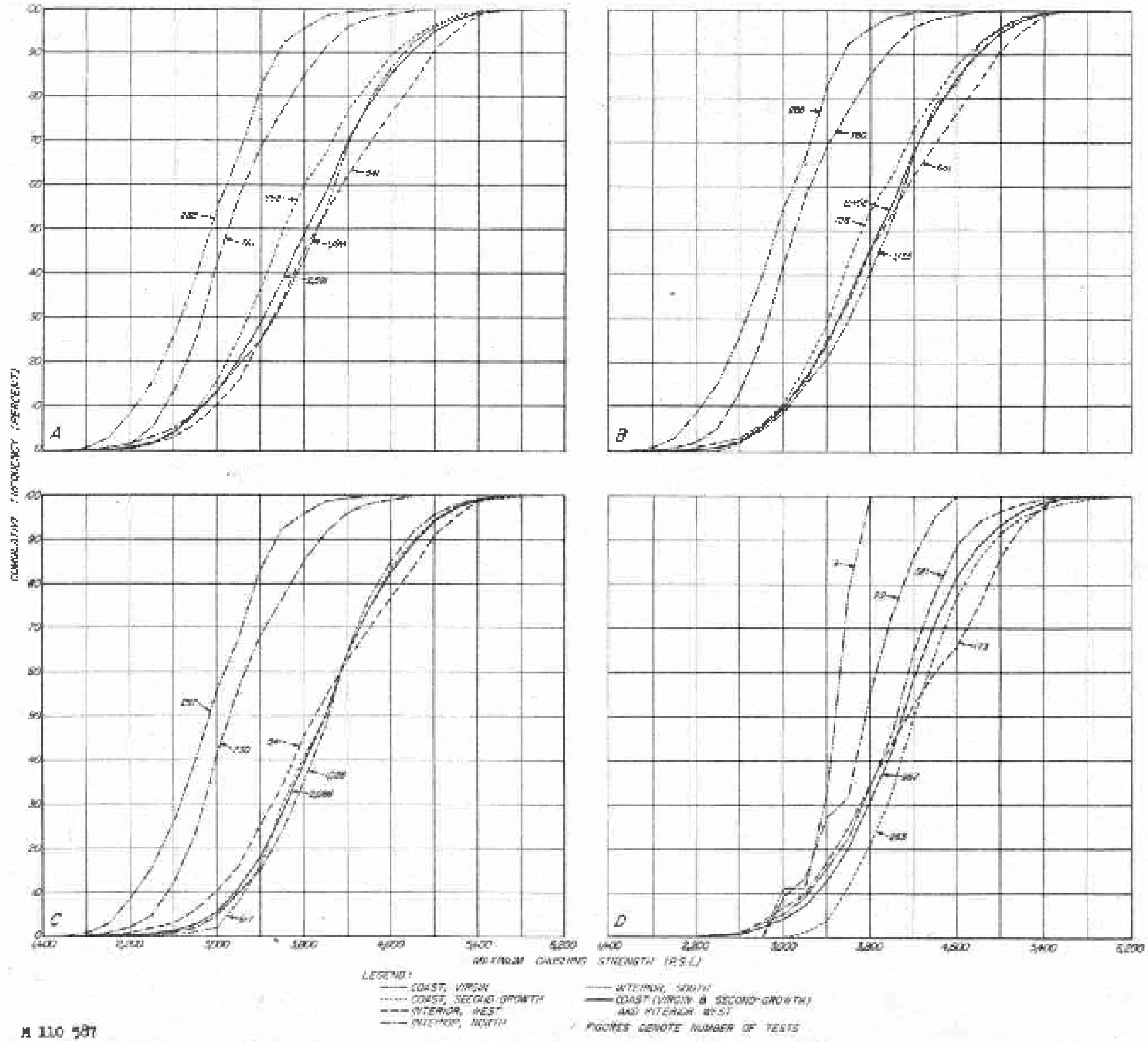

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Figure 25. --Cumulative frequency distribution curves for maximum crushing strength in compression parallel to grain of Douglas-fir tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and D, specimens qualifying as dense.

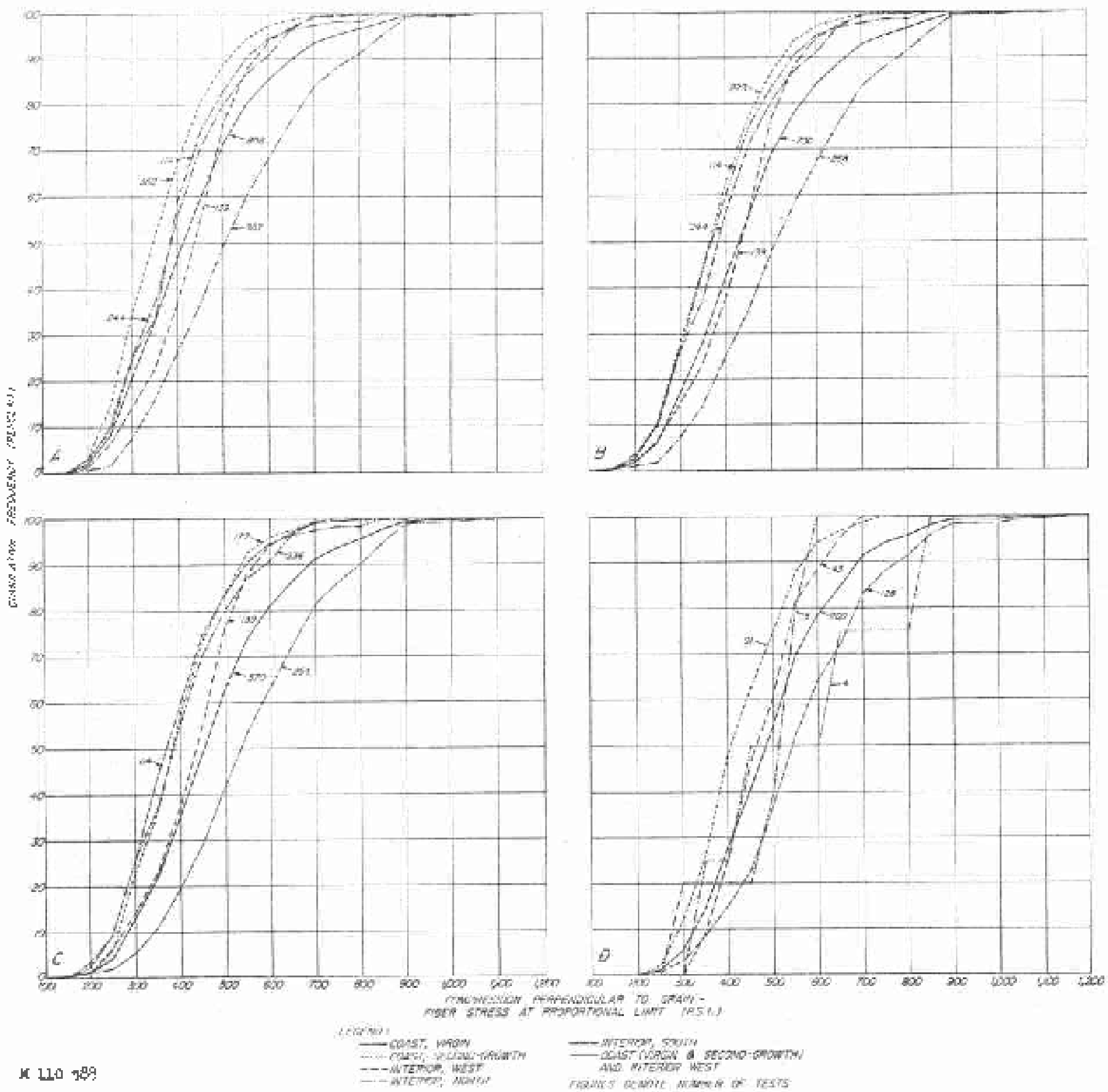

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Figure 26.--Cumulative frequency distribution curves for fiber stress at proportional limit in compression parallel to grain for all Douglas-fir specimens tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and D, specimens qualifying as dense.

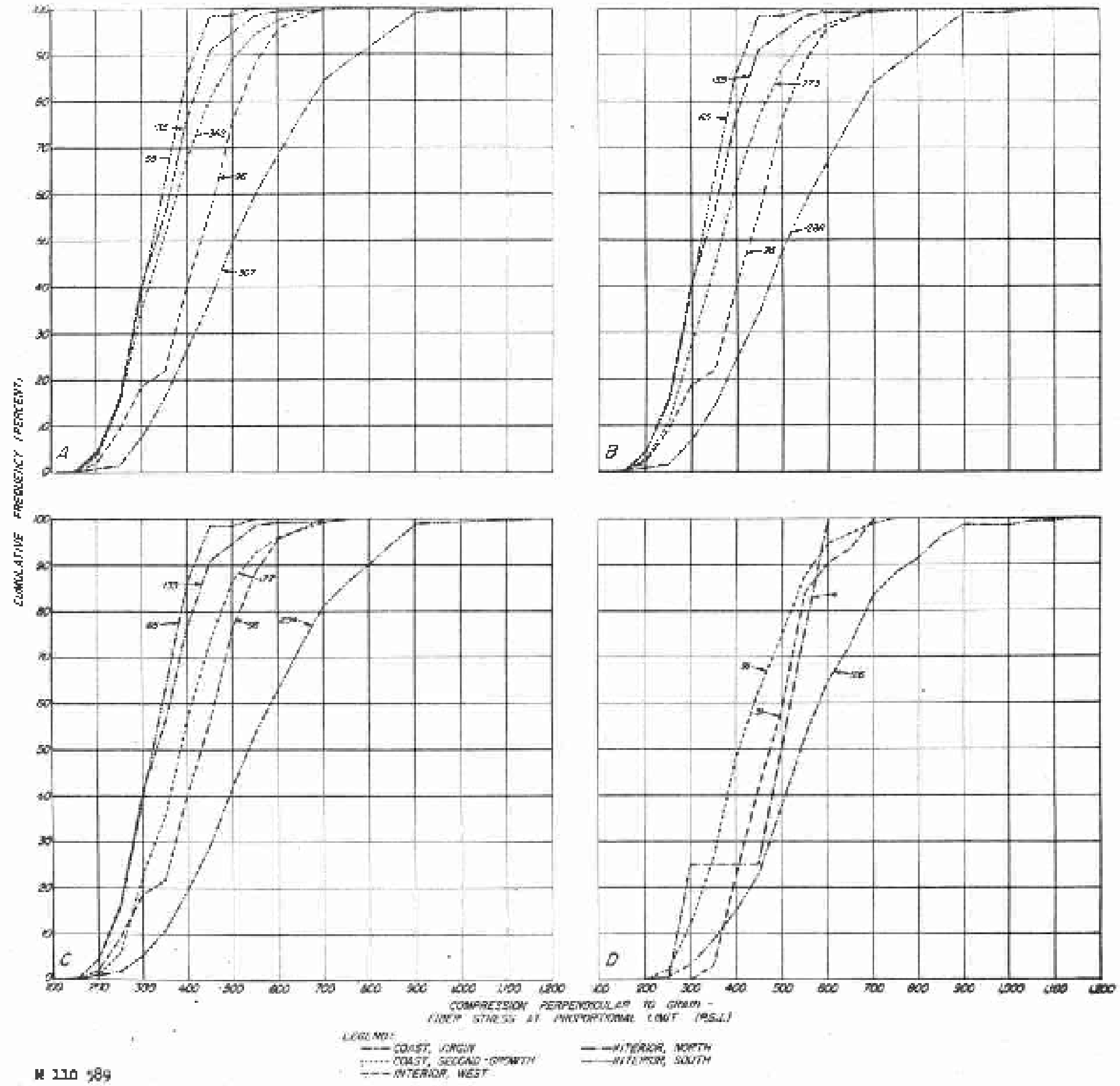

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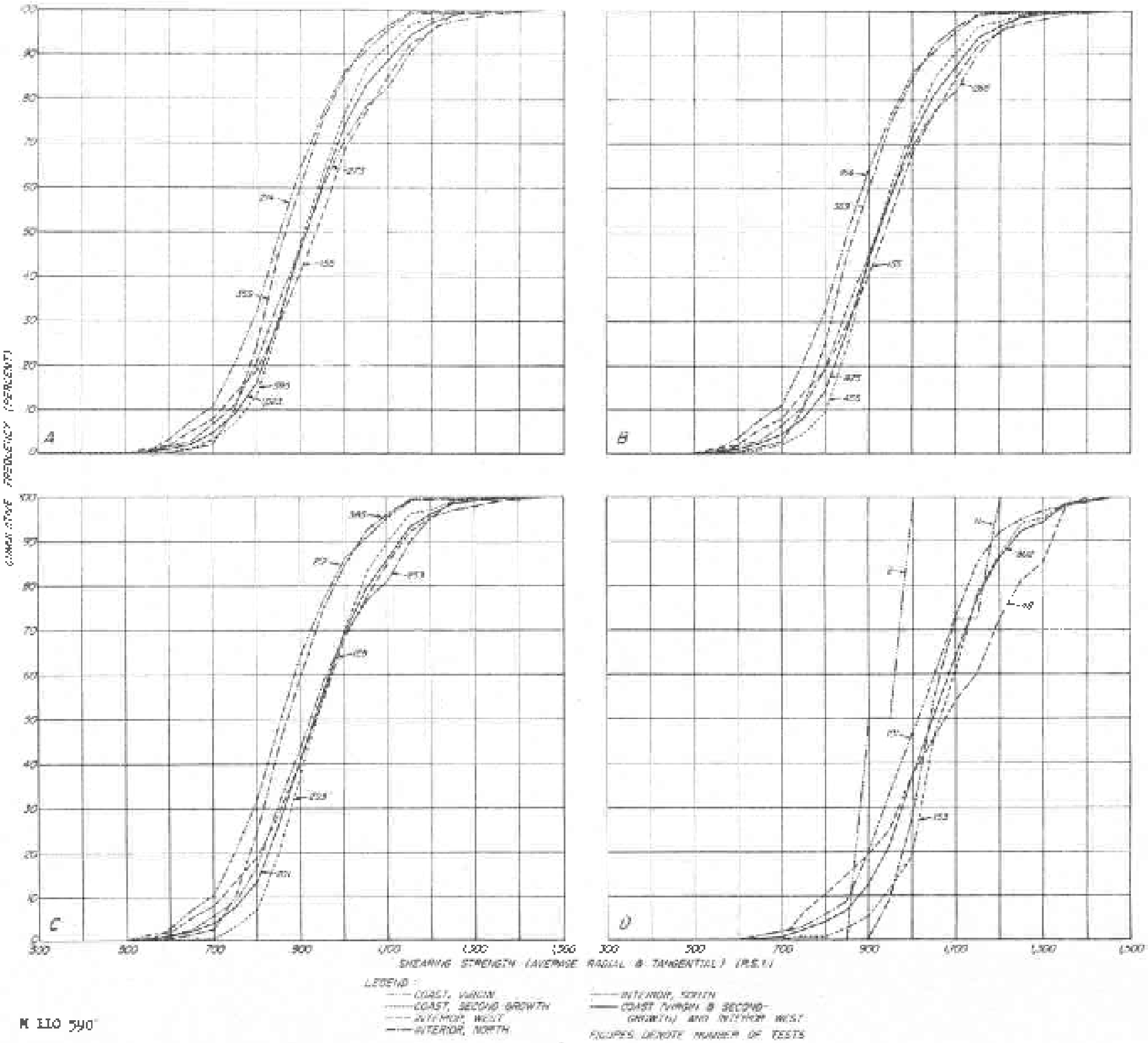
Figure 27. --Cumulative frequency distribution curves for fiber stress at proportional limit in compression perpendicular to grain for Douglas-fir specimens in segregated shipments tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and D, specimens qualifying as dense.



M 110 590

Figure 28. --Cumulative frequency distribution curves for average radial and tangential maximum shearing strength for Douglas-fir tested at the U. S. Forest Products Laboratory. A, All specimens; B, specimens with 4 or more annual rings per inch; C, specimens with 6 or more annual rings per inch; and D, specimens qualifying as dense.

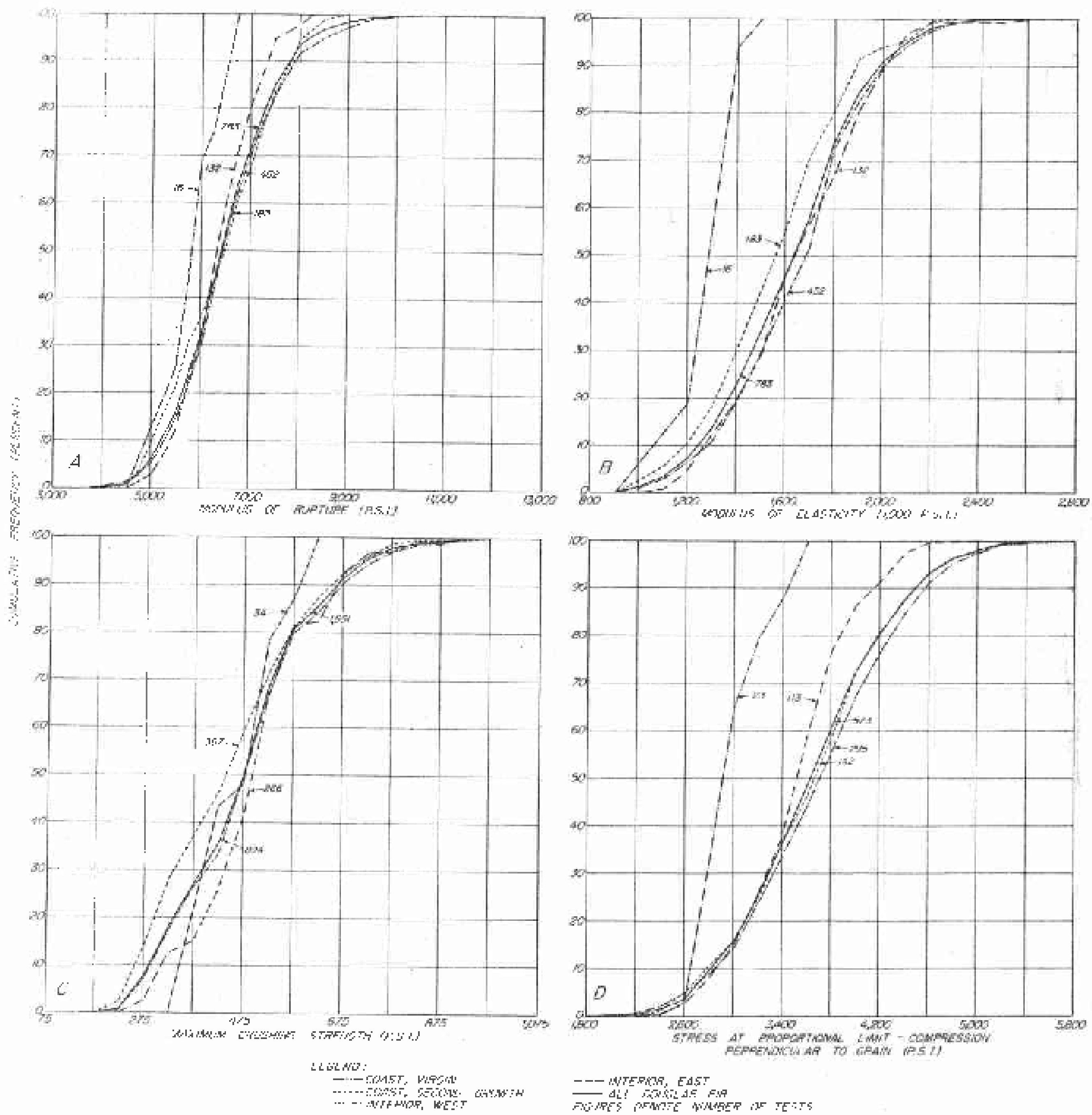


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Figure 29. --Cumulative frequency distribution curves for Canadian Douglas-fir tested at the Canadian Forest Products Laboratories. A, Modulus of rupture; B, modulus of elasticity; C, maximum crushing strength; and D, fiber stress at proportional limit in compression perpendicular to grain.

Table 1.--Douglas-fir samples[1] tested while green at the U. S. Forest Products Laboratory

Item No.	Shipment No.	County and State of origin	Test type[2]	Trees	Year collected	Elevation	Annual rainfall[3]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
				Number		Feet	Inches
		Coast:					
1	315	Lewis Co., Wash.	S	8	1914	350	50
2	318	Lane Co., Oreg.	...do..	5	1914	1,800	40
3	325	Gray's Harbor Co., Wash.	...do..	5	1914	110	75
4	354	Humboldt Co., Calif.	...do..	5	1915	300	46
5	523	Clatsop Co., Oreg.	...do..	7	1917	1,500	(60)
6	606	Clark Co., Wash.	...do..	3	1918	2,000	(40 - 50)
7	729	Washington Co., Oreg.	...do..	4	1919	....	(80)
8	1625 II O	Lane Co., Oreg. (II)	...do..	5	1946	2,350	38
9	1625 II F	............do...........	...do..	14	1946	3,000	(50)
10	1625 IV	............do...........	...do..	13	1946	3,300	(50)
11	1672	Western Oregon (II)	L	42	1953	....	(50 - 90)
12	1272	Lewis Co., Wash. (II)	SG	20	1928	1,400	(70)
13	1643 II	Pierce Co., Wash. (II)	...do..	8	1949	1,000	47
14	1643 IV	............do...........	...do..	10	1949	1,200	47
		Interior West:					
15	334	Plumas Co., Calif.	S	5	1914	5,000	50
16	1650	Chelan Co., Wash.	...do..	5	1950	2,500	41
17	1654	Trinity Co., Calif.	...do..	6	1950	3,000	60
18	1650	Chelan Co., Wash.	SG	15	1950	2,500	41
19	1654 T	Trinity Co., Calif.	...do..	13	1950	3,000	60
20	1654 H	............do...........	...do..	14	1950	3,000	65
21	1654 P	Shasta Co., Calif.	...do..	14	1950	4,300	45
22	1655	............do...........	...do..	13	1950	4,100	43
		Interior North:					
23	24	Johnson Co., Wyo.	S	5	1911	6,500	18
24	370	Missoula Co., Mont.	...do..	5	1915	4,000	16
25	973	Lincoln Co., Mont.	...do..	5	1923	2,400	22.5
26	1651	Union Co., Oreg.	...do..	6	1950	4,700	20
27	974	Shoshone Co., Idaho (II)	...do..	5	1923	3,500	35
28	1659	Teton Co., Wyo.	L	10	1952	7,500	21
29	1663	Lincoln Co., Wyo.	...do..	10	1952	8,000	(18)
30	1674	Missoula Co., Mont.	...do..	10	1953	4,450	30
31	1675	Shoshone Co., Idaho	...do..	10	1953	3,800	35
32	1676	Boise Co., Idaho	...do..	10	1953	4,800	22
33	1677	Fremont Co., Idaho	...do..	10	1953	6,625	29
34	902	Lewis Co., Idaho	SG	10	1922	4,050; 4,350	(18)
35	903	Bonner Co., Idaho	...do..	10	1922	2,150; 2,800	25
36	905	Kootenai Co., Idaho	...do..	10	1922	4,700; 4,500	30
37	906	Lincoln Co., Mont.	...do..	10	1922	3,625; 2,315	22.5
38	907	Letah Co., Idaho	...do..	10	1922	3,000; 2,900	25
39	1651	Union Co., Oreg.	...do..	15	1950	4,700	20
		Interior South:					
40	466	San Miguel Co., N. Mex.	Sp.	26	1916	8,300	18
41	1678	Douglas Co., Colo.	L	10	1953	8,000	14.6
42	1679	Taos Co., N. Mex.	...do..	10	1953	9,675	18
43	1680	Apache Co., Ariz.	...do..	10	1953	8,000	23

[1]All samples were of virgin material, except those marked II.

[2]S = Standard: Complete strength tests in accordance with ASTM Standard D143
L = Limited: Specific gravity and limited strength tests from short tree sections selected for the purpose
SG = Specific Gravity: Data on specific gravity only from material selected for the purpose
Sp. = Special: Tests of small clear specimens from structural beam tests (Shipment 466)

[3]Numbers without parentheses were obtained from local weather records; those with parentheses were estimated from average annual precipitation charts of the U. S. Weather Bureau.

Table 2.--Douglas-fir samples[1] tested when green at other laboratories

Item No.	Shipment No.	Location	Test type[2]
		WESTERN PINE ASSOCIATION	
		Interior West:	
P1	3	Klamath Co., Oreg.	Special
P2	120	Chelan Co., Wash.	....do.....
P3	158	Calaveras Co., Calif.	....do.....
		Interior North:	
P4	6	Boise Co., Idaho	....do.....
P5	43	Lincoln Co., Mont.	....do.....
P6	76	Shoshone Co., Idaho	....do.....
		CANADIAN FOREST PRODUCTS LABORATORIES	
		Coast:	
C1	2	Abbotsford, B.C.	Standard
C2	70	Comox, B.C.	....do.....
C3	76	Kissinger, B.C.	....do.....
C4	86	Cowichan Lake, B.C.	....do.....
C5	78	Port Moody, B.C. (II)	....do.....
C6	93	Whonock, B. C. (II)	....do.....
		Interior (Canada):	
C7	1	Morley, Alberta	....do.....
C8	3	Golden, B.C.	....do.....
C9	83	Shuswap Lake, B.C.	....do.....

[1]All samples were of virgin material except those marked (II) which was second growth.

[2]Special: Tests on 10 planks selected at random presumably from 10 separate trees at each location.
Standard: Complete strength tests in accordance with ASTM Standard D143.

Table 3.--Specific gravity and related data for individual shipments of green Douglas-fir tested at the U. S. Forest Products Laboratory

Shipment No.	Area[1]	Class[2]	Test type[3]	Trees	Rings per inch: Average[4]	Rings per inch: Minimum	Rings per inch: Maximum	Summerwood: Average[5]	Summerwood: Minimum	Summerwood: Maximum	Specimens	Specific gravity[8]: Average: Tree[6]	Specific gravity[8]: Average: Specimen[7]	Specific gravity[8]: Cv[9]	Specific gravity[8]: Minimum	Specific gravity[8]: Maximum
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
				Number	Number	Number	Number	Percent	Percent	Percent	Number			Percent		
315	C	V	(S)	8	12.3	4	30	33	17	50	312	0.474	0.469	9.3	0.349	0.568
318	..do..	..do..	..do..	5	19.8	3	55	35	14	70	161	.461	.457	12.3	.340	.594
325	..do..	..do..	..do..	5	8.8	2	36	38	18	60	231	.414	.415	10.0	.308	.504
354	..do..	..do..	..do..	5	10.1	2	29	36	19	54	208	.444	.445	12.4	.309	.557
523	..do..	..do..	..do..	7	17.2	4	40	48	26	72	116	.429	.437	10.4	.350	.550
606	..do..	..do..	..do..	3	15.1	4	33	36	24	50	131	.429	.425	9.1	.335	.516
729	..do..	..do..	..do..	4	15.2	5	40	27	20	37	81	.460	.442	12.8	.379	.594
Subtotal - CV (S)				37	14.0	2	55	36	14	72	1,240	.446	.444	11.6	.308	.594
334	IW	V	(S)	5	19.4	8	57	33	14	49	167	.401	.401	8.1	.293	.482
1650	..do..	..do..	..do..	5	14.2	6	30	32	14	51	159	.466	.464	10.8	.348	.578
1654	..do..	..do..	..do..	6	20.9	7	49	30	20	47	218	.478	.477	8.3	.341	.567
Subtotal - IWV (S)				16	18.3	6	57	31	14	51	544	.450	.450	11.8	.293	.578
Subtotal - CV, IWV (S)				53	15.3	2	57	34	14	72	1,784	.447	.446	11.7	.293	.594
1650	IW	V	(SG)	15	15.2	5	57	....	....	....	162	.434	.430	11.2	.339	.555
1654T	..do..	..do..	..do..	13	21.2	5	86	....	....	....	181	.455	.456	8.2	.338	.536
1654H	..do..	..do..	..do..	14	19.9	5	105	....	....	....	176	.434	.435	10.5	.319	.559
1654P	..do..	..do..	..do..	14	15.8	6	49	....	....	....	172	.385	.382	9.5	.292	.484
1655	..do..	..do..	..do..	13	19.5	5	86	....	....	....	219	.419	.414	9.9	.294	.507
Subtotal - IWV (SG)				69	18.2	5	105	....	....	....	910	.425	.423	11.4	.292	.559
Subtotal - All IW				85	18.2	5	105	....	....	....	1,454	.430	.433	11.9	.292	.578
Subtotal - CV, All IWV				122	16.9	2	105	....	....	....	2,694	.435	.438	11.8	.292	.594
1625IIC	C	II	(S)	5	4.9	2	14	23	12	39	154	.419	.420	6.0	.344	.505
1625IIF	..do..	..do..	..do..	14	10.8	3	28	31	11	57	318	.428	.424	11.4	.330	.560
1625IV	..do..	..do..	..do..	13	20.7	3	45	37	18	58	194	.475	.476	7.7	.397	.560
1672	..do..	..do..	(L)	42	4.7	2	16	31	15	58	192	.414	.412	14.4	.294	.596
Subtotal - CII (S,L)				74	8.7	2	45	31	11	58	858	.428	.433	11.9	.294	.596
Subtotal - CV, IWV, CII (S,L)				127	11.5	2	57	33	11	72	2,642	.436	.442	11.8	.293	.596
1272	C	II	(SG)	20	7.8	2	50	....	....	....	173	.418	.415	9.8	.315	.521
1643II	..do..	..do..	..do..	8	13.6	4	50	29	7	54	53	.424	.425	11.3	.352	.549
1643IV	..do..	..do..	..do..	10	4.5	3	7	22	10	39	58	.398	.398	7.0	.357	.492
Subtotal - CII (SG)				38	8.2	2	50	25	7	54	284	.414	.413	9.9	.315	.549
Subtotal - All CII				112	8.5	2	50	30	7	58	1,142	.423	.428	11.6	.294	.596
Subtotal - All CV, IW, CII				234	12.9	2	105	....	....	....	3,836	.429	.435	11.8	.292	.596

(Sheet 1 of 2)

Table 3.--Specific gravity and related data for individual shipments of green Douglas-fir tested at the U. S. Forest Products Laboratory (continued)

Shipment No.	Area[1]	Class[2]	Test type[3]	Trees	Rings per inch			Summerwood			Specific gravity[8]					
					Average[4]	Minimum	Maximum	Average[5]	Minimum	Maximum	Specimens	Average		Cv[9]	Minimum	Maximum
												Tree[6]	Specimen[7]			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
				Number	Number	Number	Number	Percent	Percent	Percent	Number			Percent		
24	IN	V	(S)	5	17.3	8	33	27	14	60	55	.418	.422	8.1	.366	.522
370	..do.	..do..	..do.	5	26.2	11	48	29	19	40	114	.392	.392	7.7	.310	.471
973	..do.	..do..	..do.	5	19.3	10	33	...	...	...	112	.430	.426	11.8	.300	.628
1651	..do.	..do..	..do.	6	18.9	5	37	24	15	40	173	.424	.423	9.0	.326	.520
974	..do.	II	..do.	5	10.6	3	25	...	...	...	113	.390	.391	8.4	.326	.488
Subtotal - IN (S)				26	18.5	3	48	25	14	60	567	.411	.411	10.0	.300	.628
1659	IN	V	(L)	10	36.3	15	66	...	...	...	40	.447	.441	7.8	.382	.518
1663	..do.	..do..	..do.	10	37.7	10	73	...	...	...	35	.422	.422	4.7	.383	.457
1674	..do.	..do..	..do.	10	26.3	7	60	21	12	33	41	.423	.419	9.9	.342	.518
1675	..do.	..do..	..do.	10	13.5	4	41	22	12	40	48	.426	.424	9.3	.356	.508
1676	..do.	..do..	..do.	10	20.0	7	37	...	...	...	51	.423	.421	8.2	.311	.510
1677	..do.	..do..	..do.	10	19.8	8	50	19	14	28	58	.378	.377	8.5	.312	.431
Subtotal - IN (L)				60	25.6	4	73	21	12	40	273	.420	.415	9.7	.311	.518
Subtotal - IN (S,L)				86	23.5	3	73	...	...	...	840	.417	.412	9.9	.300	.628
902	IN	V	(SG)	10	16.7	6	39	26	11	50	103	.422	.418	10.3	.326	.509
903	..do.	..do..	..do.	10	18.7	6	55	25	12	36	90	.438	.437	7.4	.368	.517
905	..do.	..do..	..do.	10	18.9	5	80	22	6	61	85	.414	.413	7.3	.337	.477
906	..do.	..do..	..do.	10	24.7	12	64	32	11	54	77	.434	.438	8.9	.375	.526
907	..do.	..do..	..do.	10	17.1	7	37	41	22	87	95	.434	.431	11.0	.354	.532
1651	..do.	..do..	..do.	15	19.6	7	103	...	...	...	152	.402	.399	9.1	.298	.485
Subtotal - IN (SG)				65	19.3	5	103	29	6	87	602	.422	.420	9.8	.298	.532
Subtotal - All IN				151	21.7	3	103	...	...	...	1,442	.419	.415	9.9	.298	.628
Subtotal - IW, IN				236	20.4	3	105	...	...	...	2,896	.423	.424	11.2	.292	.628
Subtotal - CV, IWV, IN				273	19.6	2	105	...	...	...	4,136	.426	.430	11.5	.292	.628
Subtotal - All CV, CII, IW, IN				385	16.4	2	105	...	...	...	5,278	.425	.430	11.6	.292	.628
Subtotal - CV, CII, IW, IN (S,L)				213	16.3	2	73	...	...	...	3,482	.428	.434	11.8	.293	.628
466	IS	V	(Sp.)	26	12.8	5	26	26	13	36	137	.398	.399	8.6	.314	.517
1678	..do.	..do..	(L)	10	26.6	8	62	18	13	24	46	.391	.391	6.4	.342	.434
1679	..do.	..do..	..do.	10	24.0	7	65	...	...	...	51	.392	.391	7.9	.334	.450
1680	..do.	..do..	..do.	10	17.7	6	42	18	12	23	56	.349	.349	8.0	.281	.410
Subtotal - IS				56	18.1	5	65	22	12	36	290	.387	.386	9.4	.281	.517
Subtotal - All Virgin				329	19.3	2	105	...	...	...	4,426	.419	.427	11.7	.281	.628
Total				441	16.6	2	105	...	...	...	5,568	.420	.427	11.7	.281	.628

[1]C = Coast; IW = Interior West; IN = Interior North; IS = Interior South.

[2]V = Virgin; II = Second-growth.

[3]S = ASTM standard strength tests; L = Limited tests; SG = Specific gravity only; Sp = Special tests (footnote 1, Table 1).

[4]Each tree given equal weight, except shipments labeled SG in column 4 where each specimen is given equal weight.

[5]Each specimen given equal weight.

[6]Each tree given equal weight. Corresponds to values published in USDA Technical Bulletion No. 479.

[7]Each specimen given equal weight. Coefficients of variation apply to this average.

[8]Based on volume when green and weight when ovendry.

[9]Coefficient of variation (Standard deviation divided by average in column 14).

(Sheet 2 of 2)

Table 4.--Strength and related data for individual shipments of green Douglas-fir tested at the U. S. Forest Products Laboratory

Shipment	Area[1]	Class[2]	Test type[3]	Static bending: Specimens	Static bending: Modulus of rupture: Average[4]	Static bending: Modulus of rupture: Cv[5]	Static bending: Modulus of rupture: Exclusion value[6]	Static bending: Modulus of elasticity: Average[4]	Static bending: Modulus of elasticity: Cv[5]	Static bending: Modulus of elasticity: Exclusion value[6]	Compression parallel to grain: Specimens	Compression parallel to grain: Maximum crushing strength: Average[4]	Compression parallel to grain: Maximum crushing strength: Cv[5]	Compression parallel to grain: Maximum crushing strength: Exclusion value[6]	Compression perpendicular to grain: Specimens	Compression perpendicular to grain: Stress at proportional limit: Average[4]	Compression perpendicular to grain: Stress at proportional limit: Cv[5]	Compression perpendicular to grain: Stress at proportional limit: Exclusion value[6]	Shear (Radial and Tangential): Specimens	Shear: Maximum shearing strength: Average[4]	Shear: Maximum shearing strength: Cv[5]	Shear: Maximum shearing strength: Exclusion value[6]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
				Number	P.s.i.	Percent	P.s.i.	1,000 p.s.i.	Percent	1,000 p.s.i.	Number	P.s.i.	Percent	P.s.i.	Number	P.s.i.	Percent	P.s.i.	Number	P.s.i.	Percent	P.s.i.
315	C	V	(S)	162	7,940	13.1	....	1,596	15.3	....	313	4,080	14.6	....	83	558	31.3	....	44	906	13.2	....
318	..do.	..do.	..do.	78	7,790	17.0	....	1,671	15.2	....	162	4,060	18.4	....	44	539	31.6	....	30	882	15.9	....
325	..do.	..do.	..do.	99	7,090	12.9	....	1,453	17.9	....	231	3,450	19.6	....	61	489	29.9	....	30	940	13.6	....
354	..do.	..do.	..do.	104	7,500	16.1	....	1,508	22.3	....	208	3,820	18.1	....	53	541	30.0	....	30	961	15.2	....
523	..do.	..do.	..do.	73	7,480	13.6	....	1,454	17.5	....	116	3,840	14.8	....	41	500	40.9	....	70	884	16.0	....
606	..do.	..do.	..do.	58	6,820	16.5	....	1,415	16.3	....	131	3,440	17.0	....	32	474	24.1	....	63	832	15.0	....
729	..do.	..do.	..do.	40	7,370	16.3	....	1,633	17.2	....	81	4,060	15.3	....	20	402	43.1	....	34	1,127	13.3	....
Subtotal - CV (S)				614	7,510	15.4	5,510	1,536	18.5	1,050	1,242	3,820	18.3	2,600	334	516	33.1	277	301	917	17.3	678
334	IW	V	(S)	83	6,900	11.9	....	1,348	16.4	....	167	3,390	14.2	....	44	453	22.2	....	30	781	11.3	....
1650	..do.	..do.	..do.	79	7,990	14.8	....	1,672	14.9	....	159	3,990	17.6	....	41	408	30.2	....	60	1,017	13.1	....
1654	..do.	..do.	..do.	105	8,120	12.3	....	1,499	13.1	....	218	4,330	15.9	....	55	452	22.3	....	71	914	15.7	....
Subtotal - IWV (S)				267	7,700	14.8	5,360	1,378	17.5	1,105	544	3,940	18.9	2,730	140	439	24.9	235	161	928	16.6	647
Subtotal - CV, IWV (S)				881	7,570	15.3	5,630	1,549	18.2	1,050	1,786	3,860	18.5	2,630	474	493	32.6	264	462	921	17.0	670
1625IIO	C	II	(S)	71	6,890	8.9	....	1,299	14.8	....	153	3,310	9.7	....	40	375	22.9	....	38	905	7.2	....
1625IIF	..do.	..do.	..do.	152	7,290	15.3	....	1,549	19.4	....	320	3,650	18.2	....	82	330	32.0	....	111	911	12.6	....
1625IV	..do.	..do.	..do.	84	8,240	10.6	....	1,732	10.8	....	194	4,190	13.9	....	51	396	29.6	....	84	978	11.1	....
1672	..do.	..do.	(L)	194	6,950	17.6	....	1,387	21.1	....	192	3,480	20.4	....	194	375	29.6	....	370	905	13.5	....
Subtotal - CII (S,L)				501	7,260	16.0	5,400	1,481	20.4	1,009	859	3,670	18.6	2,640	367	368	29.8	206	603	916	13.0	723
Subtotal - CV, CII, W?				1,382	7,460	15.7	5,530	1,524	19.1	1,025	2,645	3,800	18.7	2,630	841	438	35.6	223	1,065	918	14.9	701
24	IN	V	(S)	29	6,320	14.1	....	1,254	17.3	....	55	2,960	17.1	....	20	434	22.6	....	30	852	11.7	....
370	..do.	..do.	..do.	58	6,440	10.0	....	1,129	15.5	....	114	3,090	12.1	....	31	470	24.7	....	27	895	9.7	....
973	..do.	..do.	..do.	56	7,060	13.4	....	1,423	16.5	....	112	3,420	15.8	....	30	519	29.7	....	40	888	9.8	....
1651	..do.	..do.	..do.	80	6,670	14.5	....	1,252	21.3	....	173	3,160	19.4	....	48	365	30.8	....	64	943	12.8	....
974	..do.	II	..do.	54	6,370	13.8	....	1,237	19.3	....	112	3,030	14.7	....	29	482	28.5	....	36	866	10.3	....
Subtotal - IN (S)				277	6,600	13.8	5,240	1,258	19.9	865	566	3,150	17.0	2,410	158	445	30.6	229	197	897	11.8	741
1659	IN	V	(L)	40	7,340	11.9	....	1,455	11.9	....	....	....	....	....	....	....	....	....	....	....	....	....
1663	..do.	..do.	..do.	35	7,360	7.8	....	1,267	13.6	....	....	....	....	....	....	....	....	....	....	....	....	....
1674	..do.	..do.	..do.	45	7,010	14.8	....	1,311	16.9	....	41	3,410	17.4	....	19	316	22.1	....	38	901	11.0	....
1675	..do.	..do.	..do.	49	7,120	13.6	....	1,298	22.1	....	48	3,240	19.8	....	21	368	18.9	....	42	917	11.3	....
1676	..do.	..do.	..do.	52	7,090	12.2	....	1,345	14.9	....	51	3,300	16.1	....	22	392	14.9	....	42	844	12.0	....
1677	..do.	..do.	..do.	59	5,890	13.5	....	1,134	17.1	....	58	2,900	16.0	....	25	266	19.5	....	50	776	11.0	....
Subtotal - IN (L)				280	6,900	15.1	5,100	1,293	18.0	888	198	3,190	18.4	2,280	87	333	23.6	194	172	855	13.1	696
Subtotal - IN (S,L)				557	6,750	14.7	5,170	1,276	19.0	874	764	3,160	17.3	2,370	245	405	32.2	216	369	878	12.6	717
Subtotal - All IW, IN				824	7,060	16.0	5,510	1,374	21.1	907	1,308	3,490	21.3	2,430	385	418	29.6	221	530	893	14.3	707
Subtotal - CV, IWV, INV				1,438	7,250	16.1	5,380	1,443	20.7	935	2,550	3,650	20.3	2,480	719	463	34.0	241	831	902	15.5	701
Subtotal - All CV, CII, IW, IN				1,939	7,250	16.1	5,390	1,453	20.6	948	3,409	3,660	19.9	2,510	1,086	431	35.1	221	1,434	908	14.5	708
466	IS	V	(Sp.)	93	6,480	13.0	....	1,011	18.5	....	137	3,130	15.0	....	50	473	27.5	....	89	938	12.8	....
1678	..do.	..do.	(L)	46	6,170	12.3	....	1,107	16.2	....	46	2,850	15.5	....	17	352	20.7	....	34	838	12.2	....
1679	..do.	..do.	..do.	52	6,310	10.2	....	1,134	11.9	....	51	2,740	14.0	....	24	356	16.5	....	47	832	11.6	....
1680	..do.	..do.	..do.	57	5,570	14.4	....	996	17.1	....	56	2,620	19.7	....	24	282	22.5	....	48	743	14.3	....
Subtotal - IS				248	6,180	13.8	4,690	1,051	17.1	755	290	2,920	17.4	2,070	115	391	32.4	212	218	857	15.5	620
Subtotal - All V				1,686	7,090	16.7	5,240	1,385	22.8	884	2,840	3,580	21.1	2,400	834	453	34.3	236	1,049	892	15.7	677
Total				2,187	7,130	16.6	5,270	1,407	22.4	903	3,699	3,600	20.5	2,440	1,201	427	35.0	220	1,652	901	14.7	698

[1] C = Coast; IW = Interior West; IN - Interior North; IS = Interior South.

[2] V = Virgin; II = Second-growth.

[3] S = ASTM Standard strength tests; L = Limited tests; Sp. - Special (Footnote 1, Table 1).

[4] Each specimen given equal weight.

[5] Coefficient of variation (Standard deviation divided by the average).

[6] Strength values corresponding to the 5 percent point in cumulative frequency distributions.

Table 5.--Specific gravity and related data for individual shipments of green Douglas-fir tested[1] at the Canadian Forest Products Laboratories

Item No.	Shipment No.	Area[2]	Class[3]	Trees	Rings per inch			Summerwood			Specific gravity					
					Average[4]	Minimum	Maximum	Average[5]	Minimum	Maximum	Specimens	Average		Cv[6]	Minimum	Maximum
												Tree[4]	Specimen[5]			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
				Number	Number	Number	Number	Percent	Percent	Percent	Number			Percent		
C1	2	C	V	5	13.2	4	37	38	16	54	124	0.442	0.443	10.5	0.338	0.574
C2	70	..do.	..do..	6	19.2	3	54	42	11	63	216	.474	.474	12.9	.337	.615
C3	76	..do.	..do..	6	22.6	4	83	38	16	74	302	.449	.448	10.3	.323	.568
C4	86	..do.	..do..	7	21.1	4	50	27	13	40	252	.419	.418	8.3	.327	.504
Subtotal - CV				24	19.4	3	83	36	11	74	894	.445	.445	11.6	.323	.615
C5	78	C	II	7	5.8	3	11	38	20	50	140	.421	.422	9.8	.329	.506
C6	93	..do.	..do..	7	6.6	3	16	40	18	63	217	.439	.439	12.7	.313	.557
Subtotal - CII				14	6.2	3	16	39	18	63	357	.430	.432	11.8	.313	.557
Subtotal - All Coast				38	14.5	3	83	37	11	74	1,251	.439	.441	11.7	.313	.615
C7	1	I	V	5	26.4	12	52	25	16	35	34	.413	.411	6.6	.362	.462
C8	3	..do.	..do..	5	17.3	7	40	32	14	48	85	.437	.422	9.1	.335	.545
C9	83	..do.	..do..	6	16.4	5	52	32	18	48	181	.465	.465	7.3	.308	.563
Subtotal - IV				16	19.8	5	52	31	14	48	300	.440	.447	9.2	.308	.563
Subtotal - CV, IV				40	19.6	3	83	35	11	74	1,194	.443	.445	11.1	.308	.615
Total				54	16.1	3	83	36	11	74	1,551	.439	.442	11.3	.308	.615

[1] All tests were ASTM Standard strength tests.

[2] C = Coast; I = Interior (Canada).

[3] V = Virgin; II = Second growth.

[4] Each tree given equal weight.

[5] Each specimen given equal weight. Coefficients of variation apply to this average.

[6] Coefficient of variation (Standard deviation divided by average).

Table 6.--Strength and related data for individual shipments of green Douglas-fir tested[1] at the Canadian Forest Products Laboratories

Item No.	Shipment No.	Area[2]	Class[3]	Static bending: Specimens	Static bending: Modulus of rupture: Average[4]	Static bending: Modulus of rupture: Cv[5]	Static bending: Modulus of elasticity: Average[4]	Static bending: Modulus of elasticity: Cv[5]	Compression parallel to grain: Specimens	Compression parallel to grain: Maximum crushing strength: Average[4]	Compression parallel to grain: Maximum crushing strength: Cv[5]	Compression perpendicular to grain: Specimens	Compression perpendicular to grain: Stress at proportional limit: Average[4]	Compression perpendicular to grain: Stress at proportional limit: Cv[5]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
				Number	P.s.i.	Percent	1,000 p.s.i.	Percent	Number	P.s.i.	Percent	Number	P.s.i.	Percent
C1	2	C	V	51	8,180	10.2	1,777	9.7	124	4,010	16.5	33	479	31.5
C2	70	do.	do.	108	8,060	16.5	1,771	17.6	216	3,760	20.3	59	530	30.8
C3	76	do.	do.	151	7,380	11.3	1,626	16.9	302	3,740	15.4	78	520	22.8
C4	86	do.	do.	142	7,130	11.9	1,540	14.5	252	3,450	15.9	125	427	30.0
Subtotal - CV				452	7,550	14.1	1,651	16.8	894	3,700	17.7	295	478	30.0
C5	78	C	II	68	7,290	12.2	1,579	14.5	140	3,610	13.3	40	426	31.5
C6	93	do.	do.	115	7,520	14.4	1,538	19.7	217	3,670	19.5	103	449	34.7
Subtotal - CII				183	7,430	13.7	1,553	17.9	357	3,650	17.3	143	443	33.8
				635	7,520	14.0	1,623	17.3	1,251	3,690	17.6	438	466	31.4
C7	1	I	V	16	6,790	8.8	1,270	10.2	34	2,950	9.1	23	463	18.9
C8	3	do.	do.	35	7,330	12.1	1,452	13.9	85	3,270	12.4	34	488	26.5
C9	83	do.	do.	97	7,370	9.5	1,717	15.5	181	3,600	12.6	79	494	24.9
Subtotal - IV				148	7,300	10.3	1,606	18.0	300	3,430	13.9	136	487	24.6
Subtotal - CV, IV				600	7,490	13.3	1,640	17.1	1,194	3,630	17.3	431	481	28.4
Total				783	7,480	13.4	1,620	17.4	1,551	3,640	17.3	574	471	29.9

[1] All tests were ASTM Standard strength tests.

[2] C = Coast; I = Interior (Canada).

[3] V = Virgin; II = Second-growth.

[4] Each specimen given equal weight.

[5] Coefficient of variation (standard deviation divided by average).

Table 7.--Specific gravity, rate of growth, and strength data for samples[1] tested by the Western Pine Association[2]

Item No.	Mill number	Trees[3]	Rings per inch[4]	Specific gravity: Specimens	Specific gravity: Average[4]	Specific gravity: Minimum	Specific gravity: Maximum	Static bending: Specimens	Static bending: Modulus of rupture	Static bending: Modulus of elasticity	Compression parallel to grain: Specimens	Compression parallel to grain: Maximum	Compression perpendicular to grain - stress at proportional limit[5]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
		Number	Number	Number				Number	P.s.i.	1,000 p.s.i.	Number	P.s.i.	P.s.i.
INTERIOR WEST													
P1	3	10	27	100	0.401	0.342	0.506	100	6,990	1,370	83	3,040	560
P2	120	10	23	92	.409	.327	.516	92	7,130	1,310	92	3,340	590
P3	158	10	16	100	.430	.337	.640	100	7,240	1,480	95	3,680	610
Subtotal		30	22	292	.413	.327	.640	292	7,120	1,390	270	3,370	590
INTERIOR NORTH													
P4	6	10	17	92	.464	.397	.588	92	7,770	1,530	87	3,370	460
P5	43	10	17	50	.447	.398	.535	50	7,030	1,380	46	3,260	500
P6	76	10	23	96	.462	.391	.557	96	8,370	1,700	93	4,020	490
Subtotal		30	19	238	.458	.391	.588	238	7,850	1,570	226	3,620	480
Total		60	20	530	.436	.327	.640	530	7,450	1,470	496	3,480	540

[1] Samples were presumed to be of virgin material.

[2] Special tests at Western Pine Association Laboratory are based on planks selected at member mills.

[3] Number not positively known. Collection instructions called for samples to be taken from separate trees.

[4] Each specimen given equal weight.

[5] The number of specimens in compression perpendicular to grain is not available.

Table 8.--Effect of growth rate and percentage summerwood restrictions on Douglas-fir specimens

Specimen classification	Specific gravity				Static bending						Maximum crushing strength			
	Specimens		Values		Specimens		Modulus of rupture		Modulus of elasticity		Specimens		Values	
	Items	Ratios[1]	Average	Ratios[1]	Items	Ratios[1]	Average	Ratios[1]	Average	Ratios[1]	Items	Ratios[1]	Average	Ratios[1]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Number	Percent		Percent	Number	Percent	P.s.i.	Percent	1,000 p.s.i.	Percent	Number	Percent	P.s.i.	Percent
COAST VIRGIN														
All strength tests	1,240	....	0.444	....	614	....	7,510	....	1,536	....	1,242	....	3,820	....
Growth rate recorded	1,196	100.0	.445	100.0	577	100.0	7,530	100.0	1,547	100.0	1,198	100.0	3,830	100.0
Four or more rings per inch[2]	1,133	94.7	.450	101.1	548	95.0	7,630	101.3	1,572	101.6	1,135	94.7	3,900	101.8
Six or more rings per inch[3]	1,027	85.9	.456	102.5	495	85.8	7,760	103.1	1,598	103.3	1,028	85.8	3,990	104.2
Growth rate and percentage summerwood recorded	956	100.0	.444	100.0	470	100.0	7,500	100.0	1,542	100.0	958	100.0	3,790	100.0
Qualifying as dense[4]	521	54.5	.459	103.4	245	52.1	8,020	106.9	1,627	105.5	521	54.4	3,980	105.0
COAST SECOND-GROWTH														
All strength tests	858	....	.433	....	501	....	7,260	....	1,481	....	859	....	3,670	....
Growth rate recorded	851	100.0	.433	100.0	463	100.0	7,210	100.0	1,471	100.0	852	100.0	3,680	100.0
Four or more rings per inch[2]	725	85.2	.440	101.6	364	78.6	7,470	103.6	1,549	105.3	726	85.2	3,780	102.7
Six or more rings per inch[3]	515	60.5	.456	105.3	245	52.9	7,790	108.0	1,648	112.0	517	60.7	3,990	108.4
Growth rate and percentage summerwood recorded	803	100.0	.429	100.0	449	100.0	7,180	100.0	1,460	100.0	804	100.0	3,640	100.0
Qualifying as dense[4]	263	32.8	.471	109.8	136	30.3	8,160	113.6	1,727	118.3	263	32.7	4,230	116.2
INTERIOR WEST														
All strength tests	544	....	.450	....	267	....	7,700	....	1,578	....	544	....	3,940	....
Growth rate recorded	541	100.0	.450	100.0	266	100.0	7,710	100.0	1,579	100.0	541	100.0	3,940	100.0
Four or more rings per inch[2]	541	100.0	.450	100.0	266	100.0	7,710	100.0	1,579	100.0	541	100.0	3,940	100.0
Six or more rings per inch[3]	541	100.0	.450	100.0	266	100.0	7,710	100.0	1,579	100.0	541	100.0	3,940	100.0
Growth rate and percentage summerwood recorded	474	100.0	.456	100.0	232	100.0	7,790	100.0	1,603	100.0	474	100.0	4,010	100.0
Qualifying as dense[4]	173	36.5	.468	102.6	87	37.5	8,070	103.6	1,612	100.6	173	36.5	4,140	103.2

(Sheet 1 of 2)

Table 8.--Effect of growth rate and percentage summerwood restrictions on Douglas-fir specimens (continued)

Specimen classification	Specific gravity				Static bending						Maximum crushing strength			
	Specimens		Values		Specimens		Modulus of rupture		Modulus of elasticity		Specimens		Values	
	Items	Ratios[1]	Average	Ratios[1]	Items	Ratios[1]	Average	Ratios[1]	Average	Ratios[1]	Items	Ratios[1]	Average	Ratios[1]
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Number	Percent		Percent	Number	Percent	P.s.i.	Percent	1,000 p.s.i.	Percent	Number	Percent	P.s.i.	Percent
INTERIOR NORTH														
All strength tests	840	....	.412	....	557	....	6,750	....	1,276	....	764	....	3,160	....
Growth rate recorded	836	100.0	.412	100.0	554	100.0	6,750	100.0	1,276	100.0	761	100.0	3,160	100.0
Four or more rings per inch[2]	835	99.9	.412	100.0	553	99.8	6,750	100.0	1,277	100.1	760	99.9	3,160	100.0
Six or more rings per inch[3]	805	96.3	.413	100.2	534	96.4	6,790	100.6	1,287	100.9	730	95.9	3,190	100.9
Growth rate and percentage summerwood recorded	465	100.0	.418	100.0	235	100.0	6,650	100.0	1,250	100.0	390	100.0	3,180	100.0
Qualifying as dense[4]	22	4.7	.458	109.6	9	3.8	7,680	115.5	1,496	119.7	22	5.6	3,710	116.7
INTERIOR SOUTH														
All strength tests	290	....	.386	....	248	....	6,180	....	1,051	....	290	....	2,920	....
Growth rate recorded	288	100.0	.386	100.0	243	100.0	6,180	100.0	1,053	100.0	288	100.0	2,920	100.0
Four or more rings per inch[2]	288	100.0	.386	100.0	243	100.0	6,180	100.0	1,053	100.0	288	100.0	2,920	100.0
Six or more rings per inch[3]	287	99.7	.386	100.0	243	100.0	6,180	100.0	1,053	100.0	287	99.7	2,920	100.0
Growth rate and percentage summerwood recorded	257	100.0	.386	100.0	175	100.0	6,120	100.0	1,022	100.0	257	100.0	2,920	100.0
Qualifying as dense[4]	9	3.5	.413	107.0	8	4.6	6,690	109.3	1,002	98.0	9	3.5	3,390	116.1
ALL AREAS														
All strength tests	3,772	....	.431	....	2,187	....	7,130	....	1,407	....	3,699	....	3,600	....
Growth rate recorded	3,712	100.0	.431	100.0	2,103	100.0	7,120	100.0	1,406	100.0	3,640	100.0	3,600	100.0
Four or more rings per inch[2]	3,522	94.9	.434	100.7	1,974	93.9	7,190	101.0	1,422	101.1	3,450	94.8	3,640	101.1
Six or more rings per inch[3]	3,175	85.5	.438	101.6	1,783	84.8	7,250	101.8	1,434	102.0	3,103	85.2	3,690	102.5
Growth rate and percentage summerwood recorded	2,955	100.0	.433	100.0	1,561	100.0	7,170	100.0	1,425	100.0	2,883	100.0	3,620	100.0
Qualifying as dense[4]	988	33.4	.463	106.9	485	31.1	8,040	112.1	1,639	115.0	988	34.3	4,060	112.2

[1] Ratios of 100 percent are assigned arbitrarily to values shown on the second and fifth lines of each area or type group (coast virgin, etc.).

[2] Essentially comparable to medium grain.

[3] Essentially comparable to close grain.

[4] Pieces averaging one-third or more summerwood with 6 or more annual rings per inch, and one-half or more summerwood with less than 6 annual rings per inch.

(Sheet 2 of 2)