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THE DISTRIBUTION AND THE MECHANICAL PROPERTIES OF ALASKA WOODS
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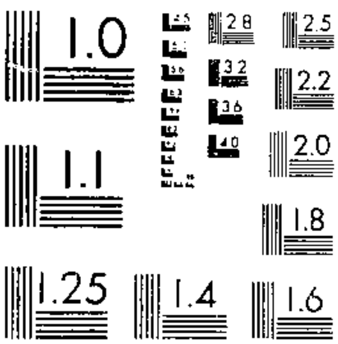

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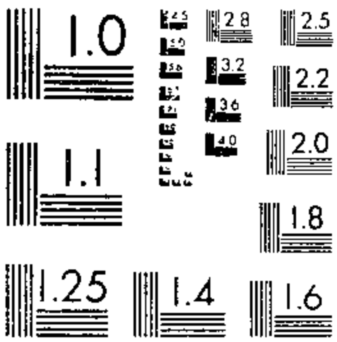

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WASHINGTON, D. C.

# THE DISTRIBUTION AND THE MECHANICAL PROPERTIES OF ALASKA WOODS

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## PURPOSE

Accurate data on the distribution and mechanical properties are invaluable when a wood suitable for a specific purpose is to be selected. This bulletin provides reliable data on the principal commercial woods of Alaska for architects, engineers, contractors, woodworkers, and others who require detailed information regarding Alaska woods and a means of comparing their respective properties.

## TIMBER RESOURCES OF ALASKA

Of Alaska's total forested area, conservatively estimated at over 70,000,000 acres, two national forests comprise 21,347,000 acres, di-

[1] Acknowledgment is made to C. H. Flory, B. F. Heintzleman, H. E. Smith, W. J. McDonald, and L. C. Pratt of the U. S. Forest Service in Alaska, for their cooperation in this work, particularly in the procurement of test material.

[2] Maintained by the U. S. Department of Agriculture at Madison, Wis., in cooperation with the University of Wisconsin.

vided as follows: Tongass National Forest, 16,547,000; Chugach National Forest, 4,800,000.

The Chugach and Tongass National Forests are under the administration of the Forest Service, United States Department of Agriculture, in much the same manner as the national forests in the States. Most national-forest business is handled locally by resident officers. The chief administrative officer is the regional forester, with headquarters at Juneau.

The remaining forest-covered land, largely the interior forest, is on the unreserved public domain under the administration of the General Land Office, United States Department of the Interior. Probably not over 5,000 acres are private forest lands (*24*).[3]

## NATIONAL-FOREST POLICY

The management policy for the Alaska national forests has as its objective the providing of a continuous and adequate supply of timber for the present and future wood-using industries of the region. It is hoped that such industries will in turn foster the permanent development of the Territory, and permit a sustained contribution to the Nation's supply of timber products. The objective, of course, includes the furnishing of a permanent and convenient supply of timber for local consumption.

Of the two national forests, the Tongass shows the most immediate promise of active development. It has, after examination and careful study, been divided into pulp-timber allotments, local-use allotments, and general-use areas.

Timber sales are made with the understanding that the wood is to be used for primary manufacture within the Territory and is not to be exported in the form of logs, cordwood, or other raw products, except in individual cases to permit more complete utilization.

## FOREST TYPES

The Alaska forests are of two distinct kinds; the coastal forests and the interior forests. (Fig. 1.) Because of its higher density of stand and its accessibility, the coastal type, as found in the national forests, is of the greater commercial importance, and is the principal source of material under consideration in this bulletin.

## COASTAL FORESTS

### TONGASS NATIONAL FOREST

The coastal forests of southern Alaska, to as far north as Cook Inlet, are of luxuriant growth and may be regarded as an extension of the forests occurring in the Pacific Northwest. The Alaska forests reach their best development in the islands and in the narrow strip of mainland extending for a distance of about 400 miles along the west side of British Columbia. (Pl. 1.) The forest floor in this region, strewn with quantities of decaying down timber, is generally covered with a heavy layer of moss, often 6 inches or more in thickness. The ground surface is rough, for the top soil, though rich, is relatively shallow and bedrock is exposed in many places.

[3] Italic numbers in parentheses refer to Literature Cited, p. 78.

Heintzleman (*10, p. 7–8*) described the forests in part, as follows:

As found in southeastern Alaska, the coast forest is predominantly a mixed stand of western hemlock and Sitka spruce. [Pl. 2.] In many places western red cedar and Alaska cedar are associated with the predominant species in small proportions. Any one of these four species may be found occasionally in a pure stand of small extent. The forests have an almost tropical density of trees and underbrush. In the usual mixed stand hemlock with some cedar forms a dense main cover, and this is overtopped by the more light-demanding spruce, which occurs singly or in small groups. Small bushy saplings of the shade-resistant hemlock and cedars, various species of blueberry (Vaccinium), and devil-club (*Echinopanax horrida*), and other shrubs form a dense understory. * * * [Pl. 3, A.]

The stands of timber are even-aged; many age classes are represented in the forest as a whole; and the stands of the older age classes are greatly in the majority, perhaps three-fourths of the commercial timber of the region being mature and overmature. The even-aged stands are characteristic of

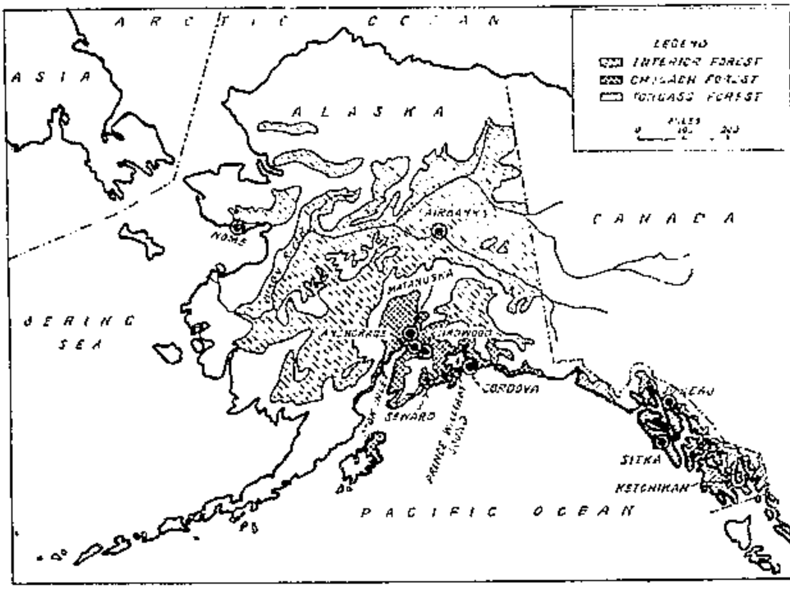


FIGURE 1.—Location of the forests of Alaska

western hemlock and Sitka spruce; the great number of age classes and the preponderance of old timber are to be expected in an extensive virgin forest.

The average stand per acre for the commercial forests as a whole is about 25,000 board feet, but the individual logging units vary widely from this average. A volume of 30,000 to 40,000 board feet per acre is common on many extensive areas, and 50,000 board feet or more per acre frequently occurs on small units. The majority of the merchantable trees are from 2 to 4 feet in diameter and from 90 to 140 feet in height.

The forest cover extends from the edge of tidewater [Pl. 3, C] to an altitudinal limit of about 2,750 feet in the southern part of the region and 2,000 feet in the northern sections. At an elevation of about 1,500 feet the commercial timber gives way to stands of dwarfed, limby trees, which are designated "subalpine" and classified as noncommercial. Because of the prevailing steep slopes the commercial forests form relatively narrow bands along the shore lines of the mainland and islands, rarely extending inland more than 5 miles, except along the valleys of the few large streams.

It is estimated that 75 per cent of the commercial timber of the Tongass National Forest lies within 2½ miles of tidewater.

The forests of commercial value are broken into large blocks by frequent extensive noncommercial areas of "scrub," as the open stands of somewhat dwarfed timber are called, and by muskegs of peat which carry only isolated small trees.

Trees with dead spike tops are a conspicuous feature of the noncommercial scrub areas and of the cedar areas. Spike-topped individuals, so decadent as to be classed as unmerchantable, are fairly prevalent also in the overmature hemlock-spruce stands, but their effect in depreciating the value of these stands is likely to be overestimated. They form a relatively small percentage of the timber, which as a whole is of good quality. Only a few spike tops occur in the extensive hemlock-spruce area of mature timber and of piling-size young timber.

Commercial timber of the principal species in the Tongass National Forest is conservatively estimated to occur by volume in the following amounts: Western hemlock, 74 per cent; Sitka spruce, 20 per cent; western red cedar, 3 per cent; and Alaska cedar, 3 per cent. The total stand of saw timber in this forest is about 78,500,000,000 feet, board measure. The character of the stand, distance from markets, and availability of water power favor the development of pulp and paper manufacture as the principal utilization, but lumber and other products will always be of importance, particularly in meeting the local needs and supplying local industry. At the same time, lumber of the more valuable kinds and grades should furnish an important item of export.

### CHUGACH NATIONAL FOREST

The northern section of the coastal forest includes the important timbered areas extending from the Prince William Sound region to Cook Inlet. Practically all of the merchantable timber in this section is included within the Chugach National Forest. This forest also includes a small amount of the type of timber found in the interior of Alaska as represented by white spruce and Alaska white birch, which reaches tidewater at the head of Cook Inlet. The forest is quite similar to that of southeastern Alaska, except that no red cedar is found, some additional species are present, and the trees are smaller and on the whole contain less clear lumber.

The principal species in the Chugach National Forest occur in the following percentages: Western hemlock, 65 per cent; Sitka spruce, 22 per cent; white spruce, 11 per cent; cottonwood, 1 per cent; Alaska white birch, 1 per cent (*9*). Some mountain hemlock also is to be found. The total stand of the Chugach National Forest is approximately 6,260,000,000 feet, board measure (*20*).

Considerable quantities of timber are cut for local use, which includes sales of ties and lumber for the two railroads which touch this forest. Because of distance from market no lumber exports are at present made from this region, although it is possible that a demand will develop for the hardwoods, particularly birch. As is the case with the Tongass National Forest, the timber is also suitable for pulp and paper purposes.

## INTERIOR FORESTS

The forests of interior Alaska are confined chiefly to the river basins and are of the woodland type, very slow in growth and very light in stand. While of great local value, they can not compare in commercial importance to the forests of the coastal type.

The interior forests have received so little study and are distributed over such large areas that no close estimate can be made of their extent. They are on the unreserved public domain of the United States and in general have had but little, if any, fire protection (*8*). Millions of acres have been burned within recent years. The area of the interior forests has been conservatively estimated at 50,000,000 acres, bearing at least 10 cords per acre, which gives a total volume of not less than 500,000,000 cords. It is unlikely that much of this timber will ever reach the general market, but it has high potential value for local use in connection with the development of the mining and agricultural resources of the vast region over which it occurs.

The principal tree species found in the interior forests are white spruce (pl. 4, A), Alaska white birch (pl. 4, B), Kenai birch, balsam poplar, aspen, black spruce, and tamarack. Of these white spruce is the most important (pl. 5, A), although Alaska white birch comprises a large percentage of the stand, and in some places occurs in almost pure stands. Balsam poplar and aspen (pl. 5, B) are found mainly along the streams. Black spruce frequents the swampy areas and is of comparatively little importance.

### TIMBER PRODUCTION, EXPORT, AND YIELD

For the year 1929, the timber cut on the two national forests of Alaska amounted to 47,462,000 feet, board measure, with a stumpage value of $71,409. In 1929, 2,405,000 board feet of " wood, timber, and lumber," valued at $140,031, were shipped to other parts of the United States; and a total of 163,251 board feet of sawed lumber, valued at $4,738, were shipped to foreign countries (*23*).

The studies of yield have not progressed far enough to indicate definitely the amount of timber that can be produced in a second crop in a given number of years. However, sufficient has been done in the case of the Tongass National Forest to indicate that in southeastern Alaska the rotation for pulpwood is likely to be between 85 and 100 years, and that the crop produced in this period will have a volume per acre at least twice the average volume now found in the virgin commercial forest. Allowing 90 years as a rotation period for pulpwood, and assuming the present virgin timber to be entirely cut in this period, approximately 1,500,000 cords of wood of 600 board feet each can be removed from the Tongass National Forest yearly in this period. This output is sufficient to produce not less than 1,000,000 tons of newsprint a year. As the new crop of timber in which cutting will begin after 90 years will have at least twice the volume per acre of the virgin stand, a plan of forest management based on a sustained yield of 1,500,000 cords of pulpwood should prove to be conservative (*10*).

## DESCRIPTION OF SPECIES

A general description of the characteristics, range, supply, production, properties, and uses of each of the Alaska species [4] is presented. In referring to the various physical and mechanical properties, a graduated set of descriptive terms, each corresponding to a

[4] The names of species appearing in this bulletin are the standard common names given in Check List of the Forest Trees of the United States, Their Names and Ranges (*18*).

certain numerical range of the property under consideration, is used to permit a more accurate evaluation of the property, and to afford a uniform basis of comparison between species. These terms are used in connection with the following properties: Weight, strength in bending and compression, stiffness, hardness, shock resistance, and shrinkage. Descriptive terms are also given for ease of kiln drying, ability to stay in place, workability, nail-holding ability, ease of gluing, and resistance to decay, although for these properties sufficiently complete information is not available on most species to permit as accurate a classification as is desired.

The complete set of terms for the above properties, applicable to all species, is presented in Table 1. An examination of this table will give a background for appraising the relationship of each term to that of the others. The index figures in column 1 of Table 1 are suggested as a numerical scale for expressing the degree to which a species possesses each of the various properties, and thus might be employed in lieu of the corresponding descriptive term. In the species descriptions which follow, however, only the descriptive terms are used. The classification limits given in Table 1 apply to specific gravity only although other classification limits have been set up and used for shrinkage and the mechanical properties.

TABLE 1.—*Comparative terms used in describing wood properties*

| Index figure | Specific gravity or weight | | Descriptive terms for— | |
|---|---|---|---|---|
| | Classification limits (specific gravity) | Descriptive terms | Strength in bending and compression | Stiffness |
| 1 | Below 0.20 | Extremely light | Extremely weak | Extremely limber. |
| 2 | From 0.20 to 0.25 | Exceedingly light | Exceedingly weak | Exceedingly limber. |
| 3 | From 0.25 to 0.30 | Very light | Very weak | Very limber. |
| 4 | From 0.30 to 0.36 | Light | Weak | Limber. |
| 5 | From 0.36 to 0.42 | Moderately light | Moderately weak | Moderately limber. |
| 6 | From 0.42 to 0.50 | Moderately heavy | Moderately strong | Moderately stiff. |
| 7 | From 0.50 to 0.60 | Heavy | Strong | Stiff. |
| 8 | From 0.60 to 0.72 | Very heavy | Very strong | Very stiff. |
| 9 | From 0.72 to 0.86 | Exceedingly heavy | Exceedingly strong | Exceedingly stiff. |
| 10 | Above 0.86 | Extremely heavy | Extremely strong | Extremely stiff. |

| Index figure | Descriptive terms for— | | |
|---|---|---|---|
| | Hardness | Shock resistance | Shrinkage |
| 1 | Extremely soft | Extremely low | Extremely small. |
| 2 | Exceedingly soft | Exceedingly low | Exceedingly small. |
| 3 | Very soft | Very low | Very small. |
| 4 | Soft | Low | Small. |
| 5 | Moderately soft | Moderately low | Moderately small. |
| 6 | Moderately hard | Moderately high | Moderately large. |
| 7 | Hard | High | Large. |
| 8 | Very hard | Very high | Very large. |
| 9 | Exceedingly hard | Exceedingly high | Exceedingly large. |
| 10 | Extremely hard | Extremely high | Extremely large. |

| Index figure | Descriptive terms for— | | | | | |
|---|---|---|---|---|---|---|
| | Ease of kiln drying | Ability to stay in place | Workability | Nail-holding ability | Ease of gluing | Resistance to decay |
| 2 | Very easy | Very good | Very easy | Very high | Very easy | Very high. |
| 4 | Easy | Good | Easy | High | Easy | High. |
| 6 | Moderate | Moderate | Moderate | Moderate | Moderate | Moderate. |
| 8 | Difficult | Poor | Difficult | Low | Difficult | Low. |
| 10 | Very difficult | Very poor | Very difficult | Very low | Very difficult | Very low. |

## ALASKA WHITE BIRCH

(*Betula neoalaskana* Sargent)

### OTHER NAMES

Alaska white birch is also known as Alaska birch, white birch, and yellow birch. It should not, however, be confused with paper birch (*Betula papyrifera* Marshall) which is often called white birch, or with *B. lutea* Michaux which is officially called yellow birch.

### GENERAL DESCRIPTION

Alaska white birch is one of the few hardwood species found in Alaska, and has the densest wood of the Alaska tree species. The heartwood is light reddish brown; the moderately wide sapwood is practically white. The wood has a fine even texture, and finishes well. The trees are of relatively slow growth; the test material from 10 trees of one site near Whitney averaged 29 rings per inch. (Pl. 6, A.)

### DISTRIBUTION AND GROWTH

The general range of Alaska white birch is from the Saskatchewan Valley to the Yukon River Valley (*18*).

The most important birch forests in Alaska are those of the upper Cook Inlet region. The Alaska white birch-white spruce type is the typical forest of this region (7). It occupies the rolling bench land above the bottoms and extends up the lower slopes of the foothills to an elevation of about 800 feet. Here the Alaska white birch is associated with white spruce (*Picea glauca* (Moench) Voss), Kenai birch (*Betula kenaica* Evans), and aspen (*Populus tremuloides*). The trees at an age of from 100 to 130 years on the more favorable sites attain a height of 60 to 70 feet and a diameter of 10 to 14 inches, although the average diameter breast high is from 8 to 10 inches. Occasionally a diameter of 24 inches is reached.

In trees over 8 inches diameter breast high, the heartwood for varying distances from the pith is commonly stained, and frequently advance stages of decay are present.

### SUPPLY

No intensive cruise has been made as a basis for accurately determining the amount of Alaska white birch, but the total stand in the upper Cook Inlet region is roughly estimated as about 2,000,000,000 feet, board measure.

### PRODUCTION

In the vicinity of the larger cities, like Anchorage, thousands of cords of Alaska birch have been cut for fuel. Prior to the construction of the Alaska Railroad, when wood was the only available fuel, the rate of cutting was higher than it is at present. No figures are available on the total or present yearly volume of the cut. Industrial uses for the wood have not yet been developed.

### PROPERTIES

The wood of Alaska white birch is moderately heavy, moderately strong in bending and compression, stiff, moderately hard, high in shock resistance, and has a very large shrinkage. It resembles paper birch more closely in its mechanical properties than any of the other birches. Less definite information is available on certain of the other properties. Judging from observations on the material tested for strength, Alaska white birch would be expected to rank as moderate in ease of kiln drying, good in ability to stay in place, easy to work, high in nail-holding ability, difficult to glue, and low in resistance to decay. Like the other species of birch, it is diffuse-porous in structure. It has a fine, even texture, and should take finishes and stains satisfactorily.

#### PRINCIPAL USES

Alaska white birch has so far been used but little except locally for fuel and mine props. Since it is similar in structure to the other birches and falls between paper birch (*Betula papyrifera*) and yellow birch (*B. lutea*) in its mechanical properties, it would seem safe to infer that sound material of Alaska white birch would be adaptable to many of the same uses. Drake (7) reports that tests were made of the possibilities of Alaska white birch for shoe pegs, spools, and bobbins, and it was found highly satisfactory; also that furniture made of this birch has a pleasing appearance and when stained resembles mahogany.

The birches of the United States are used for planing-mill products, furniture, musical instruments, woodenware and novelties, kitchen ware, athletic goods, broom and mop handles, brush and tool handles, fruit packages, boxes and crates, baskets, shoe lasts, clothespins, bungs, paper-roll plugs, skewers, golf tees, arrow shafts, spools, and dowels. Paper birch is used for turned products, principally spools, novelties, toys, toothpicks, and shoe pegs. Birch is also one of the principal woods used for hardwood distillation in the production of wood alcohol, acetate of lime, and charcoal.

## ALASKA CEDAR

(*Chamaecyparis nootkatensis* (Lambert) Sudworth)

#### OTHER NAMES

Alaska cedar is also known as yellow cedar (Oregon), Sitka cypress (Oregon, California), yellow cypress (Oregon, Washington), Nootka cypress (California), Nootka sound cypress (England), Alaska sound cypress (California), Alaska cypress (California), and Alaska yellow cedar (trade).

#### GENERAL DESCRIPTION

Alaska cedar is a little-known softwood which is closely related botanically to southern white cedar (*Chamaecyparis thyoides* (Linnaeus) Britton, Sterns, and Poggenberg) and Port Oxford cedar (*C. lawsoniana* (A. Murray) Parlatore). The heartwood is a bright clear yellow; the sapwood is noticeably lighter in color, particularly when green, and forms but a comparatively narrow band. The wood contains a natural volatile oil, which gives it a distinctive odor and seems to add a slight gloss to a newly cut smooth side-grain surface. It has a fine, even texture, and is relatively straight-

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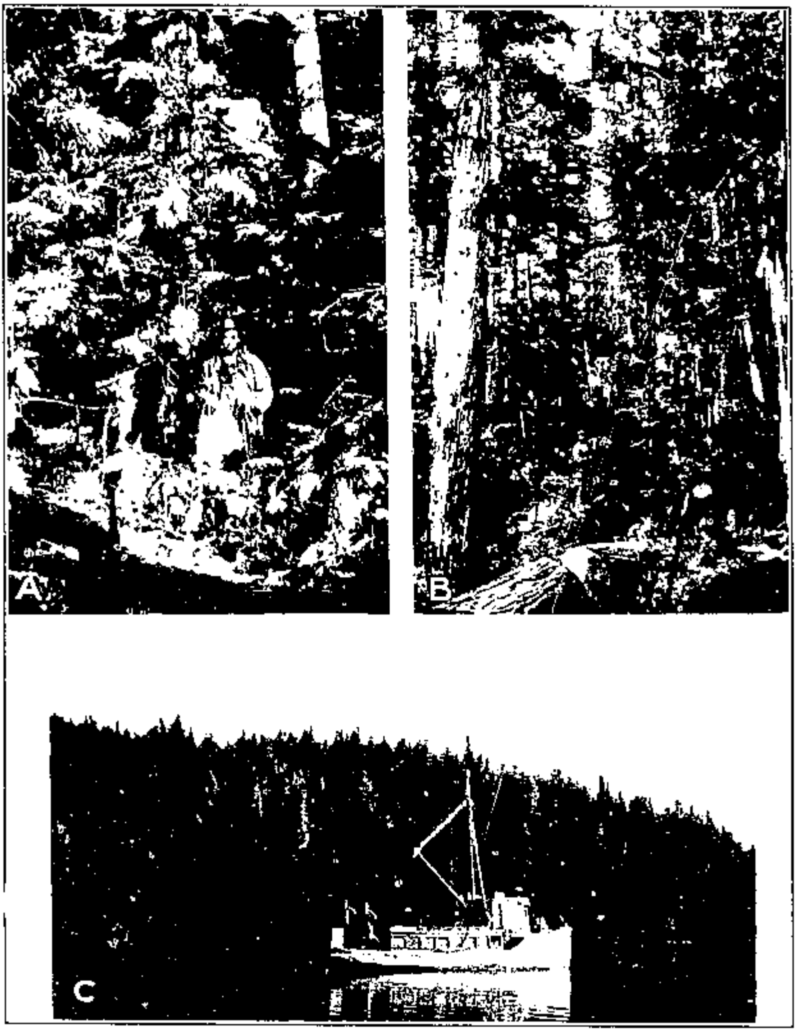
DENSE FORESTS OF HEMLOCK AND SPRUCE GROW ALONG THE SHORE LINES OF THE VAST NETWORK OF PROTECTED WATERWAYS IN SOUTHEASTERN ALASKA

M 461 F

IMMATURE STAND OF SITKA SPRUCE AND WESTERN HEMLOCK IN SOUTHEASTERN ALASKA

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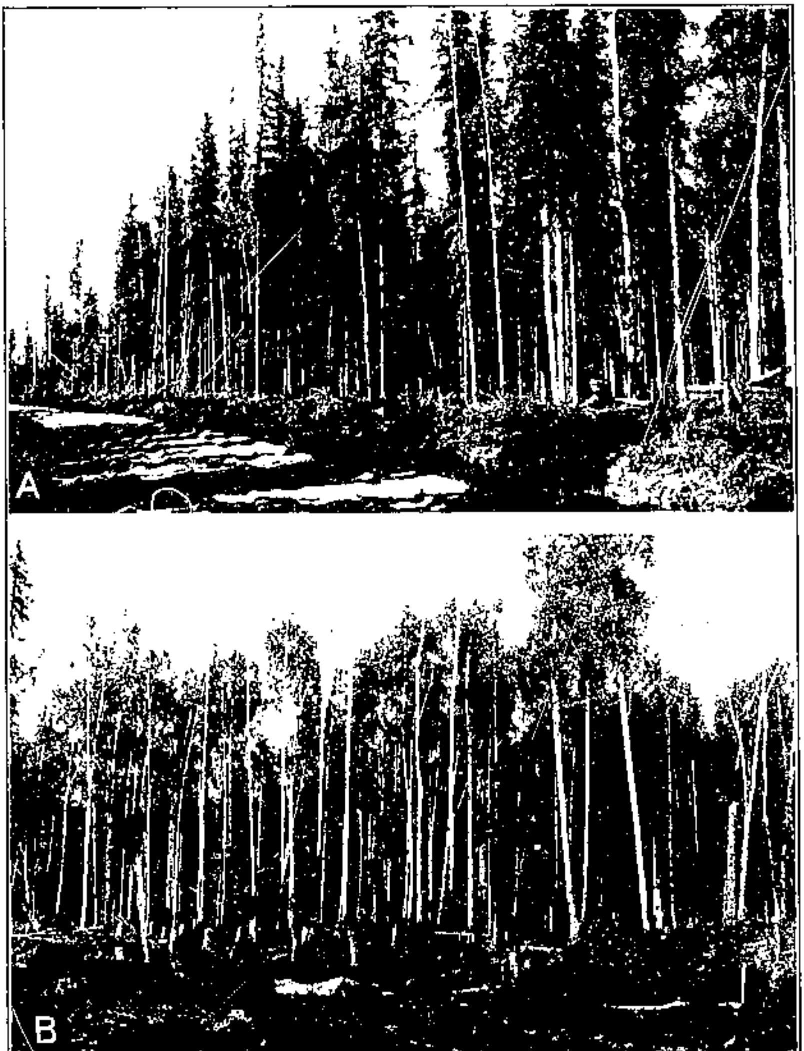
A, Typical view of the dense understory in the Tongass National Forest; B, western red cedar in the Tongass National Forest; C, waterways furnish ready access to the principal forest stands of Alaska, making expensive logging railroads unnecessary.


A, White spruce near Fairbanks in interior Alaska; B, stand of pure white birch in interior Alaska





A, White spruce and white birch in interior Alaska; B, forest of white birch, balsam poplar, and aspen in interior Alaska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A, Alaska white birch selected for test at the Forest Products Laboratory; B, western hemlock from the Chugach National Forest selected for test at the Forest Products Laboratory. These logs are from representative mature trees grained. The virgin trees are of slow growth, as shown by the average of 23 rings per inch for the specimens tested from Alaska.

### DISTRIBUTION AND GROWTH

Alaska cedar grows in the Pacific coast region of North America from southwestern Alaska southward to northern Oregon. It is widely distributed in southeastern Alaska and reaches the best development at elevations between 500 and 1,200 feet. It generally reaches a height of about 80 feet and a diameter of 2 to 3 feet. Trees 4 to 5 feet in diameter and 100 feet high are common (*19*). Trees 15 to 20 inches in diameter are generally 200 to 300 years old.

Alaska cedar grows in southeastern Alaska in combination with western red cedar, in pure stands and as scattered trees in the spruce-hemlock forests. The best trees are found in the spruce-hemlock forests, and are logged in connection with saw timber and piling operations. To obtain any considerable quantity, however, it is necessary to log the cedar stands which are usually in patches of one-half million feet or less. These patches are most frequently found on steep slopes some distance inland from tidewater so that the cost of logging is consequently high. While Alaska cedar lumber is very resistant to decay, the overmature trees are inclined to be defective, many containing as much as 25 to 30 per cent rot at the center (*9*).

### SUPPLY

Estimates of the total stand of Alaska cedar are lacking. A rough estimate of the total stand in Alaska, British Columbia, Washington, and Oregon is about 10,000,000,000 board feet, with about 2,500,000,000 board feet in Alaska.

### PRODUCTION

No definite figures are available on the amount of Alaska cedar cut in Alaska. The cut of cedar in Washington in 1928 was 151,970,000 board feet. Under "cedar" is included western red cedar, Alaska cedar, and several other species. It is estimated that between 5 and 10 per cent of this cut in Washington, roughly 10,000,000 board feet, was Alaska cedar. The production of lumber from Alaska cedar may be expected to increase considerably.

### PROPERTIES

The wood of Alaska cedar is moderately light in weight, moderately weak in bending and compression, moderately stiff, moderately hard, moderately high in shock resistance, and has a small shrinkage. Less definite information is available on certain of the other properties. On the basis of approximate classifications Alaska cedar is estimated to rank as very easy to kiln dry, good in ability to stay in place, very easy to work, low in nail-holding ability, easy to glue, and very high in resistance to decay. In resistance to decay, the heartwood of Alaska cedar ranks with that of Port Orford cedar, western red cedar, southern cypress, and redwood. Alaska cedar and Port Orford cedar differ from western red cedar and most other species in that the spring wood is firmer and consequently they have a much more uniform texture which makes them admirably adapted for such purposes as carving, veneers, battery separators, and where smooth wear is desirable. Alaska cedar is reputed locally not to hold paint well, particularly on boat hulls, but experiments on dry samples at the Forest Products Laboratory have not shown any unusual difficulty. Like other species, it would not be expected to take paint well if not well dried, and it is possible that any difficulty encountered may be due to this cause.

The static and impact bending specimens of Alaska cedar exhibited during test an evidence of toughness not usually found in a softwood species of its density. Some of the 2 by 2 by 30-inch bending specimens when green deflected 6 inches without complete failure, the compression tending to distribute itself as in some of the hardwoods, rather than sharply localizing as is more characteristic of the softwoods. This indicates that Alaska cedar may be adapted to uses where bending to form is required, and its properties are otherwise suitable, but additional tests would be necessary to determine whether or not this is a species characteristic, or merely of occasional occurrence. The behavior observed is contrary to reports that Alaska cedar is inclined to be brash.

#### PRINCIPAL USES

A large part of the cut of Alaska cedar is used locally for poles, interior finish, furniture, small boat hulls, cabinetwork, and novelties. It is considered valuable for patterns, toys, turned articles, chests, battery boxes, and battery separators. It is also reported as used for picture frames, brush backs, venetian blinds, curtain poles, sash, doors, stair work, millwork, and store and office fixtures. A small amount is shipped to Japan in log form. A specialty use of Alaska cedar is for patterns. It has long been the customary wood of the Alaska Indians for canoe paddles.

## WESTERN RED CEDAR

(*Thuja plicata* D. Don)

#### OTHER NAMES

Western red cedar is also known as red cedar (Idaho, Oregon, Washington, Montana, British Columbia), canoe cedar (Oregon, Washington), arborvitae (California), shinglewood (Idaho), gigantic cedar (California), cedar (Oregon, Montana, Idaho, Pacific coast trade), gigantic red cedar (California literature), western cedar, Washington red cedar (trade), Washington cedar (trade), Idaho cedar (trade), Oregon cedar (trade), California cedar (trade), British Columbia cedar (trade), Pacific arborvitae (literature), western arborvitae (literature), red cedar pine (trade), Lobb's arborvitae (England), Pacific red cedar (California literature), and giant arborvitae (literature and horticulture).

#### GENERAL DESCRIPTION

Western red cedar is a moderately slow-growing, long-lived tree that is closely related to the well-known northern white cedar

(*Thuja occidentalis* Linnaeus). The heartwood is a reddish brown; the narrow sapwood is white. The reddish color of the heartwood is thought to be due partly to certain extractives, which appear to be responsible for the high resistance of the wood to decay. The wood has a distinctive odor characteristic of the cedars. The narrow summer-wood bands are distinctly darker and harder than the adjacent spring wood. The wood has a fine, moderately even texture.

#### DISTRIBUTION AND GROWTH

Western red cedar grows principally in a belt along the western coast of North America, extending from the southern half of southeastern Alaska to northern California. In Alaska it reaches its best development below an elevation of 500 feet.

Western red cedar has a characteristic buttressed base, tapering trunk, and conical crown; it sometimes grows in small pure stands but generally in mixture with other species, by which it is frequently overtopped. The tree is capable of enduring shade but under such conditions the rate of growth is reduced. Large trees in southeastern Alaska are from 100 to 130 feet high and 3 to 6 feet in diameter. The mature trees are limby, heavily tapered, and are subject to severe heart rot, but trees of pole size are well formed and sound. In Alaska the best trees are those occurring as scattered individuals or in small groups (pl. 3, B) in stands of hemlock and spruce. The trees of the pure cedar type of forest average somewhat poorer in quality but are sufficiently good to be classed as merchantable. The open stands of cedar and other species found so commonly on the swamp soils are uniformly poor in quality and are not considered merchantable, the trees being short, limby, and defective.

#### SUPPLY

The stand of western red cedar in the United States is estimated at 53,348,000,000 board feet. Of this total approximately 49,000,000,000 board feet is in the Pacific coast region and the remainder in the Rocky Mountain region (*20*). The stand in Alaska is estimated at 2,350,000,000 board feet (*10*).

#### PRODUCTION

The cut of western red cedar lumber in the United States, exclusive of Alaska, in 1928 is estimated at about 200,000,000 board feet. In 1928 a total of about 5,342,000,000 shingles, equivalent to 534,000,000 board feet, were produced in the United States proper (*21*). It is probable that at least an additional 100,000,000 board feet is cut for poles, posts, and piling. The cut of western red cedar in Alaska is, however, still very small.

#### PROPERTIES

The wood of western red cedar is light in weight, weak in bending and compression, moderately limber, moderately soft, low in shock resistance, and has a very small shrinkage. On a basis of approximate classification, western red cedar is estimated to rank as moderate in case of kiln drying, good in ability to stay in place, very easy to work, very low in nail-holding ability, moderate in ease of gluing, and very high in decay resistance. In decay resistance, the heartwood ranks with that of Alaska cedar, Port Orford cedar, redwood, and southern cypress.

#### PRINCIPAL USES

Western red cedar is used principally for shingles, lumber, poles, posts, and piling. About nine-tenths of all the shingles manufactured in the United States are western red cedar. The decay resistance, ease of working, and lightness of the wood make it highly satisfactory for this purpose. Considerable quantities of western red cedar lumber are used for siding, tank stock, boat building, porch columns, hothouse construction, and for other purposes where decay resistence and ease of working or lightness are especially desirable. Western red cedar is also reported as used for beehives, finish, trim, boxes, carving, caskets, ceiling, furniture parts, incubators and brooders, moldings, patterns, pencils, picture frames, window frames and sash, light cooperage, ice-cream tubs, core stock, drafting boards, fixtures, and fishing-net floats.

Western red cedar poles on account of their desirable properties and form and size are shipped from various northwestern States to nearly all parts of the United States. For posts the wood is widely used; for piling it is used less, as it is liable to crush under the blows of the pile driver. Although the heartwood of western red cedar is very decay resistant it is nevertheless good practice to apply a preservative to posts and poles, particularly to prolong the life of the nondurable sapwood. The western red cedar of Alaska will probably be utilized in fairly large quantities after the depletion of the virgin stands in Washington and British Columbia has progressed farther.

### NORTHERN BLACK COTTONWOOD

(*Populus trichocarpa hastata* Henry)

#### OTHER NAMES

Northern black cottonwood is also known as Cottonwood (Oregon), balsam cottonwood, balm (Oregon), and black balsam poplar.

#### GENERAL DESCRIPTION

Northern black cottonwood is a lightweight hardwood (broad-leaved) species of the Pacific Northwest, which is closely related to the aspens and poplars. The wood is grayish white to light brown. It is diffuse porous, and has a fine, even texture. The annual rings are scarcely noticeable. The sapwood is wide and not clearly defined, but merges gradually into the heartwood. Northern black cottonwood is a tree of normally rapid growth, but in maturity and overmaturity the rate of growth is much slower.

#### DISTRIBUTION AND GROWTH

Northern black cottonwood occurs from southern Alaska to California and extends inland as far as in western Montana. It grows best at lower levels on river bottoms and sand bars. In Alaska it occurs in quantity only on the valley floors of a few large mainland streams, principally the Stikine and Taku Rivers, where mature trees reach an average diameter of 3 feet and a height of 80 to 90 feet. Though black-heart and black knots are common in mature trees, extensive areas of immature trees of excellent quality are found.

#### SUPPLY

The total stand in the continental United States of the three cottonwoods—eastern, swamp, and northern black—of saw-timber size is estimated at 7,500,000,000 board feet, of which black cottonwood comprises about 1,500,000,000 board feet. The supply in southeastern Alaska is relatively small, although exact figures are lacking.

#### PRODUCTION

The term "cottonwood" as used in the lumber-cut statistics of the United States includes the eastern, swamp, and black cottonwoods and in addition the aspens and balsam poplar. It is difficult, therefore, to give any very close figures for northern black cottonwood. The total cut of black cottonwood lumber in the United States, including Alaska, is relatively small, being estimated roughly as 2,500,000 board feet in 1928. The cut in Alaska has so far been negligible.

#### PROPERTIES

Northern black cottonwood is light in weight, weak in bending and compression, moderately limber, soft, moderately low in shock resistance, and has a moderately large shrinkage. It is estimated to rank as moderate in case of kiln drying, poor in ability to stay in place, easy to work, very low in nail-holding ability, easy to glue, and very low in resistance to decay.

#### PRINCIPAL USES

Lumber cut from eastern, swamp, and black cottonwood is used principally for boxes and crates. Although northern black cottonwood is not high in nail holding, its light weight and ability to take nails without splitting combined with a good color for stenciling and lack of odor make it suitable for a wide variety of boxes. Over half of the cottonwood lumber goes into boxes. Other uses reported for cottonwood lumber include automobile-body work, planing-mill products, agricultural implements, refrigerators, woodenware, laundry appliances, kitchen cabinets, trunks, furniture, and millwork.

Cottonwood veneer in the form of plywood is widely used in furniture and musical instruments and for similar purposes where thin panels are needed.

Other important cottonwood products are paper (generally high-grade book paper made by the soda process) and excelsior. The light color, fairly straight grain, and uniform texture of cottonwood make it well fitted for excelsior manufacture.

## MOUNTAIN HEMLOCK

(*Tsuga mertensiana* (Bongard) Sargent)

### OTHER NAMES

Mountain hemlock is also known as Williamson's spruce (California), weeping spruce (California), alpine spruce (California), hemlock spruce (California), Patton's spruce, alpine western spruce (literature), black hemlock (literature), Patton's hemlock (Washington), and alpine hemlock (Alaska, Washington, California).

### GENERAL DESCRIPTION

Mountain hemlock is a near relative of western hemlock (*Tsuga heterophylla* (Rafinesque) Sargent), and is somewhat similar in appearance, but the tree is smaller and the trunk has more taper and is less clear of branches and knots. The heartwood is a pale reddish brown; the sapwood is moderately thin. The summer wood is quite pronounced, and is distinguishable from the lighter appearing spring wood. The wood has a moderately fine and moderately even texture. The mountain hemlock from Alaska tested at the Forest Products Laboratory averaged 29 growth rings per inch.

### DISTRIBUTION AND GROWTH

Mountain hemlock grows in the mountains of the Pacific coast region of North America from southern Alaska to the high Sierras of California, extending as far eastward as Idaho and Montana. It is mainly a timber-line tree, but in Alaska it also grows near sea level on rocky sites. Mountain hemlock at its best occasionally reaches a height of 100 to 125 feet and a diameter of 30 to 40 inches. Such trees, however, are uncommon. At the other extreme, it sprawls among the rocks to but a few feet in height on bleak windswept crests.

### SUPPLY AND PRODUCTION

Because mountain hemlock is mainly confined to the higher altitudes, it is largely inaccessible. The supply is relatively limited and, as a whole the production is small, and the species is not important commercially. There are places, however, particularly in the Chugach National Forest, where the species is found near sea level, and as a result it has been cut with western hemlock and spruce for ties used for the Alaska Railroad.

### PROPERTIES

Mountain hemlock is one of the few species in which shrinkage and the principal strength properties all closely and uniformly correspond to what would be expected for its density. Most species have at least one property which differs from the general law. The wood of mountain hemlock is slightly above the median of the different species, and may be classed as moderate in its properties. Hence it is moderately heavy, moderately strong in bending and compression, moderately stiff, moderately hard, moderately high in shock resistance, and has a moderately large shrinkage. Experience with this wood is very limited. A few samples were machined satisfactorily and finished smoothly.

#### PRINCIPAL USES

Mountain hemlock at present is but little used and is not important commercially. Judging from its density, strength properties, and appearance, it would seem to be suitable for such uses as those for which western hemlock is employed.

## WESTERN HEMLOCK

(*Tsuga heterophylla* (Rafinesque) Sargent)

#### OTHER NAMES

Western hemlock is also known as hemlock spruce (California), hemlock (Alaska, Oregon, Idaho, Washington, Montana, and trade), western hemlock spruce (literature), California hemlock spruce, western hemlock fir (England), Prince Alberts fir (England), Alaska pine (northwestern lumbermen), west coast hemlock (trade), Pacific hemlock (trade), Pacific coast hemlock (trade), and Pacific (western) hemlock (trade).

#### GENERAL DESCRIPTION

Western hemlock is related botanically to eastern hemlock (*Tsuga canadensis* (Linnaeus) Carriere), but differs from it in appearance, in characteristic defects, and, to a lesser extent, in its mechanical properties. The general color is a pale reddish brown, with the sapwood very similar and generally not easily distinguishable from the heartwood when dry. The summer-wood bands, although marked, do not contrast decidedly with the lighter-colored spring wood. The contrast is less pronounced than in Douglas fir and southern yellow pine, but more so than in Sitka spruce and northern white pine. The wood has a moderately fine and moderately even texture and is nonresinous. It has a sour odor when green, but is odorless and tasteless when dry. The annual growth rings are usually comparatively uniform in width. Western hemlock from Alaska, however, appears to have a somewhat slower average growth than that from Washington and Oregon, and to the extent that this is true the Alaska-grown material should exhibit a more even texture.

#### DISTRIBUTION AND GROWTH

Western hemlock grows in the Pacific coast region of North America from southern Alaska to northern California and western Montana. In Alaska the stands of mature trees of about 200 to 250 years in age range from 2 to 4 feet in diameter and are about 150 feet in height. (Pl. 6, B.) The tree has a long, slender bole, and a short narrow crown. The trees are clear of branches well to the top. They are commonly sound when young, but when mature and overmature at diameters of 3 to 3½ feet, heart rot is very prevalent; many of these old overmature trees are so defective as to be classed as unmerchantable. The stands vary from almost pure to admixtures of Sitka spruce, western red cedar, and Alaska cedar. Western hemlock is the most abundant and important species in Alaska. It reproduces prolifically, grows well on a variety of soils, and is very tolerant of shade. In Alaska, hemlock trees on the poorest sites and occurring as scattered trees in pure spruce stands frequently have deeply fluted lower trunks. The lumber from these fluted trunks often contains many large bark pockets and decay spots. In the commercial forests as a whole, however, fluting is not an important factor.

### SUPPLY

The total stand of western hemlock saw timber in the United States, including Alaska, is about 149,000,000,000 board feet, of which 62,000,000,000 board feet are in Alaska.

### PRODUCTION

The cut of western hemlock lumber in the United States in 1928 was about 1,550,000,000 board feet, and in Alaska 7,853,000 board feet (*21*). The total production of western hemlock for lumber has shown a tenfold increase in the past 20 years. It is expected, however, that the principal future cut of western hemlock in Alaska will be for pulpwood, as the wood is well adapted for that use.

### PROPERTIES

The wood of western hemlock is moderately light in weight, moderately weak in bending and compression, moderately stiff, moderately hard, moderately low in shock resistance, and has a moderately large shrinkage. Less definite information is available on the other properties. Western hemlock is estimated to rank as moderate in ease of kiln drying, moderate in ability to stay in place, moderate in workability, moderate in nail-holding ability, very easy to glue, and very low in resistance to decay. Western hemlock takes paint satisfactorily, being about equal with eastern hemlock and the spruces.

### PRINCIPAL USES

The most important use of western hemlock is for building material, such as common boards and shiplap, sheathing, studding, joists, subfloors, floors, finish, lath, trim, millwork, and many other items. It is also used for shipping containers, cooperage, railway cars, ladders, concrete forms, furniture, veneer, poles, piles, railroad ties, and mine timbers (*12*). Tests by the United States Bureau of Animal Industry indicate that it may be used for butter containers without imparting sufficient woody flavor to be commercially objectionable. Western hemlock has an established high value as a pulpwood, particularly in Alaska, because of the relatively pure stands, and because water power is conveniently available for manufacture.

Hemlock is used extensively as piling for the construction of fish traps, which are operated in the coastal waters of Alaska by the salmon-canning industry. Many of the sticks cut for this purpose are from 90 to 130 feet in length. Hemlock ties are now sawn in quantity by the local mills for use on the Alaska Railroad. Very little hemlock lumber is being cut in Alaska because it can not profitably be shipped to the general market in competition with Puget


M 428 F

A, Mature balsam poplar trees in the Chugach National Forest. This species attains a height of about 100 feet; B, butt log of Sitka spruce from the Tongass National Forest awaiting manufacture at an Alaska sawmill; C, Sitka spruce in the hemlock-spruce type of forest on the southeastern coast of Alaska

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A, A shipment of test material from Alaska being unloaded at the Forest Products Laboratory; B, a Sitka spruce log being marked at the Forest Products Laboratory for sawing into small, clear specimens for mechanical tests; C, method of measuring specimens at the Forest Products Laboratory to determine radial and tangential shrinkage

Sound hemlock. The consumption is increasing, however, as the merits of western hemlock lumber become better known.

## BALSAM POPLAR

(*Populus balsamifera* Linnaeus)

### OTHER NAMES

Balsam poplar is also known as balsam (New Hampshire, New York, Wisconsin, Michigan, Minnesota, Nebraska, Montana, Ohio, Ontario), balm-of-Gilead (Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, New York, Michigan, Nebraska, Minnesota, North Dakota, Ontario), cottonwood (Idaho), poplar (Wisconsin, Minnesota), balsam poplar (New Hampshire, Nebraska, Minnesota), tacamahac (Minnesota), baumier (Quebec), and rough-barked poplar (Hudson Bay region).

### GENERAL DESCRIPTION

Balsam poplar (pl. 7, A) is a hardwood species of light weight, which is closely related botanically to the aspens and cottonwoods. It should not be confused with yellow poplar (*Liriodendron tulipifera* Linnaeus), the well-known species of the eastern United States, to which it bears no botanical relation.

The heartwood of balsam poplar is a light brown; the moderately thick sapwood nearly white. The wood is diffuse porous, and, consequently has a fine, even texture. The tree is normally of rapid growth; the trees collected for test from Girdwood, Alaska, averaged 14 rings per inch.

### DISTRIBUTION AND GROWTH

Balsam poplar grows principally in Alaska and Canada. Its range extends from Alaska to Hudson Bay and Newfoundland and southward to the United States along the Canadian border from Maine to Oregon. It is distinctly a northern tree and parts of its range are characterized by a short growing season and long severe winters; conditions too severe for the existence of most other trees. It is confined mainly to alluvial bottom lands and to the borders of streams and swamps in moist, sandy and gravelly soils. Seeds are abundant and are scattered widely by the wind. The trees secured for test from Girdwood averaged 88 feet in height and ranged from 78 to 98 feet. They averaged 23 inches in diameter and 162 years of age.

### SUPPLY

While the total stand of balsam poplar saw timber (exclusive of pulpwood) in the United States proper is estimated very roughly at 1,250,000,000 board feet, definite estimates are lacking for the Alaska supply. The stand of balsam poplar, if the smaller pulpwood sizes are included, is much less than that of the aspens.

### PRODUCTION

There has been but little demand for balsam poplar in Alaska, and, consequently, the cut has been small. It is estimated that in the United States proper approximately 6,000,000 board feet of balsam poplar lumber has been produced annually during the years 1922 to 1927. Balsam poplar pulp wood is also cut with the cottonwoods and aspens without distinction. The total annual cut of balsam poplar for various purposes, including pulpwood, is estimated roughly at from 12,000,000 to 15,000,000 board feet for 1927.

#### PROPERTIES

The wood of balsam poplar is light in weight, exceedingly weak in bending and compression, limber, soft, low in shock resistance, and has a moderately small shrinkage. It is considered to rank as moderate in ease of kiln drying, poor in ability to stay in place, easy to work, very low in nail-holding ability, easy to glue, and very low in resistance to decay. The wood has excellent pulping qualities and is well suited for paper making both by the sulphite and soda processes.

#### PRINCIPAL USES

Balsam poplar is used principally for box and crate lumber and for pulp wood in the manufacture of paper. A small amount of the lumber goes into the manufacture of containers for druggists' supplies, and some of the high-grade logs are cut into veneer from which various kinds of fruit baskets are made. A small amount of balsam poplar is also used for making excelsior.

### SITKA SPRUCE

(*Picea sitchensis* (Bongard) Carriere)

#### OTHER NAMES

Sitka spruce is also known as tide-land spruce (California, Oregon, Washington), Menzies' spruce, western spruce, great tide-land spruce (California, literature). yellow spruce (trade), western Sitka spruce (trade), silver spruce (trade), Sequoia silver spruce (trade), spruce (trade), and west coast spruce (trade).

#### GENERAL DESCRIPTION

Sitka spruce, while related botanically to the white spruce, so eclipses the latter in size as to make it much more important, commercially. The heartwood is light reddish brown, the sapwood nearly white. The wood is classified as nonporous and has a fine, moderately uneven texture. The tree, except in overmaturity, is of moderately rapid growth in Alaska. The test material from Girdwood averaged 23 rings per inch, and the large trees from near Ketchikan averaged 17.

#### DISTRIBUTION AND GROWTH

Sitka spruce is found along the Pacific coast region from Alaska to northern California, extending inland about 50 miles. It is reported to occur from sea level to as high as 5,000 feet, but it grows mainly at altitudes of less than 1,500 feet. It forms pure forests, but also occurs in mixed stands. In the usual mixed forest the faster-growing and more light-demanding spruces are larger in diameter than the western hemlock with which they are associated and exceed them in height.

The tree is ordinarily 80 to 125 feet high and from 3½ to 6 feet in diameter (*19*). In the Tongass National Forest the average mature tree is about 160 feet high and 5 feet in diameter, but trees with a height of 200 feet and a diameter of 7 feet are common. (Pl. 7, B and C.) The largest known Sitka spruce in Alaska is 14½ feet in diameter at a point 6 feet above the ground (*10*). The trees from which test material from the Tongass National Forest were selected ranged from 4½ feet to 5¾ feet in diameter at the stump, with an average of 5 feet, and from 147 to 228 feet in height, with an average of 197 feet. The oldest tree was 757 years of age; the youngest 248. The trees selected for test from the Chugach National Forest were much smaller, averaging 17 inches in diameter, 80 feet in height, and 203 years of age.

Sitka spruce is commonly sound and straight grained, but on exposed sites is subject to spiral grain. The most common defect of overmature trees is butt rot.

### SUPPLY

The estimated volume of Sitka spruce of commercial size on the Tongass National Forest is 15,800,000,000 feet, board measure (*10*), and on the Chugach National Forest about 1,400,000,000 feet, board measure. Alaska contains about two-fifths of the total supply of Sitka spruce.

### PRODUCTION

Of the 571,917,000 board feet of spruce (all spruces) lumber produced in the United States in 1928, Oregon and Washington furnished over one-half, most of which was Sitka spruce. The production of spruce lumber in Alaska in 1928 was 22,748,000 board feet (*21*). Statistics show exports from Alaska to foreign countries of spruce boards amounting to 2,411,000 board feet in 1928 and 85,000 board feet in 1929.

The export of high-grade spruce lumber from Alaska started during the World War, and since then considerable quantities of clear spruce for airplanes and other special uses have been sent out by the local mills and transhipped through Seattle to North American and to foreign markets. Full cargo shipments of merchantable grade lumber are made at irregular intervals to Atlantic and trans-Pacific ports.

### PROPERTIES

The wood of Sitka spruce is moderately light in weight, moderately weak in bending and compression, moderately stiff, moderately soft, moderately low in shock resistance, and has a moderately large shrinkage. It may be classed as easy to kiln-dry, good in ability to stay in place, easy to work, low in nail-holding ability, very easy to glue, and very low in resistance to decay. It is a nonporous wood and has a fine, moderately even texture.

Knots, when present, are usually sound. The wood contains small resin ducts, the direction of which on a flat-sawn surface indicates the direction of the grain, and is a useful guide in inspection for such uses as airplanes and ladders where strength is the controlling requirement.

Sitka spruce, in common with other softwood species, frequently contains compression wood. Compression wood is characterized by high density, wide rings, and a large percentage of summer wood. Although such material, because of its density and large amount of summer wood superficially presents certain external characteristics of the strongest and most desirable material, it is, nevertheless, unreliable as to strength and has an appreciable longitudinal shrinkage which causes it to warp and twist badly, particularly when present with normal wood. Fortunately, compression wood is not excessive in amount, is easily recognized, and, because of its warping tendencies, is likely to be culled before it reaches the finished product.

#### PRINCIPAL USES

Sitka spruce is an excellent material for airplane construction where its light weight and relatively high strength make it the most sought for species for such parts as wing beams and wing-rib cap strips. It is estimated that but 2 or 3 per cent of all the mill-run stock is suitable for airplane use, although selected logs are reported to yield as high as 7 per cent.

Sitka spruce has long been used for piano sounding boards because of the uniformity of structure obtainable, its high resonance properties, its freedom from defects, the large sizes available, and the ease of conditioning or seasoning.

Sitka spruce is also used extensively for ladders. Among its other uses are furniture, stringed musical instruments, refrigerator framework, ironing boards, washboards, clothes drying racks, laundry tubs, butter containers, baskets and hampers, fruit and vegetable containers, tanks, boxes and crates, oars, paddles, and building construction. Much of the low-grade lumber is manufactured into packing cases for the Alaska salmon industry.

In addition, Sitka spruce is probably the best species for pulpwood on the Pacific coast and compares favorably with the highly rated white spruce in this respect.

## WHITE SPRUCE

(*Picea glauca* (Moench) Voss)

#### OTHER NAMES

White spruce is also known as single spruce (Maine, Vermont, Minnesota), bog spruce (New England), skunk spruce (Wisconsin, Maine, New England, Ontario), cat spruce (Maine, New England), spruce (Vermont), pine (Hudson Bay), double spruce (Vermont), blue spruce (Maine), eastern spruce (trade—in part), Canadian spruce, and Adirondack spruce (trade).

#### GENERAL DESCRIPTION

White spruce is a softwood species that has long been in popular favor and use. It is related botanically to several other species, the more important of which are Sitka spruce, red spruce, and Engelmann spruce. Of these, red, Sitka, and white spruce are very similar in their mechanical properties and may be used on a like basis in airplane construction.

The heartwood and the sapwood are practically white; consequently they are not readily distinguishable when dry. The wood in common with that of other coniferous species is classifield as nonporous. It has a fine, moderately uneven texture, and can be machined and worked easily. In Alaska the tree is of relatively slow growth; the test material obtained from near Matanuska averaged 22 rings per inch.

#### DISTRIBUTION AND GROWTH

White spruce grows over a wide area extending from Labrador to Hudson Bay and northwestward through Alaska to Bering Strait; extending southward to the Great Lakes region and the States adjoining Canada to the East.

In Alaska, white spruce is typically a tree of the interior rather than of the coastal region, although it extends to tidewater in a few places. It is found in forests of the woodland type, principally along the valley floors of the great rivers, and is by far the most important species of the interior.

White spruce is rarely more than 60 to 70 feet in height, and has a trunk of not more than 2 feet in diameter. The trees selected for test from near Matanuska averaged 56 feet in height and 97 years of age, the age ranging from 83 to 113 years. The diameter at the stump was 12 to 15 inches.

#### SUPPLY

It is estimated that white spruce comprises about 11 per cent of the 6,260,000,000 board feet of timber in the Chugach National Forest of Alaska or about 700,000,000 board feet. It represents a much larger percentage of the saw-timber stand of the interior.

#### PRODUCTION

The bulk of timber cut in the interior of Alaska is for firewood; probably several times as much is used each year for fuel as for lumber. Several small sawmills operate in the interior and spruce has been sawed for many years for local purposes. Thus white spruce has contributed greatly to the economic development of the country and will continue to do so, but as lumber for export it can not be regarded as important. In the United States proper the production of spruce saw timber of all species was one-half billion board feet in 1928, of which perhaps one-third was the white spruce. Large quantities are of course used in addition as pulpwood in the United States.

#### PROPERTIES

The wood of white spruce is moderately light in weight, weak in bending and compression, moderately limber, moderately soft, moderately low in shock resistance, and has a large shrinkage. It is ranked as easy to kiln dry, good in ability to stay in place, easy to work, low in nail-holding ability, very easy to glue and very low in decay resistance.

#### PRINCIPAL USES

The chief local uses of white spruce lumber in Alaska have been for flume and sluice boxes, boats, and building construction. White spruce is also used for certain airplane parts, sounding boards, organ pipes, ladders, joinery, boxes, and crates. It is one of the principal species for pulp and paper.

## STUDIES OF MECHANICAL PROPERTIES

### NATURE OF STUDIES

Three distinct types of studies have been made by the Forest Service on the mechanical properties of Alaska woods, as follows: (1) Standard tests on small, clear specimens of eight species, comprising Alaska white birch, Alaska cedar, western red cedar, mountain hemlock, western hemlock, balsam poplar, Sitka spruce, and white spruce; (2) tests on full-sized sawed structural timbers (containing defects) of Sitka spruce and western hemlock; and (3) tests on full-sized round mine timbers of Alaska white birch, western hemlock, Sitka spruce, and white spruce.

In considering the mechanical properties of woods grown in Alaska in connection with utilization requirements, three questions present themselves: (1) What are the strength properties of the species found in Alaska? (2) How do the properties of Alaska-grown timber compare with those of the same and other species grown elsewhere? (3) In using wood from Alaska for structural purposes, what working stresses are permissible?

The results of the several strength studies together with other data available furnish a basis for obtaining definite answers to these pertinent questions.

### STANDARD TESTS OF SMALL, CLEAR SPECIMENS

#### SELECTION OF MATERIAL

The material used for determining the average properties of a wood from any one locality consisted of logs 5 feet or 9 feet in length taken from each of five or more representative trees, the upper part of the section usually being 16 feet above the stump. The Alaska species for test in the form of small, clear specimens were obtained from eight locations all of which were less than 400 feet above sea level.

The material collected in the Chugach National Forest near the Alaska Railroad was transported by train to Seward, Alaska, and thence by steamship to Seattle, Wash. The logs from the Tongass National Forest were rafted to Ketchikan, Alaska, for boat shipment to Seattle. The tests were made at the Forest Products Laboratory, Madison, Wis. (Pl. 8, A.)

#### CHARACTER OF TESTS

The standard tests, such as were made on small, clear specimens of Alaska woods as well as for similar studies of other species, serve as a basis for comparing and substituting species, promoting the use of unknown and little-used woods, aiding in the determination of safe working stresses for design, determining the influence on strength of such factors as locality of growth, position in tree, rate of growth, and seasoning, grouping of species into utility classes for individual uses, such as boxes and ladders, developing specific gravity-strength laws, comparing virgin-growth and second-growth timber, determining the effect of growth conditions on properties, and studying the variability of wood.

The tests were made in accordance with the general plan used in testing woods from other parts of the United States (*2*), and, in general, similar to that now in use in Canada, England, New Zealand, India, and South Africa. The tests included both green and air-dried material. The air seasoning was accomplished by open piling the stock in a covered shed, open at the sides to permit circulation. The specimens (pl. 8, B) were 2 by 2 inches in cross section, except the specimens used for radial and tangential shrinkage, which were based on width measurements of pieces 1 inch thick, 4 inches wide, and 1 inch along the grain (pl. 8, C). Bending specimens were 30 inches long; others were shorter, depending on the kind of test. The results obtained on Alaska woods are consequently directly comparable with those of previous tests as reported in United States Department of Agriculture Bulletin 556 (*17*).

#### EXPLANATION OF TABLES 2, 3, AND 4

Table 2 presents the average test results of the Alaska woods for each locality from which specimens were obtained. In a few cases this permits comparing material from two sections of Alaska. Table 3 presents similar data on some of the same species grown in other parts of the United States, and thus, in conjunction with Table 2, affords a basis for comparing the strength of Alaska-grown wood with that of the same species from other regions.

TABLE 2.—*Average mechanical properties, by localities, of woods from Alaska*

[Based on tests of small, [1] clear specimens in the green and air-dry condition [2]]

| Common and botanical name | Place of growth in Alaska of material tested | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity oven dry, based on— Volume when green or at 12 per cent moisture | Specific gravity oven dry, based on— Volume when oven dry | Weight per cubic foot | Shrinkage from green to oven-dry condition, based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Fiber stress at elastic limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Lbs.* | *Per cent* | *Per cent* | *Per cent* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* |
| Birch, Alaska white (Betula neoalaskana): | | | | | | | | | | | | | | |
| Green | Anchorage | 10 | 29 | | 58 | 0.49 | 0.59 | 48 | 16.7 | 6.5 | 9.9 | 3,800 | 7,100 | 1,350 |
| Seasoned | do | | | | 12 | .55 | | 38 | | | | 7,800 | 13,800 | 1,900 |
| Cedar, Alaska (Chamaecyparis nootkatensis): | | | | | | | | | | | | | | |
| Green | Ketchikan | 3 | 23 | | 35 | .44 | .51 | 37 | 11.4 | 4.2 | 7.7 | 4,100 | 6,900 | 1,420 |
| Seasoned | do | | | | 12 | .47 | | 33 | | | | 8,200 | 13,200 | 1,700 |
| Cedar, western red (Thuja plicata): | | | | | | | | | | | | | | |
| Green | do | 5 | 18 | | 34 | .31 | .34 | 26 | 7.0 | 2.2 | 4.6 | 3,000 | 4,900 | 850 |
| Seasoned | do | | | | 12 | .33 | | 23 | | | | 5,700 | 8,000 | 1,040 |
| Hemlock, mountain (Tsuga mertensiana): | | | | | | | | | | | | | | |
| Green | Girdwood | 5 | 29 | | 54 | .45 | .53 | 43 | 11.9 | 4.4 | 7.6 | 4,100 | 7,200 | 1,220 |
| Seasoned | do | | | | 12 | .50 | | 35 | | | | 8,500 | 12,600 | 1,520 |
| Hemlock, western (Tsuga heterophylla): | | | | | | | | | | | | | | |
| Green | Cordova | 5 | 21 | | 79 | .36 | .42 | 40 | 11.3 | 3.9 | 7.9 | 3,000 | 5,600 | 1,120 |
| Seasoned | do | | | | 12 | .40 | | 28 | | | | 6,000 | 9,200 | 1,380 |
| Green | Ketchikan | 6 | 21 | | 66 | .41 | .47 | 42 | 12.4 | 4.5 | 7.8 | 3,800 | 6,600 | 1,320 |
| Seasoned | do | | | | 12 | .44 | | 31 | | | | 7,800 | 11,600 | 1,620 |
| Poplar, balsam (Populus balsamifera): | | | | | | | | | | | | | | |
| Green | Girdwood | 5 | | | 104 | .30 | .36 | 38 | 13.0 | 4.0 | 8.7 | 2,100 | 3,700 | 700 |
| Seasoned | do | | | | 12 | .34 | | 24 | | | | 4,600 | 6,800 | 1,190 |
| Spruce, Sitka (Picea sitchensis): | | | | | | | | | | | | | | |
| Green | do | 5 | 23 | | 39 | .39 | .46 | 34 | 11.4 | 4.4 | 7.6 | 3,400 | 5,800 | 1,140 |
| Seasoned | do | | | | 12 | .42 | | 29 | | | | 6,800 | 11,300 | 1,620 |
| Green | Ketchikan | 5 | 17 | | 39 | .38 | .43 | 33 | 11.6 | 4.0 | 7.7 | 3,300 | 5,900 | 1,300 |
| Seasoned | do | | | | 12 | .42 | | 29 | | | | 7,000 | 10,700 | 1,580 |
| Spruce, white (Picea glauca): | | | | | | | | | | | | | | |
| Green | Matanuska | 5 | 22 | | 50 | .39 | .46 | 36 | 12.6 | 5.8 | 9.1 | 3,200 | 5,700 | 1,150 |
| Seasoned | do | | | | 12 | .43 | | 30 | | | | 6,700 | 10,600 | 1,400 |

| Common and botanical name | Place of growth in Alaska of material tested | Static bending: Work in bending—To elastic limit | Static bending: Work in bending—To maximum load | Impact bending: Fiber stress at elastic limit | Impact bending: Work in bending to elastic limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Fiber stress at elastic limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain, fiber stress at elastic limit | Shearing strength parallel to grain | Tension perpendicular to grain | Hardness (load required to embed a 0.444-inch ball to one-half its diameter): End | Hardness: Side |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| | | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *In.-lbs. per cu. in.* | *Ins.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs.* | *Lbs.* |
| Birch, Alaska white (Betula neoalaskana): | | | | | | | | | | | | | |
| Green | Anchorage | 0.60 | 11.6 | 9,800 | 3.7 | 37 | 1,970 | 3,030 | 430 | 920 | 200 | 550 | 560 |
| Seasoned | do | 1.87 | 13.8 | 13,800 | 4.8 | 40 | 4,900 | 7,510 | 830 | 1,420 | 670 | 860 | 840 |
| Cedar, Alaska (Chamaecyparis nootkatensis): | | | | | | | | | | | | | |
| Green | Ketchikan | .77 | 8.8 | 9,900 | 3.3 | 27 | 2,800 | 3,330 | 470 | 880 | 430 | 570 | 500 |
| Seasoned | do | 2.12 | 13.0 | 12,500 | 4.1 | 29 | 6,100 | 7,520 | 910 | 1,380 | 370 | 950 | 690 |
| Cedar, western red (Thuja plicata): | | | | | | | | | | | | | |
| Green | do | .62 | 4.9 | 6,600 | 2.5 | 17 | 2,130 | 2,560 | 380 | 690 | 280 | 450 | 290 |
| Seasoned | do | 1.80 | 5.6 | 8,100 | 3.4 | 19 | 4,060 | 4,990 | 700 | 870 | 300 | 720 | 390 |
| Hemlock, mountain (Tsuga mertensiana): | | | | | | | | | | | | | |
| Green | Girdwood | .80 | 9.8 | 9,400 | 3.4 | 28 | 2,480 | 3,410 | 540 | 940 | 300 | 610 | 540 |
| Seasoned | do | 2.70 | 8.4 | 12,900 | 5.0 | 29 | 5,730 | 7,790 | 1,060 | 1,290 | 300 | 1,260 | 860 |
| Hemlock, western (Tsuga heterophylla): | | | | | | | | | | | | | |
| Green | Cordova | .48 | 7.0 | 7,700 | 2.8 | 21 | 2,220 | 2,780 | 390 | 770 | 330 | 450 | 380 |
| Seasoned | do | 1.52 | 7.4 | 11,800 | 5.2 | 23 | 4,510 | 5,700 | 620 | 1,160 | 360 | 920 | 530 |
| Green | Ketchikan | .62 | 7.3 | 8,500 | 3.0 | 26 | 2,680 | 3,240 | 460 | 840 | 330 | 560 | 480 |
| Seasoned | do | 2.10 | 8.8 | 13,600 | 6.1 | 31 | 5,900 | 7,020 | 780 | 1,320 | 340 | 1,040 | 660 |
| Poplar, balsam (Populus balsamifera): | | | | | | | | | | | | | |
| Green | Girdwood | .37 | 4.2 | 5,700 | 2.2 | 13 | 1,080 | 1,660 | 180 | 490 | 150 | 210 | 200 |
| Seasoned | do | 1.04 | 4.4 | 8,400 | 2.6 | 14 | 2,750 | 4,230 | 350 | 750 | 380 | 360 | 290 |
| Spruce, Sitka (Picea sitchensis): | | | | | | | | | | | | | |
| Green | do | .56 | 6.7 | 8,400 | 3.1 | 23 | 2,240 | 2,710 | 420 | 760 | 330 | 400 | 330 |
| Seasoned | do | 1.59 | 10.1 | 10,800 | 3.8 | 21 | 4,700 | 6,340 | 690 | 1,110 | 340 | 650 | 520 |
| Green | Ketchikan | .51 | 6.3 | 8,300 | 2.9 | 23 | 2,290 | 2,810 | 380 | 780 | 300 | 460 | 400 |
| Seasoned | do | 1.76 | 9.6 | 10,000 | 3.3 | 29 | 4,800 | 5,920 | 720 | 1,060 | 420 | 950 | 580 |
| Spruce, white (Picea glauca): | | | | | | | | | | | | | |
| Green | Matanuska | .51 | 5.8 | 7,600 | 2.7 | 24 | 2,150 | 2,720 | 330 | 710 | 230 | 370 | 350 |
| Seasoned | do | 1.83 | 8.0 | 11,100 | 4.2 | 22 | 4,750 | 6,230 | 740 | 1,310 | 390 | 640 | 500 |

[1] Test specimens 2 by 2 inches in section. Bending specimens 30 inches long; others shorter, depending on kind of test.
[2] The values in the first line for each species are from tests of green material; those in the second line are from tests of seasoned material adjusted to an average air-dry condition of 12 per cent moisture.

TABLE 3.—*Average mechanical properties, by localities, of woods from the United States proper whose range of growth includes Alaska*

[Based on tests of small,[1] clear specimens in the green and air-dry condition [2]]

| Common and botanical name | Place of growth of material tested | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity oven-dry, based on— | | Weight per cubic foot | Shrinkage from green to oven-dry condition, based on dimensions when green | | | Static bending | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Volume when green or at 12 per cent moisture | Volume when oven dry | | Volumetric | Radial | Tangential | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Lbs.* | *Per cent* | *Per cent* | *Per cent* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* |
| Cedar, Alaska (Chamaecyparis nootkatensis): | | | | | | | | | | | | | | |
| Green | Lane County, Oreg | 5 | 31 | | 40 | 0.40 | 0.44 | 35 | 7.9 | 1.9 | 5.0 | 3,600 | 6,200 | 960 |
| Seasoned | do | | | | 12 | .42 | | 29 | | | | 6,700 | 10,100 | 1,270 |
| Cedar western red (Thuja plicata): | | | | | | | | | | | | | | |
| Green | Missoula County, Mont | 5 | 21 | 42 | 33 | .29 | .33 | 24 | 7.6 | 2.5 | 4.6 | 2,900 | 4,800 | 890 |
| Seasoned | do | | | | 12 | .31 | | 22 | | | | 4,600 | 7,000 | 1,120 |
| Green | Snohomish County Wash. | 5 | 20 | 31 | 45 | .33 | .36 | 30 | 8.6 | 2.5 | 5.6 | 3,600 | 5,700 | 1,020 |
| Seasoned | do | | | | 12 | .35 | | 24 | | | | 5,700 | 8,400 | 1,220 |
| Hemlock, mountain (Tsuga mertensiana): | | | | | | | | | | | | | | |
| Green | Montana | 5 | 23 | 45 | 70 | .42 | .48 | 45 | 10.8 | 4.4 | 7.1 | 3,500 | 6,000 | 940 |
| Seasoned | do | | | | 12 | .45 | | 31 | | | | 6,300 | 9,900 | 1,130 |
| Hemlock, western (Tsuga heterophylla): | | | | | | | | | | | | | | |
| Green | Chehalis County, Wash | 5 | 10 | 27 | 71 | .38 | .43 | 41 | 11.6 | 4.5 | 7.9 | 3,400 | 6,100 | 1,190 |
| Seasoned | do | | | | 12 | .40 | | 28 | | | | 6,100 | 9,000 | 1,420 |
| Green | Oregon | 2 | 12 | 40 | 92 | .38 | .44 | 46 | 11.8 | | | 3,800 | 6,200 | 1,270 |
| Seasoned | do | | | | 12 | .41 | | 29 | | | | 7,600 | 10,100 | 1,540 |
| Poplar, balsam (Populus balsamifera): | | | | | | | | | | | | | | |
| Green | Bennington County, Vt | 5 | 5 | | 121 | .30 | .33 | 42 | 8.0 | 2.0 | 5.4 | 2,100 | 4,000 | 800 |
| Seasoned | do | | | | 12 | .32 | | 22 | | | | 3,900 | 6,800 | 1,020 |
| Spruce, Sitka (Picea sitchensis): | | | | | | | | | | | | | | |
| Green | Chehalis County, Wash | 5 | 9 | 24 | 53 | .34 | .37 | 32 | 11.2 | 4.5 | 7.4 | 3,000 | 5,500 | 1,180 |
| Seasoned | do | | | | 12 | .37 | | 26 | | | | 6,200 | 9,800 | 1,520 |
| Green | Clatsop County, Oreg | 4 | 15 | | 45 | .34 | .38 | 31 | 10.7 | 4.0 | 7.0 | 3,200 | 4,900 | 1,090 |
| Seasoned | do | | | | 12 | .38 | | 27 | | | | 6,300 | 8,500 | 1,370 |
| Green | Oregon | 3 | 14 | 47 | 36 | .38 | .44 | 32 | 12.8 | | | 3,700 | 6,000 | 1,460 |
| Seasoned | do | | | | 12 | .42 | | 29 | | | | 7,700 | 11,400 | 1,740 |
| Green | do | 3 | 10 | 41 | 34 | .37 | .42 | 31 | 11.2 | 4.5 | 7.9 | 3,600 | 5,900 | 1,310 |
| Seasoned | do | | | | 12 | .38 | | 27 | | | | 6,200 | 9,300 | 1,560 |
| Spruce, white (Picea glauca): | | | | | | | | | | | | | | |
| Green | Coos County, N. H | 5 | 11 | 22 | 52 | .35 | | 33 | | | | 3,300 | 5,700 | 1,060 |
| Seasoned | do | | | | 12 | .37 | | 26 | | | | 6,000 | 9,300 | 1,360 |
| Green | Rusk County, Wis | 5 | 17 | 29 | 48 | .38 | .43 | 35 | 14.8 | 3.7 | 7.3 | 3,400 | 5,400 | 990 |
| Seasoned | do | | | | 12 | .41 | | 29 | | | | 6,200 | 9,000 | 1,500 |

| Common and botanical name | Place of growth of material tested | Static bending: Work in bending—To elastic limit | Static bending: Work in bending—To maximum load | Impact bending: Fiber stress at elastic limit | Impact bending: Work in bending to elastic limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Fiber stress at elastic limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain, fiber stress at elastic limit | Shearing strength parallel to grain | Tension perpendicular to grain | Hardness (load required to embed a 0.444-inch ball to one-half its diameter): End | Hardness: Side |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| | | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *In.-lbs. per cu. in.* | *Ins.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs.* | *Lbs.* |
| Cedar, Alaska (Chamaecyparis nootkatensis): | | | | | | | | | | | | | |
| Green | Lane County, Oreg | 0.77 | 9.5 | 8,600 | 3.2 | 27 | 2,390 | 2,880 | 410 | 820 | 260 | 520 | 410 |
| Seasoned | do | 2.10 | 8.8 | 12,200 | 5.8 | 28 | 5,330 | 5,800 | 720 | 1,000 | 360 | 700 | 520 |
| Cedar, western red (Thuja plicata): | | | | | | | | | | | | | |
| Green | Missoula County, Mont. | .54 | 4.5 | 6,400 | 2.0 | 16 | 2,300 | 2,630 | 280 | 700 | 220 | 390 | 250 |
| Seasoned | do | 1.08 | 4.8 | 9,000 | 3.3 | 11 | 4,170 | 4,920 | 460 | 810 | 190 | 550 | 300 |
| Green | Snohomish County, Wash. | .74 | 5.6 | 7,800 | 2.9 | 18 | 2,690 | 3,050 | 350 | 740 | 200 | 460 | 270 |
| Seasoned | do | 1.54 | 7.2 | 8,800 | 3.0 | 20 | 4,720 | 5,450 | 690 | 920 | ------ | 740 | 380 |
| Hemlock, mountain (Tsuga mertensiana): | | | | | | | | | | | | | |
| Green | Montana | .78 | 9.4 | 8,800 | 3.6 | 36 | 2,590 | 2,890 | 400 | 880 | 360 | 580 | 460 |
| Seasoned | do | 2.09 | 9.2 | 13,800 | 6.7 | 36 | 3,890 | 6,090 | 1,030 | 1,170 | 340 | 1,080 | 640 |
| Hemlock, western (Tsuga heterophylla): | | | | | | | | | | | | | |
| Green | Chehalis County, Wash. | .58 | 6.0 | 7,800 | 2.4 | 20 | 2,290 | 2,890 | 350 | 810 | 260 | 540 | 430 |
| Seasoned | do | 1.57 | 6.1 | 11,100 | 4.5 | 24 | 5,260 | 5,760 | 620 | 1,040 | 190 | 840 | 550 |
| Green | Oregon | .62 | 6.6 | 9,000 | 3.1 | 20 | -------- | 3,040 | 320 | 800 | 300 | 510 | 400 |
| Seasoned | do | 2.11 | 7.4 | 13,300 | 5.7 | 24 | -------- | 6,080 | 640 | 1,080 | 370 | 830 | 500 |
| Poplar, balsam (Populus balsamifera): | | | | | | | | | | | | | |
| Green | Bennington County, Vt. | .32 | 4.2 | 6,200 | 2.3 | 18 | 1,200 | 1,720 | 160 | 520 | 180 | 260 | 250 |
| Seasoned | do | .92 | 5.7 | 7,700 | 2.8 | 14 | 2,020 | 3,810 | 390 | 840 | 320 | 400 | 320 |
| Spruce, Sitka (Picea sitchensis): | | | | | | | | | | | | | |
| Green | Chehalis County, Wash. | .44 | 6.4 | 7,900 | 2.5 | 29 | 2,260 | 2,600 | 330 | 780 | 230 | 430 | 370 |
| Seasoned | do | 1.38 | 9.5 | 12,500 | 4.5 | 26 | 4,390 | 5,000 | 800 | 1,110 | 440 | 700 | 500 |

[1] Test specimens 2 by 2 inches in section. Bending specimens 30 inches long; others shorter, depending on kind of test.

[2] The values in the first line for each species are from tests of green material; those in the second line are from tests of seasoned material adjusted to an average air-dry condition of 12 per cent moisture.

TABLE 3.—*Average mechanical properties, by localities, of woods from the United States proper whose range of growth includes Alaska*—Continued

| Common and botanical name | Place of growth in Alaska of material tested | Static bending: Work in bending—To elastic limit | Static bending: Work in bending—To maximum load | Impact bending: Fiber stress at elastic limit | Impact bending: Work in bending to elastic limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Fiber stress at elastic limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain, fiber stress at elastic limit | Shearing strength parallel to grain | Tension perpendicular to grain | Hardness (load required to embed a 0.444-inch ball to one-half its diameter): End | Hardness: Side |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| | | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *In.-lbs. per cu. in.* | *Ins.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs.* | *Lbs.* |
| Spruce, Sitka (Picea sitchensis)—Continued. | | | | | | | | | | | | | |
| Green | Clatsop County, Oreg. | 0.53 | 5.4 | 7,800 | 2.7 | 20 | 1,920 | 2,180 | 220 | 700 | 170 | 350 | 280 |
| Seasoned | do | 1.52 | 7.4 | 10,000 | 3.7 | 21 | 3,750 | 4,730 | 580 | 1,260 | 440 | 690 | 440 |
| Green | Oregon | .58 | 6.2 | 9,600 | 3.5 | 24 | | 2,840 | 360 | 780 | 160 | 480 | 350 |
| Seasoned | do | 1.93 | 11.4 | 13,800 | 5.7 | 28 | | 5,850 | 750 | 1,280 | 370 | 810 | 520 |
| Green | do | .59 | 6.5 | 9,300 | 3.9 | 23 | | 2,930 | 350 | 750 | 300 | 480 | 350 |
| Seasoned | do | 1.41 | 8.1 | 12,000 | 4.7 | 24 | | 5,830 | 680 | 1,110 | 340 | 780 | 450 |
| Spruce, white (Picea glauca): | | | | | | | | | | | | | |
| Green | Coos County, N. H. | .61 | 6.7 | | | | 1,990 | 2,440 | 280 | 680 | | 220 | 240 |
| Seasoned | do | 1.47 | 8.0 | 9,700 | 3.5 | 20 | 4,230 | 5,020 | 460 | 1,130 | 350 | 540 | 440 |
| Green | Rusk County, Wis. | .69 | 5.4 | 6,800 | 2.0 | 20 | 2,140 | 2,550 | 270 | 690 | 200 | 290 | 280 |
| Seasoned | do | 1.67 | 6.6 | | | | 3,660 | 5,320 | 540 | 770 | | 700 | 530 |

TABLE 4.—*Average mechanical properties of eighteen species of wood* [1]

[Based on tests of small, [2] clear specimens in the green and air-dry condition [3]]

| Common and botanical name | Place of growth of material tested | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity, oven-dry, based on—: Volume when green or at 12 per cent moisture | Specific gravity, oven-dry, based on—: Volume when oven dry | Weight per cubic foot | Shrinkage from green to oven-dry condition, based on dimensions when green: Volumetric | Shrinkage: Radial | Shrinkage: Tangential | Static bending: Fiber stress at elastic limit | Static bending: Modulus of rupture | Static bending: Modulus of elasticity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Lbs.* | *Per cent* | *Per cent* | *Per cent* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* |
| Alder, red (Alnus rubra): | | | | | | | | | | | | | | |
| Green | Washington | 6 | 11 | ----- | 98 | 0.37 | 0.43 | 46 | 12.6 | 4.4 | 7.3 | 3,800 | 6,500 | 1,170 |
| Seasoned | do | ----- | ----- | ----- | 12 | .41 | ----- | 28 | ----- | ----- | ----- | 7,100 | 10,000 | 1,380 |
| Birch, Alaska white (Betula neoalaskana): | | | | | | | | | | | | | | |
| Green | Alaska | 10 | 29 | ----- | 58 | .49 | .59 | 48 | 16.7 | 6.5 | 9.9 | 3,800 | 7,100 | 1,350 |
| Seasoned | do | ----- | ----- | ----- | 12 | .55 | ----- | 38 | ----- | ----- | ----- | 7,800 | 13,800 | 1,900 |
| Birch, gray (Betula populifolia): | | | | | | | | | | | | | | |
| Green | New Hampshire | 5 | ----- | ----- | 63 | .45 | .55 | 46 | 14.7 | 5.2 | ----- | 1,800 | 4,900 | 400 |
| Seasoned | do | ----- | ----- | ----- | 12 | .51 | ----- | 35 | ----- | ----- | ----- | 5,400 | 9,800 | 1,130 |
| Birch, yellow (Betula lutea): | | | | | | | | | | | | | | |
| Green | Wisconsin, Vermont, Pennsylvania. | 17 | 16 | 26 | 67 | .55 | .66 | 57 | 16.7 | 7.2 | 9.2 | 4,200 | 8,300 | 1,500 |
| Seasoned | do | ----- | ----- | ----- | 12 | .62 | ----- | 43 | ----- | ----- | ----- | 10,000 | 16,600 | 2,010 |
| Cedar, Alaska (Chamaecyparis nootkatensis): | | | | | | | | | | | | | | |
| Green | Alaska, Oregon | 8 | 28 | ----- | 38 | .42 | .46 | 36 | 9.2 | 2.8 | 6.0 | 3,800 | 6,400 | 1,140 |
| Seasoned | do | ----- | ----- | ----- | 12 | .44 | ----- | 30 | ----- | ----- | ----- | 7,300 | 11,300 | 1,430 |
| Cedar, northern white (Thuja occidentalis): | | | | | | | | | | | | | | |
| Green | Wisconsin | 5 | 23 | 36 | 55 | .29 | .32 | 28 | 7.0 | 2.1 | 4.7 | 2,600 | 4,200 | 640 |
| Seasoned | do | ----- | ----- | ----- | 12 | .31 | ----- | 22 | ----- | ----- | ----- | 4,900 | 6,500 | 800 |

[1] The values given in this table comprise the average of all comparable data on each species regardless of region where grown. Any differences of these values from those given in U. S. Dept. Agr. Bul. 556, Mechanical Properties of Woods Grown in the United States (*17*), for the same species are due (1) to additional tests made since that bulletin was published (1917) and (2) to the fact that the values for air-dry material are herein reduced to a uniform moisture basis to make the results directly comparable.

[2] Test specimens 2 by 2 inches in section. Bending specimens 30 inches long; others shorter, depending on kind of test.

[3] The values in the first line for each species are from tests of green material; those in the second line are from tests of seasoned material adjusted to an average air-dry condition of 12 per cent moisture.

TABLE 4.—*Average mechanical properties of eighteen species of wood*—Continued

| Common and botanical name | Place of growth in Alaska of material tested | Trees tested | Rings per inch | Summer wood | Moisture content | Specific gravity oven dry, based on— | | Weight per cubic foot | Shrinkage from green to oven-dry condition, based on dimensions when green | | | Static bending | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Volume when green or at 12 per cent moisture | Volume when oven dry | | Volumetric | Radial | Tangential | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
| | | *Number* | *Number* | *Per cent* | *Per cent* | | | *Lbs.* | *Per cent* | *Per cent* | *Per cent* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* |
| Cedar, western red (Thuja plicata): | | | | | | | | | | | | | | |
| Green | Alaska, Montana, Washington. | 15 | 19 | 36 | 37 | 0.31 | 0.34 | 27 | 7.7 | 2.4 | 5.0 | 3,200 | 5,100 | 920 |
| Seasoned | do | | | | 12 | .33 | | 23 | | | | 5,400 | 7,800 | 1,120 |
| Cottonwood, northern black (Populus trichocarpa hastata): | | | | | | | | | | | | | | |
| Green | Washington | 5 | 6 | | 132 | .32 | .37 | 46 | 12.4 | 3.6 | 8.6 | 2,900 | 4,800 | 1,070 |
| Seasoned | do | | | | 12 | .35 | | 24 | | | | 5,400 | 8,500 | 1,260 |
| Douglas fir (coast type) (Pseudotsuga taxifolia): | | | | | | | | | | | | | | |
| Green | Washington, Oregon, California. | 34 | 14 | 36 | 36 | .45 | .51 | 38 | 11.8 | 5.0 | 7.8 | 4,800 | 7,600 | 1,550 |
| Seasoned | do | | | | 12 | .48 | | 34 | | | | 8,200 | 11,900 | 1,930 |
| Douglas fir (mountain type) (Pseudotsuga taxifolia): | | | | | | | | | | | | | | |
| Green | Montana, Wyoming | 10 | 22 | 27 | 38 | .40 | .45 | 35 | 10.6 | 3.6 | 6.2 | 3,600 | 6,400 | 1,180 |
| Seasoned | do | | | | 12 | .43 | | 30 | | | | 6,300 | 9,600 | 1,410 |
| Hemlock, eastern (Tsuga canadensis): | | | | | | | | | | | | | | |
| Green | Wisconsin, Tennessee, New Hampshire, Vermont. | 20 | 17 | 34 | 111 | .38 | .43 | 50 | 9.7 | 3.0 | 6.8 | 3,800 | 6,400 | 1,070 |
| Seasoned | do | | | | 12 | .40 | | 28 | | | | 6,100 | 9,000 | 1,210 |
| Hemlock, mountain (Tsuga mertensiana): | | | | | | | | | | | | | | |
| Green | Alaska, Montana | 10 | 26 | 45 | 62 | .43 | .51 | 44 | 11.4 | 4.4 | 7.4 | 3,800 | 6,600 | 1,080 |
| Seasoned | do | | | | 12 | .47 | | 33 | | | | 7,400 | 11,200 | 1,330 |
| Hemlock, western (Tsuga heterophylla): | | | | | | | | | | | | | | |
| Green | Alaska, Washington, Oregon. | 18 | 17 | 31 | 74 | .38 | .44 | 42 | 11.9 | 4.3 | 7.9 | 3,400 | 6,100 | 1,220 |
| Seasoned | do | | | | 12 | .42 | | 29 | | | | 6,800 | 10,000 | 1,490 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Maple, bigleaf (Acer macrophyllum): | | | | | | | | | | | | | | |
| Green | Washington | 5 | 12 | | 72 | .44 | .51 | 47 | 11.6 | 3.7 | 7.1 | 4,400 | 7,400 | 1,090 |
| Seasoned | do | | | | 12 | .48 | | 34 | | | | 6,700 | 10,800 | 1,470 |
| Pine, western white (Pinus monticola): | | | | | | | | | | | | | | |
| Green | Idaho, Montana | 14 | 20 | 33 | 54 | .36 | .42 | 35 | 11.8 | 4.1 | 7.4 | 3,400 | 5,200 | 1,170 |
| Seasoned | do | | | | 12 | .38 | | 27 | | | | 6,300 | 9,600 | 1,520 |
| Poplar, balsam (Populus balsamifera): | | | | | | | | | | | | | | |
| Green | Alaska, Vermont | 10 | 7 | | 112 | .30 | .35 | 40 | 10.5 | 3.0 | 7.1 | 2,100 | 3,900 | 750 |
| Seasoned | do | | | | 12 | .33 | | 23 | | | | 4,200 | 6,800 | 1,110 |
| Spruce, Sitka (Picea sitchensis): | | | | | | | | | | | | | | |
| Green | Alaska, Washington, Oregon. | 25 | 15 | 35 | 42 | .37 | .42 | 32 | 11.5 | 4.3 | 7.5 | 3,300 | 5,700 | 1,230 |
| Seasoned | do | | | | 12 | .40 | | 28 | | | | 6,700 | 10,200 | 1,570 |
| Spruce, white (Picea glauca): | | | | | | | | | | | | | | |
| Green | Alaska, Wisconsin, New Hampshire. | 15 | 17 | 26 | 50 | .37 | .45 | 35 | 13.7 | 4.7 | 8.2 | 3,300 | 5,600 | 1,070 |
| Seasoned | do | | | | 12 | .40 | | 28 | | | | 6,300 | 9,600 | 1,420 |

TABLE 4.—*Average mechanical properties of eighteen species of wood*—Continued

| Common and botanical name | Place of growth of material tested | Static bending—Continued: Work in bending—To elastic limit | Static bending—Continued: Work in bending—To maximum load | Impact bending: Fiber stress at elastic limit | Impact bending: Work in bending to elastic limit | Impact bending: Height of drop causing complete failure (50-pound hammer) | Compression parallel to grain: Fiber stress at elastic limit | Compression parallel to grain: Maximum crushing strength | Compression perpendicular to grain, fiber stress at elastic limit | Shearing strength parallel to grain | Tension perpendicular to grain | Hardness (load required to embed a 0.444-inch ball to one-half its diameter): End | Hardness (load required to embed a 0.444-inch ball to one-half its diameter): Side |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| | | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *In.-lbs. per cu. in.* | *Inches* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *Lbs.* | *Lbs.* |
| Alder, red (Alnus rubra): | | | | | | | | | | | | | |
| Green | Washington | 0.70 | 8.0 | 8,000 | 2.6 | 22 | 2,650 | 2,960 | 310 | 770 | 390 | 550 | 440 |
| Seasoned | do | 1.90 | 8.4 | 11,700 | 4.9 | 20 | 4,660 | 5,960 | 550 | 1,100 | 420 | 980 | 600 |
| Birch, Alaska white (Betula neoalaskana): | | | | | | | | | | | | | |
| Green | Alaska | .60 | 11.6 | 9,800 | 3.7 | 37 | 1,970 | 3,030 | 430 | 920 | 200 | 550 | 560 |
| Seasoned | do | 1.57 | 13.8 | 13,800 | 4.8 | 40 | 4,900 | 7,510 | 830 | 1,420 | 670 | 860 | 840 |
| Birch, gray (Betula populifolia): | | | | | | | | | | | | | |
| Green | New Hampshire | .47 | 13.9 | 7,400 | 2.6 | 59 | 1,000 | 1,860 | 300 | ---- | ---- | 440 | 480 |
| Seasoned | do | 1.44 | 10.8 | 10,400 | 3.5 | 35 | 3,050 | 4,880 | 950 | ---- | ---- | 690 | 770 |
| Birch, yellow (Betula lutea): | | | | | | | | | | | | | |
| Green | Wisconsin, Vermont, Pennsylvania. | .70 | 16.1 | 11,500 | 4.4 | 48 | 2,530 | 3,380 | 530 | 1,110 | 430 | 810 | 780 |
| Seasoned | do | 2.87 | 20.8 | 17,200 | 7.2 | 55 | 5,930 | 8,110 | 1,180 | 1,900 | 920 | 1,480 | 1,260 |
| Cedar, Alaska (Chamaecyparis nootkatensis): | | | | | | | | | | | | | |
| Green | Alaska, Oregon | .77 | 9.2 | 9,100 | 3.2 | 27 | 2,540 | 3,050 | 430 | 840 | 330 | 540 | 440 |
| Seasoned | do | 2.11 | 10.4 | 12,300 | 5.2 | 29 | 5,620 | 6,440 | 790 | 1,140 | 360 | 800 | 590 |
| Cedar, northern white (Thuja occidentalis): | | | | | | | | | | | | | |
| Green | Wisconsin | .60 | 5.7 | 5,300 | 2.0 | 15 | 1,420 | 1,990 | 290 | 620 | 240 | 320 | 230 |
| Seasoned | do | 1.73 | 4.8 | 7,100 | 2.8 | 12 | 2,730 | 3,980 | 380 | 890 | 240 | 450 | 320 |
| Cedar, western red (Thuja plicata) | | | | | | | | | | | | | |
| Green | Alaska, Montana, Washington. | .63 | 5.0 | 6,900 | 2.5 | 17 | 2,370 | 2,750 | 340 | 710 | 250 | 430 | 270 |
| Seasoned | do | 1.47 | 5.9 | 8,600 | 3.2 | 17 | 4,320 | 5,120 | 620 | 870 | 240 | 670 | 360 |
| Cottonwood, northern black (Populus trichocarpa hastata): | | | | | | | | | | | | | |
| Green | Washington | .44 | 5.0 | 6,800 | 2.2 | 20 | 1,770 | 2,160 | 200 | 600 | 270 | 280 | 250 |
| Seasoned | do | 1.28 | 6.7 | 9,900 | 3.8 | 22 | 3,680 | 4,510 | 380 | 1,010 | 330 | 550 | 350 |

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| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Douglas fir (coast type) (Pseudotsuga taxifolia): | | | | | | | | | | | | | |
| Green | Washington, Oregon, California. | .85 | 6.8 | 9,800 | 3.2 | 24 | 3,430 | 3,890 | 510 | 930 | 250 | 510 | 480 |
| Seasoned | do | 2.02 | 8.7 | 12,900 | 4.6 | 30 | 6,870 | 7,590 | 920 | 1,140 | 310 | 770 | 670 |
| Douglas fir (mountain type) (Pseudotsuga taxifolia): | | | | | | | | | | | | | |
| Green | Montana, Wyoming | .65 | 6.8 | 9,100 | 3.0 | 20 | 2,520 | 3,000 | 450 | 880 | 350 | 450 | 400 |
| Seasoned | do | 1.61 | 6.4 | 12,200 | 4.8 | 26 | 4,720 | 6,140 | 830 | 1,040 | 320 | 740 | 630 |
| Hemlock eastern (Tsuga canadensis): | | | | | | | | | | | | | |
| Green | Wisconsin, Tennessee, New Hampshire, Vermont. | .76 | 6.7 | 7,900 | 2.9 | 21 | 2,480 | 3,080 | 440 | 850 | 230 | 500 | 400 |
| Seasoned | do | 1.81 | 6.8 | 10,700 | 4.8 | 20 | 3,960 | 5,490 | 820 | 1,070 | 220 | 820 | 510 |
| Hemlock, mountain (Tsuga mertensiana): | | | | | | | | | | | | | |
| Green | Alaska, Montana | .79 | 9.6 | 9,100 | 3.5 | 32 | 2,540 | 3,150 | 470 | 910 | 330 | 600 | 500 |
| Seasoned | do | 2.40 | 8.8 | 13,400 | 5.8 | 32 | 4,810 | 6,940 | 1,040 | 1,230 | 320 | 1,170 | 750 |
| Hemlock, western (Tsuga heterophylla): | | | | | | | | | | | | | |
| Green | Alaska, Washington, Oregon. | .57 | 6.8 | 8,100 | 2.8 | 22 | 2,410 | 2,990 | 390 | 810 | 310 | 520 | 430 |
| Seasoned | do | 1.80 | 7.5 | 12,400 | 5.4 | 26 | 5,210 | 6,200 | 670 | 1,160 | 310 | 940 | 580 |
| Maple, bigleaf (Acer macrophyllum): | | | | | | | | | | | | | |
| Green | Washington | 1.02 | 8.7 | 8,500 | 2.8 | 23 | 2,380 | 3,240 | 550 | 1,110 | 600 | 760 | 620 |
| Seasoned | do | 1.68 | 7.8 | -------- | -------- | 28 | 5,200 | 6,[illegible] | 940 | 1,770 | 540 | 1,360 | 850 |
| Pine, western white (Pinus monticola): | | | | | | | | | | | | | |
| Green | Idaho, Montana | .56 | 5.0 | 7,600 | 2.6 | 19 | 2,390 | 2,650 | 290 | 640 | 260 | 310 | 310 |
| Seasoned | do | 1.51 | 8.9 | 12,000 | 4.5 | 23 | 4,910 | 5,720 | 540 | 940 | 280 | 440 | 350 |
| Poplar, balsam (Populus balsami era): | | | | | | | | | | | | | |
| Green | Alaska, Vermont | .35 | 4.2 | 6,000 | 2.2 | 16 | 1,140 | 1,690 | 170 | 500 | 160 | 240 | 230 |
| Seasoned | do | .98 | 5.0 | 8,000 | 2.7 | 14 | 2,840 | 4,020 | 370 | 800 | 350 | 350 | 300 |
| Spruce, Sitka (Picea sitchensis): | | | | | | | | | | | | | |
| Green | Alaska, Washington, Oregon. | .53 | 6.3 | 8,400 | 3.0 | 24 | 2,190 | 2,670 | 340 | 760 | 250 | 430 | 350 |
| Seasoned | do | 1.61 | 9.4 | 11,400 | 4.1 | 25 | 4,460 | 5,590 | 710 | 1,140 | 400 | 760 | 510 |
| Spruce, white (Picea glauca): | | | | | | | | | | | | | |
| Green | Alaska, Wisconsin, New Hampshire. | .60 | 6.0 | 7,200 | 2.4 | 22 | 2,090 | 2,570 | 290 | 690 | 210 | 300 | 290 |
| Seasoned | do | 1.66 | 7.5 | 10,400 | 3.8 | 21 | 4,230 | 5,520 | 580 | 1,070 | 370 | 630 | 490 |

Table 4 presents the average results of all comparable tests made by the Forest Products Laboratory on woods that grow in Alaska, and in addition, other data on well-known species. Previous studies by the laboratory have shown that the average results for material from all localities tested is a better criterion of the properties of material from any untested site than are the results of tests from seemingly similar sites, as appraised by the usually recorded characteristics. Table 4 represents the best estimate of the true average for each of the species, and accordingly affords the best basis for comparing the various species. These data are second only in importance to the grade of timber in determining safe working stresses for timber design.

The first line of figures for each species in Tables 2, 3, and 4 are the results of tests on green material; those in the second line are from tests of seasoned material adjusted to an average air-dry condition of 12 per cent moisture.

### COLUMN 1, COMMON AND BOTANICAL NAMES OF SPECIES

Many of the species have numerous common names, and not infrequently one common name is applied to several species. This leads to so much confusion that it is necessary to refer to a standard nomenclature. The common and botanical names used in the tables are those given in Check List of the Forest Trees of the United States, Their Names and Ranges (*18*).

### COLUMN 2, PLACE OF GROWTH OF MATERIAL TESTED

In the second columns of Tables 2 and 3 are listed the locality in which the test specimens were grown; in the second column of Table 4 the States from which test material represented in the average figures was obtained.

### COLUMN 3, NUMBER OF TREES TESTED

The number of trees from which test specimens were taken is given in the third column of Tables 2, 3, and 4. As previously mentioned, five is the usual number from a single locality.

### COLUMN 4, NUMBER OF RINGS PER INCH

The number of rings per inch is an inverse measure of the rate of diameter growth. It is taken along a radial line on the end section of each specimen. One ring, consisting of a band of spring wood and a band of summer wood, is formed by each year's growth; consequently, few rings per inch indicate fast growth, and conversely.

### COLUMN 5, SUMMER WOOD

The amount of summer wood is expressed as a percentage of the entire cross section. (See definition of summer wood, p. 75.) It is measured along a representative radial line. In some species the proportion of summer wood gives a fairly accurate estimate of the density; in others the contrast between spring wood and summer wood is so indistinct that no measurement can be made. It is of no practical value except in species in which the relation to density has been worked out.

### Column 6, Moisture Content

Moisture content is the weight of water contained in the wood, expressed as a percentage of the oven-dry weight of the wood.

The moisture content given for green material is the average for specimens taken from the pith to the circumference of the log, and hence represents a combination of the moisture as found in the heartwood and in the sapwood. In many species there is much more moisture in the sapwood than in the heartwood.

The moisture content of the air-dry material when tested varied somewhat among the different species. To facilitate comparison of strength properties, the test values were adjusted to conform to the uniform condition of 12 per cent moisture as indicated.

### Columns 7 and 8, Specific Gravity

Specifiic gravity of wood is its weight divided by the weight of an equal volume of water.

Obviously, the weight of wood in a given volume changes with the shrinkage and swelling caused by changes in moisture. Consequently, specific gravity is an indefinite quantity unless the circumstances under which it is determined are specified. Each of the columns of specific gravity figures given in Tables 2, 3, and 4 is based on the weight of the wood when oven dry and on its volume when green or at a specified stage of drying.

### Column 9, Weight per Cubic Foot

The weight per cubic foot that is given in the first horizontal line of figures opposite each species in Tables 2, 3, and 4, is the weight per cubic foot of the wood (including moisture) as received at the Forest Products Laboratory, and because of the protection from seasoning in transit and pending test, it represents closely the weight of the wood as it comes from the living tree. The various species differ largely as to the wetness of the green wood. The weight per cubic foot that is given in the second horizontal line of figures opposite each species, is from tests of seasoned material adjusted to an average air-dry condition of 12 per cent moisture content.

### Columns 10, 11, and 12, Shrinkage from Green to Oven-Dry Condition

When wood is dried below the fiber-saturation point,[5] shrinkage begins and continues until the moisture is all driven off. Shrinkage along the length of timber is small. Shrinkage in directions at right angles to the length is much greater.

All shrinkages given in Tables 2, 3, and 4 are expressed in percentages of the original or green dimensions, and are total shrinkages

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[5] Green wood usually contains "absorbed" water within the cell walls and "free" water in the cell cavities. In drying, the free water from the cell cavities is the first to be evaporated. The fiber-saturation point is that point at which no water exists in the cell cavities of the timber, but at which the cell walls are still saturated. The fiber-saturation point varies with the species. The ordinary proportion of moisture at the fiber-saturation point is from 22 to 30 per cent of the dry weight of the wood.

from green to zero moisture. The specimens on which the data are based were air dried at room temperatures from the green condition and then oven dried to constant weight at 100° C. Shrinkage to an air-dry condition of about 12 per cent moisture is sometimes more and sometimes less than half the total shrinkage. Radial shrinkage is the measure of the change in width of a quarter-sawed or edge-grain board. Tangential shrinkage is the measure of the change in width of a flat-sawed board.

### Columns 13, 14, 15, 16, and 17, Static Bending

In the static bending test a 2 by 2 by 30 inch beam is supported over a 28-inch span. Loading is applied to its center and at a constant rate of deflection until the beam fails. (Fig. 2.) Readings of load and deflection are taken simultaneously.

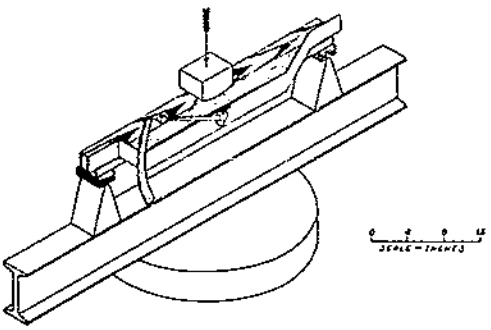

Figure 2.—Diagrammatic sketch of method of conducting static bending test

The values derived from this test are applicable to beams of any size by the use of a bending formula, except for the defects that occur in the larger sizes.

#### Fiber Stress at Elastic Limit

Fiber stress at elastic limit is the stress obtained in a timber by loading it to its elastic limit. It is the greatest stress the timber is capable of developing without a permanent deformation remaining upon complete removal of the load.

#### Modulus of Rupture

Modulus of rupture is the computed fiber stress in the outermost fibers of a beam at the maximum load and is a measure of the ability of a beam to support a slowly applied load for a very short time. The formula by which modulus of rupture is computed is the same as that for fiber stress at elastic limit, the maximum load being substituted for the elastic limit load. The assumptions on which this formula are based hold only up to the elastic limit, hence modulus of rupture is not a true fiber stress. It is, however, a universally accepted term, and the values are quite comparable for various species and sizes of timber. It is a definite quantity, and the personal factor does not enter to any great extent into obtaining it. It is consequently not so subject to error as the fiber stress at elastic limit, and for that reason is used more than any other value to represent the strength of wood. Modulus of rupture should always be considered in calculating the strength of beams to be used as stringers, floor joists, and the like.

Safe working stresses for carefully selected structural timbers, with all exceptionally light pieces excluded, subjected to bending in dry interior construction and where only small deflections are allowable are about one-fifth the modulus of rupture values given in Table

4 for green material. In some interior construction where beams may be allowed to sag somewhat without damage, the working stresses may be slightly increased. But for timbers used in bridges or other structures exposed to moisture, the working stress should be lower. However, beams can not be correctly designed on the basis of outer fiber stress in bending alone. Strength in longitudinal shear and bearing area must also be taken into account.

#### MODULUS OF ELASTICITY

The modulus of elasticity is a measure of the stiffness or rigidity of a material. In the case of a beam, modulus of elasticity is a measure of its resistance to deflection. The formula connecting modulus of elasticity, load, and deflection shows that the deflection under a given load varies inversely as the modulus of elasticity; that is, a beam with a high modulus deflects but little. Modulus of elasticity is of value in computing the deflections of joists, beams, and stringers, and in computing safe loads for long columns. The values given are derived from the static bending test, but are applicable to both beams and long columns.

#### WORK IN BENDING TO ELASTIC LIMIT

Work to elastic limit in static bending is a measure of the work that a beam is able to resist or the shock that it can absorb without being stressed beyond the elastic limit as determined under slowly applied loads.

#### WORK IN BENDING TO MAXIMUM LOAD

Work to maximum load in static bending represents the ability of the timber to absorb shock with some permanent deformation and with more or less injury to the timber. Work to maximum load is a measure of the combined strength and toughness of a material under bending stresses. Superiority in this quality is one characteristic which makes hickory better than ash, and oak better than longleaf pine, for such uses as handles and vehicle parts. Many species yield butt cuts that exceed upper cuts in combined strength and toughness, hickory showing this characteristic most markedly. The superiority of butt cuts of hickory to upper cuts for ax handles is well known to experienced woodsmen.

### Columns 18, 19, and 20, Impact Bending

The impact bending test is made upon a beam 2 by 2 by 30 inches over a 28-inch span. A 50-pound hammer is dropped upon the stick at the center of the span, first from a height of 1 inch, next 2 inches, and so on up to 10 inches, then increasing 2 inches at a time until complete failure occurs. The deflections of the specimen are recorded on a revolving drum by a pointer attached to the hammer. The pointer also records the position the specimen assumes after the shock. Thus data are obtained for determining the various properties of the wood when subjected to shock.

#### FIBER STRESS AT ELASTIC LIMIT

Fiber stress at elastic limit is the greatest stress to which a timber may be subjected under impact loading and recover immediately. Fiber stress at elastic limit in impact is approximately double the fiber stress at elastic limit in static bending. This is an expression of the fact that a small beam, if suddenly strained, bends approximately twice as far to the elastic limit as when loaded slowly. (See also fiber stress at elastic limit, p. 73.)

#### WORK IN BENDING TO ELASTIC LIMIT

Work in bending to the elastic limit in impact is a measure of the ability of a timber to absorb shock and recover therefrom immediately and without injury. The values apply only to resistance to falling bodies or to other conditions in which the stress is applied and relieved in one twenty-fifth of a second or less. It represents a quality important in tool handles and in athletic goods, such as baseball bats.

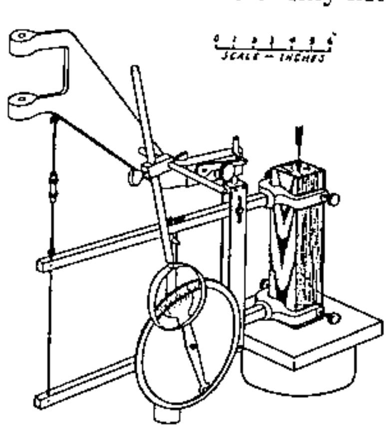


FIGURE 3.—Diagrammatic sketch of compressometer and method of conducting compression-parallel-to-grain test

### COLUMNS 21 AND 22 COMPRESSION PARALLEL TO GRAIN

Height of drop is the maximum or the last drop of the hammer that causes failure. It represents a quality important in articles that are occasionally stressed under a shock beyond their elastic limit, such as handles and vehicle and implement parts.

### COLUMNS 21 AND 22 COMPRESSION PARALLEL TO GRAIN

In the compression parallel to grain test a 2 by 2 by 8 inch block is compressed in the direction of its length. (Fig. 3.) Deformation is measured between two collars attached 6 inches apart to the specimen.

#### FIBER STRESS AT ELASTIC LIMIT

Fiber stress at elastic limit in compression parallel to the grain is little used because it is usually more convenient to use maximum crushing strength, which is less variable and easier to obtain. Fiber stress at elastic limit is important in the derivation of safe working stresses for structural timber. (See also fiber stress at elastic limit, p. 73.)

#### MAXIMUM CRUSHING STRENGTH

The maximum crushing strength is the maximum ability of a short block to sustain a slowly applied end load. It is obtained by dividing the maximum load obtained in the test by the area of cross section of the block. This property is important in estimating the strength of short columns and those of intermediate length.

Tests of the crushing strength, because of their simplicity, are frequently the only tests used in studying the effect of various influences or processes on strength. Crushing strength is not necessarily representative of the other strength properties.

A safe working stress for carefully selected structural timbers used as short columns and in dry interior construction, provided all exceptionally light pieces are excluded, is about one-third to one-fourth the crushing strength as given in Table 4 for tests on green materials. If the column is longer than about 10 times its least diameter, a formula should be used that will take care of the increased stress which would be caused by eccentric loading or by the bending of the column (*14*).

### Column 23, Compression Perpendicular to Grain

In the compression-perpendicular-to-grain test, a block 2 by 2 inches in cross section and 6 inches long is laid upon its side and pressure applied to it through an iron plate 2 inches wide laid across the center of the piece and at right angles to its length. (Fig. 4.) Hence but one-third of the surface is directly subjected to compression.

The only strength value obtained in this test is the fiber stress at elastic limit. It represents the maximum stress across the grain which can be applied to the timber without injury. It is important in computing the bearing area for beams, stringers, and joists, and in comparing species for railroad ties.

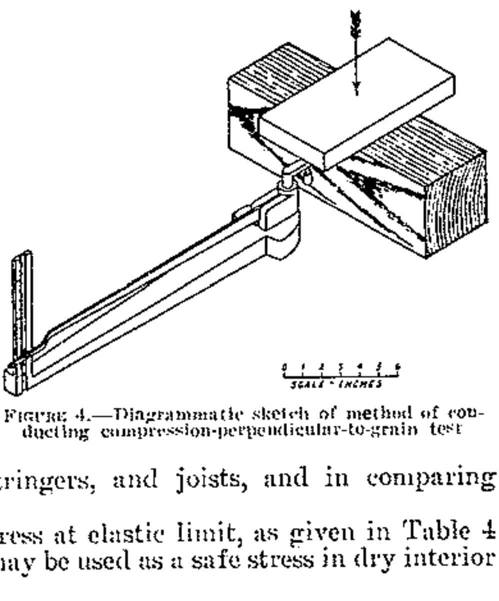


Figure 4.—Diagrammatic sketch of method of conducting compression-perpendicular-to-grain test

Two-thirds of the fiber stress at elastic limit, as given in Table 4 for tests on green material, may be used as a safe stress in dry interior construction.

### Column 24, Shearing Strength Parallel to Grain

The shearing test is made by applying force to a 2 by 2 inch lip projecting from the side of a block. (Fig. 5.) The shearing stress is the maximum force required to shear off the projection divided by the area of the plane of failure.

Shearing strength parallel to the grain is a measure of the ability of timber to resist slipping of one part upon another along the grain. Shearing stress is produced in most uses of timber. It is most important in beams, where it is known as horizontal shear—the stress tending to cause the upper half of the beam to slide upon the lower. It is also important in the design of various kinds of timber joints.

Only about one-eighth of the values given in the table for green material (Table 4) should be used as allowable stress in horizontal shear in beams. For small details, in timber unaffected by shakes or checks, the allowable stress may be taken as 50 per cent greater.

### Column 25, Tension Perpendicular to Grain

The tension-perpendicular-to-grain tests are made on specimens 2 inches square and 2½ inches long, the tension area being 1 by 2 inches. The tension force is applied perpendicular to the grain. (Fig. 6.) The values are of use in estimating the resistance of timber to the splitting actions of bolts and other fastenings. A factor of 5 should be applied to the values in Table 4 to get the allowable stress for design; that is, one-fifth of the values given in the table.

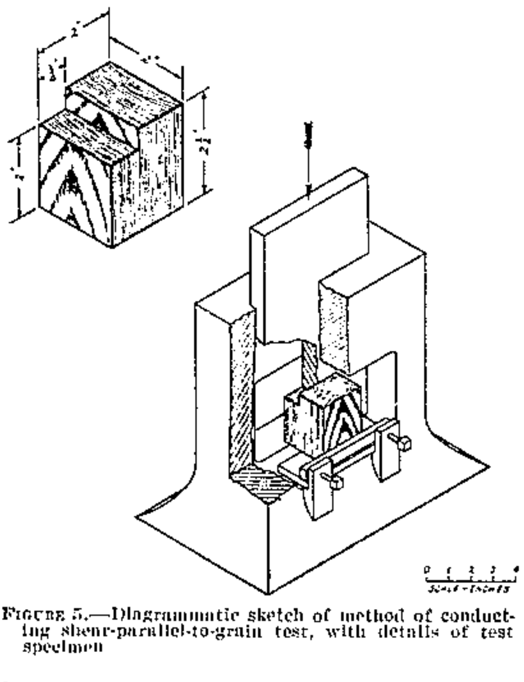

Figure 5.—Diagrammatic sketch of method of conducting shear-parallel-to-grain test, with details of test specimen

### Columns 26 and 27 Hardness

Hardness is tested by measuring the load required to embed a 0.444-inch ball to one-half its diameter in the wood. (Fig. 7.) The hardness test is applied to end, radial, and tangential surfaces of the timber. There is no significant difference between radial and tangential hardness and they are averaged and tabulated as "side hardness." End hardness is usually greater than side hardness. The quality represented by the figures is important in woods for railroad ties, furniture, flooring, and the like.

## PRECAUTIONS TO BE OBSERVED IN THE USE OF DATA

The test results obtained in studying the properties of clear wood are dependent on the size and form of test specimens, the rate of loading, and other factors entering into methods of testing, and in seasoned material on the moisture content. Care should accordingly be used in attempting to compare the data with that from other sources in which a different test procedure has been used.

The figures of Tables 2, 3, and 4 are primarily for the comparison of species in the form of clear lumber. For comparing structural timbers in which the defects are limited with reference to their effect on strength, the allowable working stresses presented in Table 19 are recommended.

## VARIATION IN STRENGTH OF WOOD

Variability is a characteristic of all materials, although there may be wide differences in its magnitude. The living tree is subjected to numerous influences that have a bearing on the wood produced, and it is not surprising as a result that even the clear wood is often regarded as a variable product. The influences acting on the tree include the amount of sunlight, type of soil, temperature, rainfall, heredity, and the like. Fortunately, the variations in the properties of wood usually bear a relation to the specific gravity or density, and

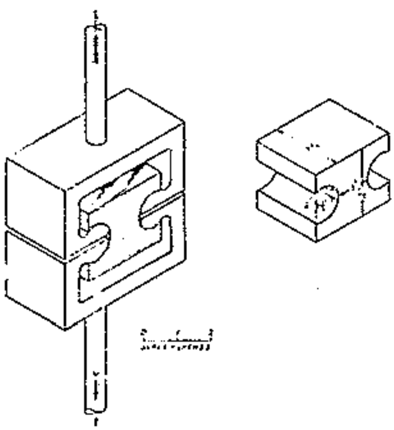

FIGURE 6.—Diagrammatic sketch of method of conducting tension-perpendicular-to-grain test, with details of test specimen

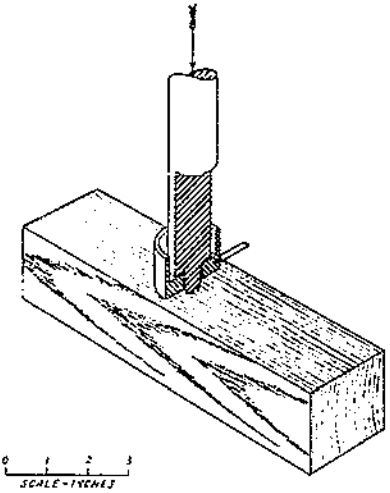


FIGURE 7.—Diagrammatic sketch of method of conducting hardness test

in some cases to physical characteristics, such as proportion of summer wood or rate of growth, so that in cases of importance, selection methods can be used to secure wood of desired properties to meet any given requirements. Accordingly, the variability which is usually thought of as a liability may actually become an asset, particularly inasmuch as a range in properties permits adaptation to a range of uses.

In studying the mechanical properties of wood, tests are made on many specimens of a species. The most useful and convenient method of presenting these test results is in the form of average figures, as is done in Tables 2, 3, and 4. At times, however, it is necessary to know something of the range in properties or of the variability of the results. Table 5 affords a basis for estimating variability of any species with respect to its different properties.

TABLE 5.—*Approximate figures for variation of properties with specific gravity; reliability of averages, and probable deviations of individual specimens from averages*

[For use with Tables 2, 3, and 4]

| Property | Approximate power of specific gravity according to which property varies | Probable variation of present average (when from 5 trees) from true species average | Estimated probable variation of an individual piece from average for species |
|---|---|---|---|
| 1 | 2 | 3 | 4 |
| | | *Per cent* | *Per cent* |
| Specific gravity based on volume when green | | 2.4 | 8 |
| Weight per cubic foot [1] | | | |
| Shrinkage: [1] | | | |
| Radial | | | 11 |
| Tangential | | | 10 |
| Volumetric | 1 | | 12 |
| Static bending: | | | |
| Fiber stress at elastic limit | 1¼ | 5 | 16 |
| Modulus of rupture | 1¼ | 4 | 12 |
| Modulus of elasticity | 1 | 5 | 16 |
| Work to elastic limit | 1½ | 7 | |
| Work to maximum load | 1¾ | 6 | 23 |
| Impact bending: | | | |
| Fiber stress at elastic limit | 1¼ | 4 | 13 |
| Work to elastic limit | 1½ | 5 | |
| Height of drop | 1¾ | 7 | 18 |
| Compression parallel to grain: | | | |
| Fiber stress at elastic limit | 1 | 5 | 18 |
| Maximum crushing strength | 1 | 4 | 13 |
| Compression perpendicular to grain—fiber stress at elastic limit | 2¼ | 6 | 21 |
| Hardness, end | 2¼ | 4 | 13 |
| Hardness, side | 2¼ | 5 | 15 |
| Shearing strength parallel to grain | 1¼ | 3 | |
| Tension perpendicular to grain | 2 | 5 | |

[1] See explanation, p. 35.

## EXPLANATION OF TABLE 5

The figures in Table 5 are presented as an aid and safeguard to the use of data given in Tables 2, 3, and 4 and are explained as follows:

### COLUMN 1

The explanation of the properties given in column 1 of Table 5 is the same as that given for Tables 2, 3, and 4.

### COLUMN 2

Study of data has shown that each of the shrinkage and strength properties of a given species can be estimated with fair accuracy from the average specific gravity, since each varies approximately according to some power of the specific gravity. This power is given in column 2. However, the specific-gravity relationship to properties should be regarded as a general trend, rather than a perfectly uniform law, as most species usually depart from it in one or more properties. A departure from the general relation that applies to most species usually indicates some exceptional characteristic of a species, which may make it particularly desirable for certain use requirements.

COLUMN 3

The figures in column 3 are derived from the original data on which the averages given in Tables 2, 3, and 4 are based, as well as on additional data, by the use of the processes usually employed to determine the accuracy of experimental data. They are not to be taken as too rigidly applicable to these averages (Tables 2, 3, and 4), but are a convenient approximate measure of the reliability of the averages.

The probable variation of the species average as given in column 3 is a measure of the reliability of the present averages and of the probable change in these averages by additional tests.

COLUMN 4

Column 4 presents an estimate of the probable variation of an individual piece from the average for a species. Conversely, it may be used to estimate the proportion of material falling within any percentage of the average. To illustrate, consider the figure for modulus of rupture, 12 per cent. This means that there is 1 chance in 4 that the modulus of rupture of an individual specimen taken at random will be below 88 per cent of the species average, 1 chance in 4 that it will be above 112 per cent, and 2 chances in 4 that it will be between 88 and 112 per cent of this average. Or, it would be expected that about 50 per cent of the material would fall within ±12 per cent of the average in modulus of rupture.

## GENERAL DISCUSSION AND DEDUCTIONS

The sampling and testing of Alaska woods has not been extensive enough to afford as complete an appraisal of the properties and range of properties as might be desired, for it is known that appreciable differences in properties may occur even in adjacent localities. In planning the study, however, it was necessary to keep the work within certain definite limitations, similar to those used in the general study of the properties of woods grown in the United States. It is felt that properly interpreted, the results are a valuable means of appraising the properties and establishing design values.

Tables 2 and 3 show a fairly close agreement in strength values obtained for certain species in Alaska with those for lots of the same species from other regions. Considering the aggregate of six of the most important strength properties, this similarity is evident in the western hemlock from Cordova, Alaska, compared with that from Washington and that from Oregon; in balsam poplar from Girdwood, Alaska, compared with the shipment from Bennington County, Vt.; and in Sitka spruce from Girdwood and Ketchikan, Alaska, compared with the two shipments from Oregon.

Of the various species tested, only western red cedar shows a difference as great as 10 per cent in average properties in favor of any shipment from other parts of the United States. In this case the material from Snohomish County, Wash., was about 10 per cent higher in the average of several properties than that from Ketchikan, Alaska. At the same time the Alaska western red cedar averaged higher by about 7 per cent than did that from Missoula County, Mont. These differences may be due to chance in sampling, or at most, can be regarded as applicable to the particular and immediate sites from which the samples were taken. They should not necessarily be interpreted, however, as representing the relative strengths of this species in these respective general geographical regions.

On the other hand, it may be noted that in six cases the averages of the Alaska material, by localities, are 10 per cent or more higher in the principal strength properties than certain individual shipments from other regions of the United States. These cases are found in Alaska cedar, mountain hemlock, western hemlock, and Sitka spruce.

In considering the causes of variations in properties of wood, it may first be observed that there are many factors affecting tree growth. Immediate site factors, such as soil, soil moisture, and competition for light and food, are subject to large variations within small areas, and are further subject to large variations within the life of the tree. Their effect, within the normal range of a species, is seemingly of greater importance than geographical location, as is shown by significant differences in strength properties of samples of a species from adjacent areas and from the inner and outer portions of the same tree and similarity in strength of samples from widely separated regions.

A specific example is noted in Sitka spruce. Tests show differences between averages of samples from two localities in Oregon of 12 per cent in specific gravity and 20 per cent or more in modulus of rupture, which is several times the probable difference that would be expected considering all Sitka spruce as belonging to the same population. In contrast, the average for samples of Sitka spruce from near Ketchikan, Alaska, tested in a green condition, was identical in specific gravity with that of one of these groups of samples from near Portland, Oreg., and was within a few per cent in modulus of rupture. These and similar observations lead to the general conclusion that, in the absence of specific data concerning any given lot of material, the general average of all material for the species is a more reliable estimate of the strength properties than data on samples from adjacent localities or from sites that appear to be the same. This does not mean, however, that there may not be differences apparent in the grade and quality of wood from different stands, such as prevalence of defects, seasoning characteristics, and the like, sufficient in importance to justify marketing preferences.

The whole problem of the effect of region, site, and conditions of stand on wood properties is an exceedingly complicated one, and sufficient data are not available nor has sufficient study been made to attempt a final appraisal. The data show quite conclusively that the mechanical properties of woods from the coastal forests of Alaska are fully the equal of those of the same species grown elsewhere. Moreover, the growth conditions appear to be favorable to the production of timber of good strength properties.

The average strength values for the species given in Table 4, which are based on all comparable tests made at the Forest Products

Laboratory, are accordingly recommended as a basis for species comparison. They may likewise be used in wood design where the properties of clear material are required or as a basis for arriving at safe working stresses for structural timbers. Comparisons with other species not listed in Table 4 may be made by means of Department Bulletin 556 (*17*); or if a less technical discussion of simplified strength properties is desired the data on Alaska woods combined with that of the same species from other regions will be found in Technical Bulletin 158 (*13*).

Taken as a whole, the information presented in Tables 2, 3, and 4 shows that the different Alaska species have a large range in properties and are available to fill many diverse demands in addition to the pulp and paper possibilities, which offer the most significant outlet for Alaska woods.

## TESTS OF FULL-SIZED SAWED STRUCTURAL TIMBERS OF SITKA SPRUCE AND WESTERN HEMLOCK[6]

### SELECTION OF MATERIAL

#### Sitka Spruce

The Sitka spruce logs from which the structural timber test material was taken were cut in the Tongass National Forest, near Ketchikan, and were from 300 to 400 years old. The logs were sawed at Ketchikan. Twenty 8 by 16 inch by 32-foot timbers, which were selected by representatives of the Forest Service, arrived at the former Seattle laboratory of the Forest Service shortly after manufacture. Although some of the pieces showed surface checking when received, the material was still in an essentially unseasoned condition. On arrival at Seattle, Wash., the timbers were numbered and cut into 16-foot lengths, after which they were graded in accordance with the export rules of the Pacific Lumber Inspection Bureau by one of their representatives.

In selecting the 32-foot stringers an effort was made to obtain pieces that could each be cut into two 16-foot lengths of the same grade, the object being to alternate the butt and top 16-foot pieces for tests of green and air-seasoned material, the green portion to consist in equal parts of high and low density pieces of the same grades and the air-seasoned portion to be made up in the same way, thus obtaining as nearly perfect matching of the two portions as possible. However, it was impracticable to obtain the 32-foot stringers in exactly the way desired, but after they were cut into 16-foot lengths and regraded, the green and seasoned pieces, alternating butt and top, matched well for both grade and density. Immediately after the material was regraded tests were started on the stringers to be tested in the green condition. The other half was stored under cover for air seasoning and were tested after drying.

#### Western Hemlock

The western hemlock logs from which the test material was taken were cut in the Tongass National Forest, near Ketchikan. The test

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[6] The tests were made by C. W. Zimmerman and H. Curtis Stinson, of the former Seattle laboratory of the Forest Service.

material, as in the case of the Sitka spruce, comprised timbers 8 by 16 inches by 32 feet, but consisted of two independent shipments.

The first shipment comprised 20 green stringers, which were received in Seattle in July, 1922. They were promptly taken to the laboratory, and there cut into 16-foot lengths, marked, graded, and divided into two matched groups for tests of green and of seasoned material.

The pieces to be tested green were kept from seasoning by storing in a bin and covering with wet sawdust, a treatment being applied to retard molding. The pieces intended for air seasoning were open piled under an open shed. They were weighed monthly until time of test to determine the rate of seasoning, and were allowed to air dry two years before testing.

The second shipment of western hemlock comprised nine green stringers, which were received in Seattle, November, 1922. The subsequent procedure was similar to that just described for the first shipment.

### CHARACTER OF TESTS

The tests on both Sitka spruce and western hemlock were of two kinds; (1) on full-sized structural members, and (2) on small, clear specimens cut from them. The study of small, clear specimens was made to determine the strength of the wood free from defects as compared with the structural sizes containing defects. The procedure used corresponded to that of the American Society for Testing Materials (*4*), except that on the small, clear specimens no hardness tests were made, 6 rather than 12 shear-parallel-to-grain specimens were tested, and the compression-perpendicular-to-grain specimens were 2 by 2 by 8 inches rather than 2 by 2 by 6 inches.

The tests on large pieces consisted of bending, compression parallel to grain, and compression perpendicular to grain; the minor tests on small, clear pieces consisted of static bending, compression parallel to grain, compression perpendicular to grain, and shear parallel to grain.

## Tests on Large Pieces

### BENDING

The static bending tests were made on 8 by 16 inch by 16 foot beams, using a 15-foot span and "third-point" loading, which consists of two symmetrical loads spaced one-third of the span. (Pl. 9.) Six beams were tested with spans slightly less than 15 feet.

### COMPRESSION PARALLEL TO GRAIN

Two compression-parallel-to-grain specimens (5½ by 5½ by 24 inches) were taken from the uninjured portion of each beam after the bending test.

### COMPRESSION PERPENDICULAR TO GRAIN

One compression-perpendicular-to-grain specimen (8 by 16 by 30 inches) was obtained from each timber after the bending test.

### TESTS ON SMALL, CLEAR SPECIMENS

Tests on small, clear specimens cut from the uninjured portion of the large beams, consisted for each beam of 6 static bending specimens (2 by 2 by 30 inches), 6 compression-parallel-to-grain specimens (2 by 2 by 8 inches), 3 compression-perpendicular-to-grain specimens (2 by 2 by 8 inches), and 6 shear-parallel-to-grain specimens (2 by 2 by 2½ inches). The testing procedure conformed in most details to that of the American Society for Testing Materials (2).

## TEST RESULTS

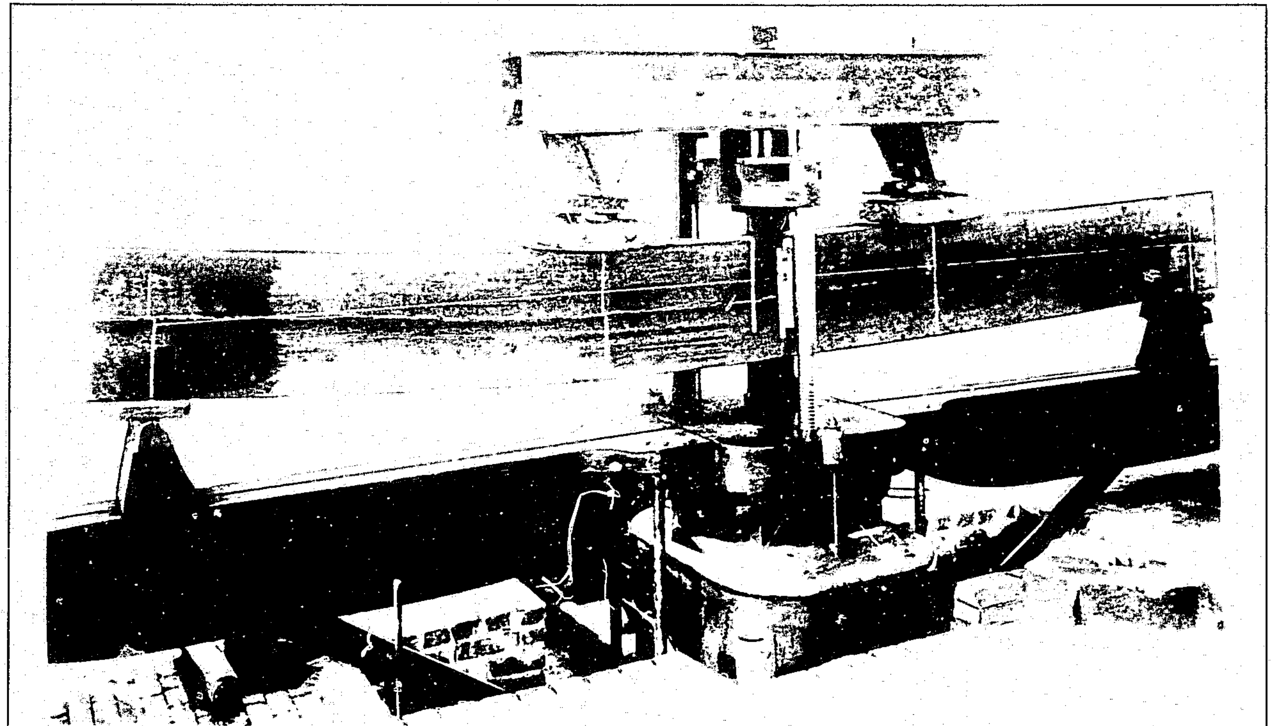
A summary of the results of tests on the western hemlock and Sitka spruce structural timbers is presented in Table 6. The results for individual timbers will be found in the appendix.

These data are in general conformity with deductions which have been previously published (*6*, *14*, *15*, *16*). The results show that the strength of structural timbers is dependent on the size and location of defects; that defects develop in large timbers with seasoning and thus tend to offset the gain in strength with loss of moisture; that knots seriously affect the bending strength (modulus of rupture), and have little effect on stiffness (modulus of elasticity); that individual timbers vary in strength because of differences in density or dry weight of the wood; and that the test values are related to safe working stresses, the engineer's guide in all timber design work.

TABLE 6.—*Average results of tests on structural timbers from Alaska and of small, clear specimens cut from them*

| Species | Condition when tested | Type of specimen | Static bending | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tests | Cross section | Span | Loading | Moisture content | Specific gravity | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity | Work to elastic limit | Work to maximum load | Horizontal shear stress at maximum load |
| | | | *No.* | *Inches* | *Inches* | | *Per cent* | | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in* | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Pounds* |
| Western hemlock | Green | Structural | 29 | 8 by 16 | 180 | Third point | 41.6 | 0.43 | 3,150 | 4,880 | 1,350 | 0.69 | 3.5 | 330 |
| Do | do | Small, clear | 174 | 2 by 2 | 28 | Center | 43.3 | .43 | 3,860 | 7,030 | 1,340 | .64 | 8.5 | 250 |
| Sitka spruce | do | Structural | 20 | 8 by 16 | 180 | Third point | 34.2 | .36 | 2,290 | 4,160 | 1,250 | .38 | 3.3 | 280 |
| Do | do | Small, clear | 119 | 2 by 2 | 28 | Center | 37.2 | .35 | 2,440 | 5,360 | 1,290 | .28 | 5.6 | 190 |
| Western hemlock | Air seasoned | Structural | 29 | 8 by 16 | 180 | Third point | 17.5 | .44 | 3,940 | 5,750 | 1,520 | .95 | 2.9 | 390 |
| Do | do | Small, clear | 174 | 2 by 2 | 28 | Center | 8.5 | .46 | 8,440 | 13,460 | 1,780 | 2.25 | 10.4 | 470 |
| Sitka spruce | do | Structural | 20 | 8 by 16 | 180 | Third point | 17.3 | .37 | 3,800 | 5,310 | 1,400 | .96 | 2.9 | 350 |
| Do | do | Small, clear | 120 | 2 by 2 | 28 | Center | 14.6 | .37 | 5,120 | 8,470 | 1,410 | 1.05 | 9.2 | 300 |

| Species | Condition when tested | Type of specimen | Compression parallel to grain | | | | Compression perpendicular to grain | | | | Shearing strength parallel to grain | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Tests | Moisture content | Specific gravity | Maximum crushing strength | Tests | Moisture content | Specific gravity | Fiber stress at elastic limit | Tests | Moisture content | Average of radial and tangential shear |
| | | | *No.* | *Per cent* | | *Lbs. per sq. in.* | *No.* | *Per cent* | | *Lbs. per sq. in.* | *No.* | *Per cent* | *Lbs. per sq. in.* |
| Western hemlock | Green | Structural | 50 | 41.0 | 0.42 | 3,140 | 29 | 42.3 | 0.42 | 360 | | | |
| Do | do | Small, clear | 174 | 42.8 | .42 | 3,200 | 87 | 48.2 | .45 | 400 | 163 | 79.7 | 710 |
| Sitka spruce | do | Structural | 37 | 35.0 | .36 | 2,510 | 20 | 35.7 | .36 | 180 | | | |
| Do | do | Small, clear | 119 | 35.8 | .35 | 2,530 | 60 | 36.6 | .35 | 260 | 120 | 35.7 | 650 |
| Western hemlock | Air seasoned | Structural | 58 | 9.7 | .45 | 6,840 | 29 | 17.7 | .44 | 580 | | | |
| Do | do | Small, clear | 174 | 8.2 | .46 | 8,500 | 87 | 8.5 | .46 | 740 | 142 | 9.3 | 1,130 |
| Sitka spruce | do | Structural | 33 | 14.9 | .37 | 4,560 | 18 | 15.1 | .38 | 440 | | | |
| Do | do | Small, clear | 118 | 13.4 | .37 | 4,860 | 54 | 13.8 | .38 | 470 | 107 | 12.8 | 850 |



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Forest Service Method of Testing Timbers of Structural Size. The Beam is 8 by 16 Inches in Cross Section and is Being Tested Under Third-Point Loading Over a Span of 15 Feet

The Sitka spruce timbers, which were cut from relatively large trees, were uniformly of high grade and in many cases of entirely clear wood on the exposed faces. It is obviously possible to secure much high-grade structural timber from Alaska-grown Sitka spruce, and this species should be very useful, particularly for local requirements. Considering the many desirable properties and characteristics of the species, however, which make it so satisfactory for higher-class uses, such as airplane wing beams and musical-instrument sounding boards, it is hardly to be expected that Sitka spruce need enter competition with other species in the structural-timber field. Its lack of natural decay resistance, furthermore, precludes its use for timbers to be used under conditions favorable to decay, except when treated with creosote or other wood preservatives.

With western hemlock, the situation is quite the reverse. Only the largest western hemlock trees are big enough to furnish long timbers of the 8x16-inch bridge-stringer size tested, and these are most naturally obtained from the butt cuts. The western hemlock timbers as a whole were of much lower grade than the Sitka spruce, because of the prevalent heart rot in the large overmature trees, the many shakes and inclosed bark pockets in the butt timbers, and the numerous rotten knots. It appears, therefore, that while western hemlock has excellent strength properties, and timbers of high grade can be secured by proper selection at the mill, the possibility of producing large-sized timbers of this species for export is not encouraging. On the other hand, there are many local uses where western hemlock timbers may be admirably adapted, perhaps to replace imported woods, and these data should furnish a sound basis and encouragement for such utilization. This is, of course, aside from the use of western hemlock for dimension, for lumber purposes, for material in the form of small, clear stock, and for pulpwood requirements.

Safe working stresses recommended by the Forest Products Laboratory for Alaska-grown woods and other common woods for the American lumber standards grades of select and common are given in the appendix.

Structural grading rules conforming to American lumber standards and specifications for timbers for different uses requiring both treated and untreated material have been adopted and published by the American Society for Testing Materials (*3*) and the American Railway Engineering Association (*1*). These specifications are excellent from both the technical and practical engineering standpoint, and are recommended for use with structural timbers of Alaska species.

## TESTS OF FULL-SIZED ROUND MINE TIMBERS OF ALASKA BIRCH, WESTERN HEMLOCK, SITKA SPRUCE, AND WHITE SPRUCE[7]

### SELECTION OF MATERIAL

The material for test consisted of 15 round props and 15 caps each of white spruce, Alaska birch, Sitka spruce, and western hemlock.

[7] The tests were made by C. W. Zimmerman, of the former Seattle laboratory of the Forest Service.

The material was grown on the Chugach National Forest and was representative of the market run of timber. The timbers were nominally 5 to 6 inches in top diameter, the props were 6 feet in length, and the caps 8 feet. They were received and tested in a green condition at the former Seattle laboratory of the Forest Service.

### CHARACTER OF TESTS

The method of testing was identical to the procedure described and illustrated in Department Bulletin 77 (*5*).

The 6-foot props were tested in compression parallel to the grain, the descent of the movable head of the testing machine being 0.12 inch per minute. The compression of the prop was measured between the movable testing machine head and the weighing platform.

The 8-foot caps were tested in bending on a 7-foot span with third-point loading. The rate of descent of the movable head of the testing machine was 0.23 inch per minute. Deflections were taken at the center of the specimen.

### TEST RESULTS

Table 7 presents a summary of the results of compression tests of mine props of four Alaska woods, together with similar data on a number of species from Colorado. Table 9 presents like information with respect to the bending tests of mine caps. The test values for individual timbers from Alaska are given in the appendix. The data on woods from Colorado are taken from Department Bulletin 77 (*5*).

TABLE 7.—*Average results of crushing tests of green round mine props from Alaska compared with those from other regions*

(Nominal size, 5-inch top diameter by 6 feet long)

| Species | Place of growth of material tested | Trees tested | Moisture content | Approximate dry weight (volume as tested) | Rings per inch | Summer wood | Sapwood |
|---|---|---|---|---|---|---|---|
| | | *Number* | *Per cent* | *Lbs. per cu. ft.* | *Number* | *Per cent* | *Per cent* |
| Alaska birch | Chugach National Forest, Alaska. | 15 | 68.4 | 32.7 | ----- | ----- | |
| Western hemlock | do | 15 | 68.1 | 31.9 | 46 | | |
| Sitka spruce | do | 15 | 50.6 | 29.9 | 40 | | |
| White spruce | do | 15 | 83.7 | 25.3 | 33 | | |
| Alpine fir | Colorado | 9 | 91.0 | 21.4 | 36 | 15 | |
| Douglas fir (mountain type) | do | 10 | 50.5 | 27.5 | 39 | 23 | 37 |
| Bristlecone pine | do | 10 | 85.9 | 27.7 | 35 | 20 | 46 |
| Lodgepole pine | do | 10 | 75.7 | 23.8 | 40 | 18 | 54 |
| Do | Boulder County, Colo. | 10 | 70.8 | 22.0 | 43 | 10 | 48 |
| Western yellow pine | Pike National Forest, Colo | 10 | 96.1 | 23.2 | 14 | 15 | |
| Do | Gunnison National Forest, Colo | 10 | 82.0 | 24.8 | 18 | 10 | ----- |
| Engelmann spruce | Pike National Forest, Colo | 11 | 62.3 | 24.1 | 32 | 10 | ----- |

TABLE 7.—*Average results of crushing tests of green round mine props from Alaska compared with those from other regions*—Continued

| Species | Place of growth of material tested | Trees tested | Diameter | | Crushing strength at maximum load | Crushing strength at elastic limit | Modulus of elasticity |
|---|---|---|---|---|---|---|---|
| | | | Top | Butt | | | |
| | | *Number* | *Ins.* | *Ins.* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* |
| Alaska birch | Chugach National Forest, Alaska. | 15 | 5.76 | 6.15 | 2,870 | 2,250 | 1,352 |
| Western hemlock | do | 15 | 5.86 | 6.36 | 3,060 | 2,230 | 1,224 |
| Sitka spruce | do | 15 | 4.84 | 5.81 | 2,460 | 1,681 | 1,040 |
| White spruce | do | 15 | 5.64 | 6.16 | 2,620 | 2,230 | 1,229 |
| Alpine fir | Colorado | 9 | 4.90 | 5.65 | 1,920 | 1,490 | 541 |
| Douglas fir (mountain type) | do | 10 | 5.48 | 6.05 | 2,580 | 2,130 | 758 |
| Bristlecone pine | do | 10 | 4.58 | 5.38 | 1,660 | 1,310 | 508 |
| Lodgepole pine | do | 10 | 5.73 | 6.18 | 1,880 | 1,490 | 599 |
| Do | Boulder County, Colo | 10 | 5.90 | 6.58 | 1,600 | 1,240 | 490 |
| Western yellow pine | Pike National Forest, Colo | 10 | 4.44 | 5.20 | 1,470 | 1,200 | 443 |
| Do | Gunnison National Forest, Colo. | 10 | 5.35 | 6.00 | 1,940 | 1,450 | 561 |
| Engelmann spruce | Pike National Forest, Colo. | 11 | 4.95 | 5.80 | 1,750 | 1,350 | 529 |

MINE PROPS

It may be seen from Table 7 that Douglas fir [8] averaged the strongest of the six species from Colorado. With the exception of Sitka spruce, however, each of the Alaska species tested averaged higher than Douglas fir (Rocky Mountain type) in crushing strength. The Sitka spruce, although a little below the Douglas fir, withstood greater average unit crushing stress than any of the other Rocky Mountain species in this series of tests. Western larch, which is higher in strength than Douglas fir (Rocky Mountain type) and is used as a mine timber in the Rocky Mountain region, was not included in these tests of mine props or mine caps.

Table 8, in which the maximum crushing strength of the green mine props is given as a percentage of Douglas fir from the Rocky Mountains, may better serve to bring out these comparisons. Values based on standard tests of small, clear specimens are also given for the same species in a green condition.

TABLE 8.—*Maximum crushing strength of green mine props and small, clear specimens of Alaska and Rocky Mountain species*

[Douglas fir considered as 100 per cent]

| Source and species | Maximum crushing strength | |
|---|---|---|
| | Mine props | Small, clear specimens |
| Alaska: | *Per cent* | *Per cent* |
| Alaska white birch | 111 | 101 |
| Western hemlock | 119 | 101 |
| Sitka spruce | 95 | 92 |
| White spruce | 102 | 91 |
| Rocky Mountains: | | |
| Douglas fir | 100 | 100 |
| Alpine fir | 74 | 69 |
| Bristlecone pine | 64 | ---------- |
| Lodgepole pine | 67 | 87 |
| Western yellow pine | 66 | 79 |
| Engelmann spruce | 68 | 66 |

[8] Douglas fir from Colorado is classed as belonging to the Rocky Mountain type, which averages lower in strength than that from the Pacific Northwest. Comparison of Alaska species is made with species from Colorado because no data on mine timbers are available for material from the Pacific Northwest.

Table 8 shows that the Alaska white birch, western hemlock, Sitka spruce, and white spruce from Alaska compared favorably with some of the species commonly used for mine props in the Rocky Mountain region.

### MINE CAPS

From Table 9 it may be observed that Douglas fir leads the other Rocky Mountain species in bending strength tests of mine caps. Each of the Alaska species tested with the exception of white spruce averaged higher than the Douglas fir (Rocky Mountain type) in modulus of rupture, and the white spruce averaged higher than the other Rocky Mountain woods.

TABLE 9.—*Average results of bending tests of green round mine caps from Alaska compared with those from other regions*

(Nominal size, 5-inch top diameter by 8 feet long; span 7 feet; third-point loading)

| Species | Place of growth of material tested | Trees tested | Moisture content | Approximate dry weight (volume as tested) | Rings per inch | Summer wood | Sapwood |
|---|---|---|---|---|---|---|---|
| | | *Number* | *Per cent* | *Lbs. per cu. ft.* | *Number* | *Per cent* | *Per cent* |
| Alaska birch | Chugach National Forest, Alaska. | 15 | 77.7 | 31.3 | | | |
| Western hemlock | do | 15 | 58.6 | 33.4 | 51 | | |
| Sitka spruce | do | 15 | 45.4 | 29.8 | 46 | | |
| White spruce | do | 15 | 81.4 | 25.2 | 38 | | |
| Alpine fir | Colorado | 9 | 99.5 | 19.6 | 21 | 16 | |
| Douglas fir (mountain type) | do | 10 | 69.4 | 26.5 | 27 | 22 | 50 |
| Bristlecone pine | do | 10 | 74.3 | 27.5 | 37 | 14 | 53 |
| Lodgepole pine | do | 10 | 89.3 | 23.9 | 43 | 19 | 54 |
| Do | Boulder County, Colo. | 10 | 60.6 | 23.8 | 43 | 15 | 40 |
| Western yellow pine | Pike National Forest, Colo. | 10 | 88.5 | 20.9 | 13 | 14 | |
| Do | Gunnison National Forest, Colo. | 10 | 147.1 | 22.2 | 26 | 17 | |
| Engelmann spruce | Pike National Forest, Colo | 11 | 51.3 | 24.0 | 30 | 20 | |

| Species | Place of growth of material tested | Trees tested | Diameter | | Modulus of rupture | Fiber stress at elastic limit | Stiffness[1] factor $\frac{P}{Id}$ |
|---|---|---|---|---|---|---|---|
| | | | Top | Butt | | | |
| | | *Number* | *Inches* | *Inches* | *Lbs. per sq. in.* | *Lbs. per sq. in.* | |
| Alaska birch | Chugach National Forest, Alaska. | 15 | 5.70 | 6.22 | 8,640 | 4,130 | 171.1 |
| Western hemlock | do | 15 | 5.88 | 6.47 | 8,500 | 4,010 | 137.1 |
| Sitka spruce | do | 15 | 5.76 | 6.74 | 7,080 | 3,270 | 119.0 |
| White spruce | do | 15 | 6.18 | 6.97 | 6,340 | 3,550 | 132.9 |
| Alpine fir | Colorado | 9 | 4.65 | 5.72 | 4,140 | 2,450 | 70.3 |
| Douglas fir (mountain type) | do | 10 | 4.78 | 5.66 | 6,570 | 3,400 | 85.2 |
| Bristlecone pine | do | 10 | 4.63 | 5.62 | 4,580 | 2,400 | 66.6 |
| Lodgepole pine | do | 10 | 5.59 | 6.20 | 5,170 | 3,100 | 108.9 |
| Do | Boulder County, Colo. | 10 | 5.78 | 6.45 | 4,770 | 2,760 | 86.0 |
| Western yellow pine | Pike National Forest, Colo. | 10 | 4.39 | 5.60 | 4,330 | 2,170 | 74.5 |
| Do | Gunnison National Forest, Colo. | 10 | 4.42 | 5.45 | 4,900 | 2,590 | 72.6 |
| Engelmann spruce | Pike National Forest, Colo. | 11 | 5.16 | 6.40 | 5,310 | 2,710 | 95.0 |

[1] Owing to the taper of round mine caps, a stiffness factor has been used instead of modulus of elasticity. In this factor $P$ equals the total load in pounds, $I$ equals the moment of inertia, and $d$ equals the deflection in inches at the center of the span.

A comparison of the modulus of rupture of the green mine caps and of small clear specimens in a green condition is presented in Table 10 for the Alaska and Rocky Mountain species.

TABLE 10.—*Modulus of rupture of green mine caps and of small clear specimens in a green condition, Alaska and Rocky Mountain species*

| Source and species | Modulus of rupture | |
|---|---|---|
| | Mine caps | Small, clear specimens |
| Alaska: | *Per cent* | *Per cent* |
| Alaska white birch | 132 | 111 |
| Western hemlock | 120 | 95 |
| Sitka spruce | 108 | 91 |
| White spruce | 97 | 89 |
| Rocky Mountains: | | |
| Douglas fir | 100 | 100 |
| Alpine fir | 63 | 69 |
| Bristlecone pine | 70 | ---------- |
| Lodgepole pine | 76 | 86 |
| Western yellow pine | 70 | 78 |
| Engelmann spruce | 81 | 66 |

The Alaska woods did not show so high ratios on the basis of the small, clear specimens as when compared by means of the results of tests on mine caps. However, even on the basis of the small, clear specimens, the Alaska white birch averaged higher in bending strength than the Rocky Mountain Douglas fir, and the other Alaska species listed exceeded the Rocky Mountain alpine fir, lodgepole pine, western yellow pine, and Engelmann spruce in modulus of rupture.

## CONCLUSIONS

The conclusions from the study of mine props and caps are that the four Alaska woods tested are on the whole about as high as or higher in strength than Douglas fir from the Rocky Mountains, and are superior in strength to the other common Rocky Mountain species used for mine timbers on which data are presented.

The data given for mine timbers are for material free from decay. It is, of course, recognized that decay is one of the principal factors to be considered in the use of timbers in mines. The heartwood of the more decay-resistant species, or preservative treatment, may be resorted to when longer life than that ordinarily to be expected is desired (*11*).

The mine timbers tested, of course, contained some defects, but it was not feasible in testing to obtain a record in such a way as to attempt to take defects into account in comparing the species. For this reason, and the fact that there is a considerable range in the density of the clear wood of any species, it is not to be expected that the exact percentages shown would be duplicated in additional tests. The figures from the mine-timber tests, therefore, should not be taken too literally in considering the relative strength of the species. In fact, the data from the tests of small, clear specimens will afford a somewhat closer appraisal of the relative species values for mine purposes than the results of the mine-timber tests themselves, although the mine-timber tests are essential for arriving at design stresses. It is evident from these data that Alaska woods can be used to advantage for mine purposes.

## SUMMARY

The Alaska forests are of two distinct kinds. The forests of the interior, covering approximately 50,000,000 acres, are of the woodland type, very slow in growth and light in stand. It is unlikely that much of the interior timber will ever reach the general market, but it has a high potential value for local use in the development of the mining and agricultural resources of the vast region over which it grows. On the other hand, the coastal forests covering 21,347,000 acres of southern and southeastern Alaska, comprised principally in the Chugach and Tongass National Forests, are of great importance commercially. They are of luxuriant growth and may be regarded as an extension of the coastal forests of Oregon, Washington, and British Columbia. These national forests are under the administration of the Forest Service, and are estimated to contain 84,760,000,000 feet, board measure, of saw timber.

The annual cut of the two coastal forests, which amounted to 47,462,000 board feet in 1929, represents but a small fraction of the estimated annual sustained yield for pulpwood purposes. The sale of timber by the Forest Service on a sustained-yield basis offers the assurance of a continuous supply and permanent local industries.

The data presented from tests of small, clear specimens permit comparison of the mechanical properties of Alaska species with a large number of othe. woods. The results show that Alaska woods are fully equal in strength to the same species grown elsewhere in the United States.

The tests on large sawn timbers containing defects show that western hemlock, Sitka spruce, and other Alaska species may be used satisfactorily as structural timbers when properly graded. Likewise, the tests of round mine timbers show that Alaska white birch, western hemlock, white spruce, and Sitka spruce compare very favorably in strength with the best of the Rocky Mountain softwoods, and exceed in strength most of the species locally available in the Rocky Mountain region for mine timbers.

Large areas suitable mainly for timber production, a present forest utilization of but a fraction of the actual and potential annual growth, a variety of species with a large range in properties, an abundance of water power and timber resources which are favorable to pulpwood development—these considerations presage for Alaska an increasing economic forest development.

# APPENDIX

## DETAILED RESULTS OF STRUCTURAL TIMBER TESTS

Tables 11 to 14 present the results of tests for each of the individual western hemlock and Sitka spruce structural timbers studied.

The modulus of rupture of the poorest structural timbers meeting the requirement of any structural grade should be about three times the allowable fiber stress in bending. This requirement is based on a factor of nine-sixteenths to keep the stress within the elastic limit for long-continued loading, and a factor of three-fifths, so that three times the allowable fiber stress in bending represents an actual factor of safety of one and two-thirds for a timber on the border line of the grade. Tables 13 and 17 show that the Sitka spruce timber (No. 20) with the lowest modulus of rupture (2,700 pounds per square inch) should be a cull because of severe cross grain. The poorest acceptable piece (No. 19), under the requirements of the American lumber standards grade of Select, which permits defects that reduce the strength by one-fourth, has a modulus of rupture of 3,330 pounds per square inch. The safe working stresses, as given in the appendix, present an allowable fiber stress in bending for the select grade of Sitka spruce when used under continuously dry conditions of 1,100 pounds per square inch, which brings the poorest acceptable timber (No. 19) just within the three-to-one limit relationship acceptable between test values and working stress.

TABLE 11.—*Detailed data on the individual structural timbers of green western hemlock from Alaska and of small, clear specimens cut from them*

| Specimen No. | Type of specimen | Actual cross-section | | Span | Static bending | | | | | | | | Compression parallel to grain | | | Compression perpendicular to grain | | | Shearing strength parallel to grain | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture content | Specific gravity | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity | Work to elastic limit | Work to maximum load | Horizontal shear stress at maximum load | Moisture content | Specific gravity | Maximum crushing strength | Moisture content | Specific gravity | Fiber stress at elastic limit | Moisture content | Average of radial and tangential |
| | | *Inches* | *Inches* | *Inches* | *Per cent* | | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | *Lbs. per sq. in.* |
| 1 | Structural | 8.13 | 16.44 | 180 | 34.4 | 0.396 | 3,300 | 5,340 | 1,308 | 0.76 | 5.23 | 365 | 33.8 | 0.385 | 2,400 | 33.7 | 0.401 | 328 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 45.3 | .402 | 3,425 | 5,955 | 1,228 | .54 | 4.51 | 215 | ------ | ------ | 2,828 | 62.0 | .426 | 483 | 101.6 | 674 |
| [1] 2 | Structural | 7.98 | 16.34 | 180 | 47.0 | .400 | 3,240 | 5,169 | 1,315 | .73 | 6.55 | 349 | 42.8 | .381 | 3,160 | 51.2 | .392 | 292 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 47.0 | .386 | 3,605 | 6,077 | 1,360 | .53 | 5.80 | 215 | 46.8 | .380 | 2,873 | 40.5 | .404 | 244 | 68.1 | 563 |
| [1] 3 | Structural | 8.16 | 16.36 | 180 | 42.5 | .428 | 4,200 | ------ | 1,077 | 1.49 | 3.47 | ------ | 54.5 | .449 | 2,615 | 43.8 | .413 | 360 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 37.2 | .431 | 3,995 | 6,982 | 1,478 | .61 | 7.74 | 245 | 40.5 | .411 | 3,342 | 38.6 | .438 | 372 | 55.4 | 770 |
| [1] 4 | Structural | 7.82 | 16.10 | 180 | 37.6 | .433 | 3,580 | 5,560 | 1,552 | .75 | 3.40 | 371 | 38.1 | .422 | 3,510 | 39.6 | .417 | 275 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 43.5 | .376 | 3,607 | 6,868 | 1,420 | .51 | 10.22 | 245 | 38.7 | .381 | 3,057 | 41.2 | .398 | 272 | 52.1 | 611 |
| [1] 5 | Structural | 8.03 | 16.17 | 180 | 46.3 | .486 | 3,980 | 6,640 | 1,632 | .88 | 9.57 | 445 | 40.2 | .447 | 3,730 | 52.5 | .446 | 283 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 51.3 | .469 | 4,290 | 8,323 | 1,280 | .80 | 14.09 | 301 | 51.6 | .464 | 3,698 | 52.0 | .461 | 477 | 56.8 | 811 |
| [1] 6 | Structural | 8.38 | 16.33 | 180 | 43.9 | .381 | 2,930 | 4,230 | 1,166 | .67 | 2.08 | 286 | 41.6 | .398 | 2,895 | 41.5 | .403 | 417 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 35.7 | .368 | 3,040 | 5,395 | 1,121 | .46 | 4.97 | 194 | 44.9 | .351 | 2,600 | 39.1 | .360 | 255 | 54.1 | 600 |
| 7 | Structural | 8.34 | 16.16 | 180 | 39.7 | .415 | 3,590 | 5,640 | 1,486 | .79 | 7.06 | 378 | 40.2 | .397 | 3,315 | 42.0 | .408 | 319 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 37.6 | .419 | 3,833 | 7,177 | 1,520 | .54 | 10.92 | 259 | 37.9 | .405 | 3,200 | 34.8 | .389 | 251 | 69.0 | 716 |
| [1] 8 | Structural | 8.08 | 16.23 | 180 | 47.2 | .444 | 3,420 | 5,860 | 1,713 | .70 | 5.86 | 394 | 43.5 | .433 | 3,400 | 52.3 | .448 | 288 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 47.8 | .403 | 4,400 | 7,495 | 1,598 | .68 | 7.79 | 268 | 43.3 | .420 | 3,685 | 44.7 | .436 | 280 | 62.5 | 708 |
| [1] 9 | Structural | 7.89 | 16.34 | 180 | 30.7 | .376 | 3,360 | 4,690 | 1,338 | .77 | 3.15 | 318 | 31.7 | .367 | 2,620 | 31.2 | .368 | 213 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 39.9 | .372 | 3,232 | 6,060 | 1,307 | .45 | 5.53 | 218 | ------ | ------ | 2,742 | 52.0 | .417 | 351 | 103.0 | 532 |
| 10 | Structural | 8.14 | 16.36 | 180 | 36.6 | .467 | 2,930 | 4,830 | 1,311 | .59 | 2.69 | 327 | 42.0 | .451 | 2,885 | 41.3 | .451 | 451 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 40.4 | .450 | 3,565 | 6,257 | 935 | .84 | 9.35 | 226 | ------ | ------ | 2,797 | 57.5 | .480 | 476 | 56.8 | 813 |
| [1] 11 | Structural | 8.39 | 16.80 | 180 | 43.0 | .399 | 3,040 | 4,640 | 1,296 | .64 | 2.26 | 322 | 39.2 | .393 | 2,655 | 46.5 | .396 | 268 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 50.6 | .402 | 3,408 | 6,015 | 1,338 | .48 | 5.34 | 216 | ------ | ------ | 2,812 | 61.3 | .431 | 387 | 97.0 | 581 |
| [1] 12 | Structural | 7.89 | 16.08 | 180 | 37.3 | .445 | 3,570 | 5,420 | 1,442 | .80 | 3.81 | 301 | 44.4 | .409 | 3,150 | 34.7 | .442 | 435 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 47.5 | .454 | 4,010 | 7,192 | 1,281 | .70 | 7.82 | 260 | ------ | ------ | 3,178 | 57.9 | .482 | 775 | 88.1 | 802 |
| [1] 13 | Structural | 8.23 | 16.49 | 180 | 43.6 | .433 | 2,570 | 4,460 | 1,092 | .54 | 3.28 | 304 | 40.6 | .411 | 2,590 | 39.6 | .411 | 342 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 41.0 | .425 | 3,312 | 5,983 | 1,236 | .50 | 5.98 | 217 | ------ | ------ | 2,542 | 61.0 | .433 | 397 | 109.5 | 652 |
| 14 | Structural | 7.99 | 16.34 | 180 | 40.0 | .449 | 3,450 | 5,670 | 1,533 | .70 | 3.46 | 384 | 51.8 | .476 | 4,125 | 42.2 | .456 | 317 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 38.1 | .450 | 4,213 | 7,650 | 1,572 | .64 | 7.65 | 275 | 37.3 | .450 | 3,587 | 34.4 | .468 | 309 | 60.4 | 756 |
| [1] 15 | Structural | 7.65 | 16.35 | 172 | 35.7 | .493 | 5,250 | 5,620 | 1,498 | 1.68 | 2.18 | 309 | 34.0 | .495 | 3,985 | 36.1 | .460 | 457 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 48.1 | .488 | 4,268 | 7,953 | 1,388 | .75 | 12.50 | 286 | ------ | ------ | 3,862 | 52.2 | .520 | 520 | 89.8 | 698 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1] 16 | Structural | 7.87 | 16.17 | 180 | 37.9 | .438 | 3,230 | 5,450 | 1,641 | .58 | 3.89 | 365 | 39.5 | .428 | 3,405 | 38.1 | .439 | 265 | | |
| | Small, clear | 2.00 | 2.00 | | 35.8 | .425 | 3,927 | 7,758 | 1,560 | .55 | 11.45 | 279 | 37.7 | .419 | 3,292 | 35.1 | .421 | 304 | 62.7 | 678 |
| 17 | Structural | 8.87 | 16.37 | 180 | 39.1 | .430 | 3,440 | 5,260 | 1,248 | .86 | 2.76 | 356 | 35.0 | .422 | 3,375 | 40.2 | .417 | 371 | | |
| | Small, clear | 2.00 | 2.00 | | 36.3 | .449 | 3,758 | 7,505 | 1,256 | .61 | 12.08 | 269 | 36.3 | .444 | 3,583 | 34.3 | .465 | 321 | 67.5 | 730 |
| [1] 18 | Structural | 7.99 | 16.28 | 180 | 53.1 | .450 | 3,010 | 5,140 | 1,354 | .60 | 3.57 | 346 | 56.3 | .458 | 3,335 | 46.4 | .468 | 527 | | |
| | Small, clear | 2.00 | 2.00 | | 52.7 | .486 | 3,970 | 7,492 | 1,252 | .73 | 7.96 | 270 | 54.1 | .477 | 3,612 | 42.4 | .542 | 556 | 60.7 | 910 |
| [1] 19 | Structural | 7.98 | 16.49 | 180 | 58.7 | .422 | 2,820 | 4,540 | 1,262 | .57 | 2.24 | 309 | 48.6 | .400 | 2,795 | 61.2 | .407 | 259 | | |
| | Small, clear | 2.00 | 2.00 | | 46.6 | .421 | 3,640 | 6,658 | 1,170 | .65 | 7.85 | 243 | 52.4 | .410 | 3,152 | 46.8 | .467 | 472 | 82.6 | 732 |
| 20 | Structural | 8.25 | 16.31 | 180 | 40.0 | .444 | 2,950 | 5,040 | 1,398 | .56 | 2.39 | 340 | 35.2 | .430 | 3,795 | 45.7 | .436 | 274 | | |
| | Small, clear | 2.00 | 2.00 | | 34.1 | .448 | 3,923 | 7,652 | 1,280 | .70 | 9.18 | 275 | 34.0 | .441 | 3,570 | 35.7 | .458 | 261 | 59.5 | 810 |
| 21 | Structural | 8.07 | 15.92 | 180 | 42.6 | .410 | 2,900 | 4,340 | 1,332 | .57 | 1.92 | 271 | 41.7 | .392 | 2,850 | 42.2 | .418 | 364 | | |
| | Small, clear | 2.00 | 2.00 | | 43.5 | .438 | 3,925 | 6,800 | 1,213 | .74 | 7.32 | 243 | | | 3,245 | 49.4 | .491 | 639 | 89.8 | 764 |
| 22 | Structural | 8.37 | 16.38 | 180 | 52.2 | .419 | 2,480 | 4,370 | 1,336 | .41 | 1.98 | 296 | 49.7 | .410 | 3,075 | 55.2 | .415 | 292 | | |
| | Small, clear | 2.00 | 2.00 | | 52.7 | .402 | 3,928 | 6,855 | 1,506 | .58 | 7.40 | 246 | 53.2 | .403 | 2,925 | 50.4 | .400 | 210 | 75.2 | 690 |
| [1] 23 | Structural | 8.18 | 16.55 | 180 | 40.5 | .449 | 2,090 | 4,420 | 981 | .40 | 3.89 | 302 | 33.2 | .435 | 3,165 | 43.2 | .420 | 491 | | |
| | Small, clear | 2.00 | 2.00 | | 42.5 | .449 | 3,890 | 7,020 | 1,063 | .84 | 10.60 | 254 | | | 2,002 | 57.8 | .469 | 550 | 86.0 | 824 |
| 24 | Structural | 8.08 | 16.00 | 172 | 34.3 | .428 | 3,020 | 4,720 | 1,253 | .66 | 2.66 | 327 | 32.7 | .442 | 3,140 | 34.0 | .414 | 398 | | |
| | Small, clear | 2.00 | 2.00 | | 43.2 | .462 | 4,170 | 7,608 | 1,557 | .62 | 8.47 | 273 | | | 3,343 | 50.1 | .505 | 420 | 101.3 | 728 |
| [1] 25 | Structural | 8.23 | 16.42 | 180 | 42.8 | .435 | 2,310 | 3,700 | 1,193 | .40 | 1.32 | 250 | 41.1 | .375 | 2,550 | 40.8 | .420 | 628 | | |
| | Small, clear | 2.00 | 2.00 | | 57.0 | .435 | 3,522 | 6,460 | 1,102 | .68 | 7.23 | 230 | | | 2,892 | 66.5 | .436 | 544 | 92.0 | 632 |
| 26 | Structural | 8.27 | 16.36 | 180 | 31.5 | .416 | 2,880 | 3,950 | 1,200 | .62 | 1.54 | 267 | 31.8 | .412 | 2,870 | 31.5 | .392 | 486 | | |
| | Small, clear | 2.00 | 2.00 | | 42.4 | .440 | 3,732 | 6,948 | 1,269 | .61 | 7.35 | 253 | | | 3,060 | 63.1 | .416 | 275 | 114.9 | 601 |
| [1] 27 | Structural | 8.14 | 16.34 | 180 | 44.4 | .470 | 3,480 | 4,420 | 1,494 | .73 | 1.36 | 298 | 46.4 | .474 | 3,135 | 47.5 | .449 | 344 | | |
| | Small, clear | 2.00 | 2.00 | | 40.3 | .461 | 4,583 | 8,230 | 1,399 | .85 | 12.23 | 286 | 43.0 | .457 | 3,820 | 50.6 | .462 | 301 | 71.4 | 790 |
| [1] 28 | Structural | 8.25 | 16.39 | 180 | 45.2 | .398 | 2,470 | 3,770 | 1,366 | .40 | 1.22 | 255 | 37.5 | .404 | 3,230 | 39.3 | .403 | 336 | | |
| | Small, clear | 2.00 | 2.00 | | 35.1 | .377 | 4,165 | 7,708 | 1,633 | .63 | 7.95 | 266 | 32.3 | .377 | 2,873 | 34.8 | .375 | 252 | 61.7 | 706 |
| [1] 29 | Structural | 8.12 | 16.12 | 168 | 37.9 | | 1,990 | 3,740 | 1,484 | .25 | 2.13 | 269 | | | | 34.0 | .429 | 315 | | |
| | Small, clear | 2.00 | 2.00 | | 41.6 | .498 | 4,563 | 7,718 | 1,450 | .83 | 8.14 | 277 | | | 3,818 | 52.0 | .520 | 497 | 82.9 | 743 |

[1] This timber contained one or more rotten knots which would not be permissible in structural timbers meeting the requirements of American lumber standards. The depth of rot was not recorded, but if the depth does not exceed the diameter of the knot, the timber may be graded as if the knot were sound, according to the principles of grading in U. S. Dept. Agr. Cir. 295. If the depth of rot at a knot exceeds the diameter, the timber would be graded as S4 or a cull by the grading principles of U. S. Dept. Agr. Cir. 295.

TABLE 12.—*Detailed data on the individual structural timbers of air-dry western hemlock from Alaska and of small, clear specimens cut from them*

| Specimen No. | Type of specimen | Actual cross-section | | Span | Static bending | | | | | | | | Compression parallel to grain | | | Compression perpendicular to grain | | | Shearing strength parallel to grain | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture content | Specific gravity | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity | Work to elastic limit | Work to maximum load | Horizontal shear stress at maximum load | Moisture content | Specific gravity | Maximum crushing strength | Moisture content | Specific gravity | Fiber stress at elastic limit | Moisture content | Average of radial and tangential |
| | | *Inches* | *Inches* | *Inches* | *Per cent* | | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | *Lbs. per sq. in.* |
| [1] 30 | Structural | 7.13 | 16.05 | 180 | 17.7 | 0.460 | 4,080 | 7,220 | 1,338 | 1.14 | 4.85 | 480 | 9.8 | 0.457 | 6,935 | 19.0 | 0.457 | 978 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.5 | .498 | 6,237 | 11,527 | 1,144 | 1.02 | 9.42 | 410 | 8.6 | .491 | 7,833 | 8.4 | .503 | 1,471 | 9.3 | ------ |
| [1] 31 | Structural | 8.02 | 15.99 | 180 | 18.5 | .389 | 3,720 | 5,490 | 1,347 | .93 | 3.92 | 333 | 9.0 | .412 | 4,835 | 17.8 | .382 | 497 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.5 | .391 | 5,923 | 10,163 | 1,494 | 1.32 | 6.48 | 356 | 8.4 | .386 | 7,100 | 8.2 | .402 | 470 | 9.1 | 909 |
| [1] 32 | Structural | 7.90 | 16.03 | 180 | 17.8 | .457 | 4,060 | 7,360 | 1,772 | .85 | 3.40 | 410 | 10.0 | .481 | 6,940 | 17.3 | .453 | 570 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.6 | .483 | 9,576 | 14,246 | 2,090 | 2.46 | 12.04 | 500 | 8.3 | .481 | 9,620 | 8.7 | .479 | 641 | 9.1 | 1,110 |
| [1] 33 | Structural | 7.65 | 16.12 | 180 | 18.9 | .437 | 4,380 | 6,580 | 1,377 | 1.27 | 4.16 | 440 | 9.6 | .415 | 6,055 | 18.9 | .432 | 462 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.5 | .447 | 8,152 | 12,905 | 1,747 | 2.11 | 8.18 | 454 | 8.4 | .450 | 8,512 | 8.4 | .442 | 571 | 9.4 | 1,027 |
| [1] 34 | Structural | 7.93 | 16.07 | 180 | 17.6 | .426 | 4,600 | 7,160 | 1,621 | 1.19 | 4.29 | 477 | 9.4 | .448 | 7,705 | 17.2 | .436 | 333 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.7 | .439 | 8,699 | 14,408 | 1,898 | 2.23 | 12.17 | 505 | 8.1 | .441 | 8,835 | 8.7 | .431 | 578 | 9.2 | 1,162 |
| [1] 35 | Structural | 8.03 | 16.22 | 174 | 17.8 | .423 | 3,440 | 5,770 | 1,430 | .76 | 2.69 | 401 | 9.1 | .419 | 7,685 | 17.5 | .409 | 596 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.4 | .450 | 7,9[illegible]8 | 11,758 | 1,544 | 2.27 | 6.53 | 414 | 8.3 | .458 | 8,193 | 8.7 | .464 | 1,103 | 9.3 | 1,065 |
| [1] 36 | Structural | 8.11 | 15.96 | 180 | 18.2 | .430 | 3,750 | 5,790 | 1,541 | .84 | 2.31 | 383 | 9.8 | .450 | 6,300 | 18.1 | .420 | 518 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.5 | .443 | 8,356 | 11,882 | 1,768 | 2.19 | 7.70 | 417 | 8.6 | .437 | 7,958 | 8.7 | .450 | 697 | 9.3 | 1,067 |
| [1] 37 | Structural | 7.86 | 15.89 | 180 | 17.2 | .436 | 5,290 | 7,010 | 1,717 | 1.49 | 2.94 | 462 | 9.6 | .455 | 8,335 | 17.6 | .410 | 522 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.5 | .452 | 8,007 | 14,777 | 1,849 | 1.96 | 13.39 | 517 | 8.1 | .459 | 9,075 | 8.0 | .458 | 724 | 9.0 | 1,310 |
| [1] 38 | Structural | 8.08 | 15.92 | 168 | 17.1 | .438 | 4,500 | 6,500 | 1,405 | 1.32 | 3.37 | 460 | 9.7 | .456 | 5,220 | 16.9 | .426 | 781 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.4 | .445 | 9,017 | 13,845 | 1,753 | 2.60 | 10.36 | 486 | 8.4 | .439 | 8,108 | 8.1 | .447 | 638 | 9.4 | 1,152 |
| [1] 39 | Structural | 7.77 | 15.85 | 180 | 16.7 | .458 | 4,220 | 6,760 | 1,825 | .89 | 2.76 | 445 | 9.6 | .468 | 6,950 | 17.0 | .454 | 528 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.8 | .454 | 9,973 | 14,380 | 2,046 | 2.74 | 9.56 | 505 | 7.9 | .466 | 9,408 | 8.2 | .476 | 718 | 9.0 | 964 |
| [1] 40 | Structural | 8.07 | 16.11 | 180 | 17.2 | .436 | 3,470 | 5,580 | 1,442 | .76 | 2.43 | 373 | 9.6 | .450 | 5,005 | 17.5 | .448 | 552 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.6 | .437 | 8,063 | 12,330 | 1,684 | 2.15 | 8.01 | 435 | 8.3 | .442 | 8,162 | 8.5 | .410 | 625 | 9.0 | 1,098 |
| 41 | Structural | 7.92 | 15.95 | 180 | 17.2 | .450 | 4,940 | 7,110 | 1,800 | 1.24 | 3.25 | 471 | 9.4 | .461 | 8,030 | 17.2 | .480 | 830 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.6 | .485 | 10,142 | 16,257 | 2,162 | 2.65 | 15.98 | 570 | 7.6 | .487 | 10,348 | 8.8 | .480 | 611 | 9.1 | 1,272 |
| [1] 42 | Structural | 8.05 | 16.09 | 180 | 18.9 | .436 | 3,530 | 5,300 | 1,248 | .91 | 3.02 | 353 | 9.8 | .426 | 5,190 | 19.0 | .436 | 508 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.8 | .466 | 7,532 | 12,220 | 1,629 | 1.94 | 10.80 | 432 | 8.2 | .485 | 8,512 | 9.1 | .509 | 723 | 9.4 | 1,144 |
| [1] 43 | Structural | 7.76 | 16.07 | 180 | 18.5 | .474 | 3,980 | 6,220 | 1,513 | .95 | 2.91 | 415 | 9.6 | .490 | 7,110 | 18.9 | .465 | 523 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.5 | .515 | 8,442 | 14,360 | 1,798 | 2.21 | 11.86 | 504 | 8.4 | .503 | 9,078 | 8.8 | .503 | 1,188 | 9.6 | 1,472 |
| 44 | Structural | 7.91 | 15.99 | 180 | 17.4 | .441 | 4,080 | 6,920 | 1,747 | .87 | 4.35 | 459 | 10.0 | .466 | 7,815 | 17.7 | .460 | 538 | ------ | ------ |
| | Small, clear | 2.00 | 2.00 | ------ | 8.8 | .463 | 10,050 | 16,000 | 2,074 | 2.71 | 14.15 | 563 | 7.6 | .460 | 9,638 | 8.3 | .467 | 671 | 9.2 | 1,101 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| [1] 45 | Structural | 8.06 | 15.91 | 180 | 17.3 | .446 | 4,440 | 6,600 | 1,771 | 1.02 | 2.70 | 435 | 10.0 | .462 | 8,005 | 17.4 | .444 | 581 | | |
| | Small, clear | 2.00 | 2.00 | | 8.7 | .470 | 9,807 | 15,323 | 2,022 | 2.66 | 12.74 | 538 | 7.9 | .479 | 9,157 | 8.7 | .475 | 537 | 9.8 | 1,162 |
| [1] 46 | Structural | 8.78 | 15.98 | 180 | 18.3 | .434 | 4,840 | 6,250 | 1,635 | 1.31 | 2.60 | 415 | 10.0 | .456 | 7,775 | 18.3 | .433 | 560 | | |
| | Small, clear | 2.00 | 2.00 | | 8.3 | .466 | 9,073 | 14,555 | 1,915 | 2.40 | 11.74 | 511 | 7.6 | .472 | 9,635 | 8.3 | .466 | 620 | 9.2 | 1,060 |
| 47 | Structural | 8.24 | 16.25 | 180 | 16.9 | .438 | 3,330 | 4,870 | 1,362 | .71 | 1.88 | 328 | 9.4 | .436 | 7,175 | 17.4 | .423 | 571 | | |
| | Small, clear | 2.00 | 2.00 | | 8.8 | .443 | 6,548 | 11,513 | 1,346 | 1.80 | 7.97 | 405 | 7.9 | .445 | 7,492 | 8.3 | .470 | 804 | 9.4 | 1,116 |
| [1] 48 | Structural | 7.84 | 16.07 | 180 | 17.1 | .417 | 4,030 | 5,460 | 1,518 | .97 | 2.71 | 364 | 9.6 | .411 | 5,870 | 16.9 | .417 | 467 | | |
| | Small, clear | 2.00 | 2.00 | | 8.5 | .437 | 8,425 | 13,842 | 1,876 | 2.10 | 11.86 | 487 | 8.6 | .442 | 7,762 | 8.8 | .458 | 779 | 9.0 | 1,028 |
| [1] 49 | Structural | 8.04 | 16.47 | 180 | 16.4 | .425 | 3,710 | 4,130 | 1,168 | 1.09 | 1.41 | 282 | 9.6 | .437 | 6,405 | 17.5 | .418 | 513 | | |
| | Small, clear | 2.00 | 2.00 | | 8.4 | .429 | 6,728 | 10,558 | 1,311 | 1.94 | 6.12 | 362 | 8.9 | .432 | 6,938 | 8.7 | .435 | 724 | 9.5 | 1,050 |
| [1] 50 | Structural | 8.13 | 16.35 | 180 | 16.5 | .417 | 3,590 | 4,240 | 1,499 | .78 | 1.21 | 287 | 9.6 | .424 | 7,015 | 17.4 | .425 | 420 | | |
| | Small, clear | 2.00 | 2.00 | | 8.2 | .416 | 7,735 | 11,980 | 1,660 | 2.02 | 7.55 | 429 | 8.2 | .416 | 7,423 | 8.1 | .407 | 722 | 9.5 | 1,108 |
| [1] 51 | Structural | 7.75 | 16.19 | 180 | 16.1 | .394 | 3,790 | 4,600 | 1,497 | .88 | 1.42 | 308 | 9.0 | .426 | 6,285 | 16.7 | .388 | 373 | | |
| | Small, clear | 2.00 | 2.00 | | 8.5 | .408 | 7,752 | 12,105 | 1,705 | 1.96 | 8.37 | 425 | 8.1 | .421 | 7,840 | 8.5 | .412 | 589 | 9.4 | 890 |
| [1] 52 | Structural | 8.01 | 16.27 | 180 | 17.4 | .420 | 2,580 | 4,480 | 1,439 | .42 | 2.07 | 301 | 9.4 | .426 | 6,305 | 17.6 | .434 | 750 | | |
| | Small, clear | 2.00 | 2.00 | | 8.5 | .436 | 8,170 | 12,110 | 1,662 | 2.25 | 7.43 | 428 | 7.8 | .458 | 8,120 | 8.7 | .483 | 721 | 9.1 | 1,106 |
| [1] 53 | Structural | 7.71 | 16.10 | 168 | 17.4 | .519 | 4,230 | 6,140 | 1,723 | .95 | 5.80 | 439 | 10.8 | .566 | 8,010 | 18.1 | .508 | 735 | | |
| | Small, clear | 2.00 | 2.00 | | 8.7 | .531 | 10,423 | 16,898 | 1,971 | 3.10 | 15.58 | 593 | 8.7 | .544 | 10,213 | 8.4 | .547 | 817 | 9.4 | 1,200 |
| 54 | Structural | 7.97 | 16.26 | 174 | 17.8 | .490 | 3,460 | 5,720 | 1,742 | .63 | 2.06 | 399 | 10.4 | .534 | 8,120 | 18.6 | .475 | 683 | | |
| | Small, clear | 2.00 | 2.00 | | 8.6 | .519 | 10,545 | 15,763 | 2,349 | 2.65 | 11.64 | 549 | 7.9 | .530 | 10,828 | 8.3 | .530 | 931 | 8.7 | 1,356 |
| [1] 55 | Structural | 7.82 | 16.14 | 180 | 17.6 | .405 | 4,000 | 4,380 | 1,326 | 1.10 | 1.47 | 293 | 9.4 | .422 | 6,560 | 17.3 | .404 | 591 | | |
| | Small, clear | 2.00 | 2.00 | | 8.6 | .464 | 7,238 | 12,080 | 1,472 | 1.99 | 9.55 | 427 | 8.2 | .480 | 7,538 | 8.7 | .448 | 724 | 9.5 | Culled. |
| [1] 56 | Structural | 7.98 | 15.98 | 180 | 17.1 | .440 | 3,560 | 4,710 | 1,423 | .81 | 1.70 | 312 | 9.2 | .406 | 6,895 | 17.3 | .447 | 596 | | |
| | Small, clear | 2.00 | 2.00 | | 8.2 | .449 | 8,618 | 13,765 | 1,820 | 2.28 | 11.82 | 488 | 8.3 | .442 | 8,060 | 8.3 | .452 | 617 | 9.2 | 1,114 |
| [1] 57 | Structural | 8.02 | 16.29 | 180 | 17.4 | .424 | 2,740 | 4,120 | 1,316 | .52 | 1.48 | 278 | 10.0 | .466 | 6,380 | 17.5 | .428 | 777 | | |
| | Small, clear | 2.00 | 2.00 | | 8.4 | .421 | 8,543 | 13,050 | 1,766 | 2.32 | 9.81 | 443 | 8.3 | .422 | 7,847 | 8.4 | .420 | 598 | 9.2 | 1,094 |
| [1] 58 | Structural | 7.76 | 15.94 | 180 | 17.3 | .467 | 3,930 | 4,190 | 1,576 | .89 | 4.17 | 277 | 9.8 | .490 | 7,340 | 17.6 | .456 | 592 | | |
| | Small, clear | 2.00 | 2.00 | | 8.6 | .474 | 9,192 | 15,812 | 1,995 | 2.36 | 12.90 | 545 | 7.9 | .475 | 9,597 | 8.2 | .473 | 689 | 9.1 | 1,206 |

[1] This timber contained one or more rotten knots which would not be permissible in structural timbers meeting the requirements of American lumber standards. The depth of rot was not recorded, but if the depth does not exceed the diameter of the knot, the timber may be graded as if the knot were sound, according to the principles of grading in U. S. Dept. Agr. Circ. 295 (*15*). If the depth of rot at a knot exceeds the diameter, the timber would be graded as S4 or a cull by the grading principles of U. S. Dept. Agr. Circ. 295.

TABLE 13.—*Detailed data on the individual structural timbers of green Sitka spruce from Alaska and of small, clear specimens cut from them*

| Specimen No. | Type of specimen | Actual cross-section | | Span | Static bending | | | | | | | | Compression parallel to grain | | | Compression perpendicular to grain | | | Shearing strength parallel to grain | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture content | Specific gravity | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity | Work to elastic limit | Work to maximum load | Horizontal shear stress at maximum load | Moisture content | Specific gravity | Maximum crushing strength | Moisture content | Specific gravity | Fiber stress at elastic limit | Moisture content | Average of radial and tangential |
| | | *Inches* | *Inches* | *Inches* | *Per cent* | | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | *Lbs. per sq. in.* |
| 1 | Structural | 7.90 | 16.10 | 180 | 44.7 | 0.337 | 2,180 | 4,100 | 1,085 | 0.40 | 4.60 | 273 | 45.5 | 0.328 | 2,165 | 44.5 | 0.323 | 171 | | |
| | Small, clear | 2.00 | 2.00 | | 55.1 | .325 | 2,020 | 4,310 | 1,044 | .23 | 6.43 | 153 | 50.8 | .316 | 1,970 | 59.4 | .324 | 244 | 59.9 | 628 |
| 2 | Structural | 8.20 | 16.18 | 180 | 33.4 | .389 | 3,050 | 5,500 | 1,563 | .54 | 8.48 | 369 | 37.1 | .378 | 2,875 | 34.1 | .376 | 214 | | |
| | Small, clear | 2.00 | 2.00 | | 37.7 | .388 | 2,800 | 5,980 | 1,700 | .26 | 5.88 | 213 | 35.9 | .382 | 2,940 | 36.8 | .393 | 225 | 35.1 | 689 |
| 3 | Structural | 8.11 | 16.11 | 180 | 31.7 | .332 | 2,270 | 4,040 | 1,260 | .38 | 3.27 | 270 | 32.3 | .318 | 2,200 | 34.7 | .325 | 163 | | |
| | Small, clear | 2.00 | 2.00 | | 30.5 | .319 | 2,330 | 4,480 | 1,140 | .27 | 4.24 | 160 | 30.8 | .313 | 2,270 | 30.0 | .321 | 274 | 31.2 | 576 |
| 4 | Structural | 8.14 | 16.22 | 180 | 40.0 | .397 | 2,550 | 4,730 | 1,300 | .46 | 5.49 | 318 | 33.7 | | 2,220 | 52.8 | .398 | 187 | | |
| | Small, clear | 2.00 | 2.00 | | 40.7 | .356 | 3,060 | 5,480 | 1,188 | .46 | 6.23 | 196 | 39.0 | .354 | 2,410 | 39.7 | .352 | 305 | 44.1 | 613 |
| 5 | Structural | 8.30 | 16.18 | 180 | 31.8 | .431 | 2,970 | 5,150 | 1,460 | .55 | 3.29 | 345 | 35.5 | .418 | 2,960 | 36.2 | .437 | 222 | | |
| | Small, clear | 2.00 | 2.00 | | 33.7 | .414 | 2,100 | 6,310 | 1,380 | .18 | 6.47 | 225 | 32.4 | .413 | 3,070 | 34.1 | .424 | 334 | 29.7 | 747 |
| 6 | Structural | 8.11 | 16.01 | 180 | 30.5 | .341 | 2,320 | 4,460 | 1,335 | .36 | 2.92 | 296 | 31.5 | .339 | 2,645 | 32.2 | .342 | 135 | | |
| | Small, clear | 2.00 | 2.00 | | 29.9 | .341 | 2,150 | 5,480 | 1,490 | .17 | 6.47 | 196 | 31.1 | .341 | 2,680 | 30.0 | .337 | 232 | 28.8 | 688 |
| 7 | Structural | 8.12 | 16.26 | 180 | 30.9 | .345 | 2,540 | 4,430 | 1,200 | .49 | 2.49 | 298 | 30.4 | .352 | 2,675 | 31.9 | .344 | 176 | | |
| | Small, clear | 2.00 | 2.00 | | 31.5 | .354 | 1,940 | 5,470 | 1,513 | .14 | 4.55 | 196 | 31.1 | .351 | 2,710 | 31.4 | .358 | 279 | 28.9 | 605 |
| 8 | Structural | 8.08 | 16.17 | 180 | 33.7 | .317 | 2,110 | 3,890 | 1,210 | .34 | 2.63 | 260 | 32.3 | .306 | 2,185 | 35.6 | .317 | 206 | | |
| | Small, clear | 2.00 | 2.00 | | 31.7 | .319 | 2,490 | 4,810 | 1,057 | .33 | 5.33 | 172 | 30.3 | .319 | 2,110 | 31.3 | .314 | 171 | 32.4 | 588 |
| 9 | Structural | 8.00 | 15.87 | 180 | 38.2 | .393 | 1,950 | 4,210 | 1,125 | .30 | 5.18 | 276 | 41.0 | .364 | 2,505 | 37.0 | .363 | 204 | | |
| | Small, clear | 2.00 | 2.00 | | 58.6 | .362 | 2,730 | 5,260 | 1,080 | .39 | 6.78 | 188 | 55.4 | .361 | 2,420 | 58.5 | .364 | 344 | 56.6 | 726 |
| 10 | Structural | 8.23 | 16.09 | 180 | 31.0 | .390 | 2,740 | 4,450 | 1,375 | .49 | 2.19 | 295 | 32.2 | .378 | 2,455 | 31.6 | .394 | 202 | | |
| | Small, clear | 2.00 | 2.00 | | 31.1 | .391 | 3,220 | 5,630 | 1,330 | .44 | 6.08 | 200 | 31.2 | .390 | 2,580 | 30.7 | .381 | 222 | 34.8 | 631 |
| 11 | Structural | 8.33 | 16.13 | 180 | 30.7 | .386 | 2,440 | 4,270 | 1,355 | .40 | 2.16 | 285 | 32.0 | .373 | 2,690 | 31.2 | .426 | 167 | | |
| | Small, clear | 2.00 | 2.00 | | 34.3 | .378 | 3,020 | 5,530 | 1,360 | .38 | 5.87 | 198 | 34.3 | .374 | 2,640 | 31.4 | .368 | 234 | 33.0 | 613 |
| 12 | Structural | 8.10 | 15.93 | 180 | 52.7 | .425 | 2,490 | 4,620 | 1,090 | .51 | 6.31 | 304 | 43.6 | .412 | 3,070 | 50.4 | .408 | 219 | | |
| | Small, clear | 2.00 | 2.00 | | 76.3 | .388 | 2,190 | 6,080 | 1,470 | .18 | 7.23 | 216 | 68.7 | .390 | 2,670 | 67.2 | .395 | 389 | 62.7 | 752 |
| 13 | Structural | 8.10 | 16.31 | 180 | 31.4 | .364 | 2,370 | 4,140 | 1,355 | .37 | 1.98 | 279 | 33.3 | .358 | 2,700 | 32.0 | .357 | 149 | | |
| | Small, clear | 2.00 | 2.00 | | 31.6 | .358 | 2,130 | 5,590 | 1,315 | .20 | 4.23 | 196 | 30.6 | .354 | 2,630 | 30.6 | .360 | 252 | 28.4 | 698 |
| 14 | Structural | 8.15 | 16.23 | 180 | 31.6 | .324 | 1,950 | 3,630 | 1,160 | .29 | 2.70 | 244 | 31.7 | .314 | 2,305 | 32.6 | .321 | 149 | | |
| | Small, clear | 2.00 | 2.00 | | 30.4 | .319 | 2,400 | 5,000 | 1,240 | .27 | 5.90 | 178 | 30.2 | .318 | 2,380 | 31.1 | .312 | 203 | 27.5 | 668 |
| 15 | Structural | 7.96 | 16.24 | 180 | 29.0 | .351 | 2,260 | 3,970 | 1,210 | .38 | 1.98 | 266 | 31.0 | .348 | 2,505 | 30.2 | .336 | 186 | | |
| | Small, clear | 2.00 | 2.00 | | 31.0 | .346 | 2,980 | 5,500 | 1,212 | .43 | 5.13 | 188 | 30.6 | .342 | 2,690 | 37.1 | .331 | 237 | 29.6 | 661 |
| 16 | Structural | 8.08 | 15.76 | 180 | 31.5 | .368 | 2,270 | 4,060 | 1,160 | .40 | 2.50 | 265 | 31.5 | .352 | 2,275 | 32.6 | .364 | 162 | | |
| | Small, clear | 2.00 | 2.00 | | 32.8 | .369 | 2,190 | 5,660 | 1,364 | .20 | 6.25 | 202 | 31.3 | .364 | 2,560 | 31.8 | .368 | 307 | 29.3 | 698 |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | Structural | 8.10 | 16.23 | 180 | 31.7 | .337 | 2,220 | 3,790 | 1,355 | .33 | 2.13 | 254 | 37.2 | .337 | 2,655 | 32.9 | .339 | 173 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 30.8 | .340 | 2,560 | 5,440 | 1,420 | .27 | 5.83 | 194 | 30.7 | .336 | 2,700 | 30.3 | .341 | 249 | 31.1 | 662 |
| 18 | Structural | 8.32 | 16.51 | 180 | 32.2 | .345 | 1,970 | 3,770 | 1,245 | .28 | 2.25 | 258 | 33.3 | .349 | 2,420 | 32.2 | .370 | 181 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 30.9 | .343 | 2,100 | 5,450 | 1,313 | .19 | 5.23 | 195 | 29.6 | .346 | 2,690 | 29.2 | .344 | 251 | 27.8 | 705 |
| 19 | Structural | 8.06 | 16.22 | 180 | 32.2 | .328 | 1,810 | 3,330 | 1,008 | .27 | 1.66 | 223 | 39.9 | .322 | 2,215 | 35.0 | .328 | 173 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 31.8 | .319 | 1,910 | 4,860 | 1,170 | .18 | 4.32 | 176 | 30.9 | .318 | 2,270 | 30.5 | .331 | 250 | 28.2 | 529 |
| 20 | Structural | 8.19 | 16.22 | 180 | 33.1 | .340 | 1,410 | 2,700 | 1,125 | .16 | 1.04 | 181 | 34.2 | .332 | 2,360 | 34.8 | .345 | 218 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 33.2 | .335 | 2,480 | 4,810 | 1,050 | .33 | 4.58 | 172 | 31.7 | .332 | 2,260 | 31.6 | .329 | 241 | 34.3 | 559 |

TABLE 14.—*Detailed data on individual structural timbers of air-dry Sitka spruce from Alaska and of small, clear specimens cut from them*

| Specimen No. | Type of specimen | Actual cross-section | | Span | Static bending | | | | | | | | Compression parallel to grain | | | Compression perpendicular to grain | | | Shearing strength parallel to grain | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture content | Specific gravity | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity | Work to elastic limit | Work to maximum load | Horizontal shear stress at maximum load | Moisture content | Specific gravity | Maximum crushing strength | Moisture content | Specific gravity | Fiber stress at elastic limit | Moisture content | Average of radial and tangential |
| | | *Inches* | *Inches* | *Inches* | *Per cent* | | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | *Lbs. per sq. in.* |
| 21 | Structural | 7.90 | 15.67 | 180 | 14.4 | 0.385 | 3,920 | 6,390 | 1,520 | 0.93 | 6.02 | 417 | 15.5 | 0.390 | 4,770 | 15.6 | 0.374 | 262 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.5 | .371 | 4,780 | 8,390 | 1,517 | .84 | 9.84 | 299 | 13.4 | .368 | 5,000 | 15.2 | .366 | 330 | 15.5 | 832 |
| 22 | Structural | 7.68 | 15.43 | 180 | 14.6 | .425 | 4,020 | 6,920 | 1,620 | .91 | 3.83 | 443 | 15.2 | .400 | 5,080 | 15.8 | .422 | 415 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.3 | .414 | 5,120 | 9,440 | 1,660 | .89 | 11.30 | 337 | 13.2 | .404 | 5,080 | 15.2 | .399 | 453 | 13.4 | 867 |
| 23 | Structural | 8.12 | 15.96 | 180 | 14.7 | .384 | 3,760 | 5,760 | 1,245 | 1.04 | 2.91 | 381 | 15.4 | .387 | 4,620 | 14.8 | .388 | 507 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.4 | .381 | 4,820 | 8,050 | 1,275 | 1.02 | 9.25 | 287 | 14.0 | .368 | 4,160 | 15.0 | .348 | 360 | 12.6 | 789 |
| 24 | Structural | 7.99 | 15.64 | 180 | 14.6 | .374 | 4,860 | 5,780 | 1,350 | 1.61 | 3.75 | 375 | 14.4 | .378 | 4,250 | 15.5 | .375 | 521 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.9 | .369 | 5,080 | 8,090 | 1,323 | 1.09 | 7.06 | 288 | 13.9 | .374 | 4,430 | 15.8 | .376 | 535 | 13.1 | 726 |
| 25 | Structural | 7.96 | 15.48 | 180 | 16.0 | .412 | 4,650 | 7,120 | 1,610 | 1.23 | 7.68 | 457 | ------- | ------- | ------- | 15.8 | .412 | 602 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.7 | .414 | 5,780 | 10,330 | 1,828 | 1.02 | 11.68 | 369 | 14.4 | .420 | 5,540 | 15.4 | .420 | 577 | 13.4 | 784 |
| 26 | Structural | 7.86 | 15.87 | 180 | 19.8 | .334 | 3,660 | 4,880 | 1,215 | 1.01 | 4.80 | 322 | 10.2 | .376 | 5,530 | 15.9 | .332 | 428 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 13.2 | .318 | 4,590 | 7,250 | 1,121 | 1.05 | 6.46 | 259 | 12.1 | .321 | 4,610 | 11.2 | .346 | 410 | 11.8 | 825 |
| 27 | Structural | 8.04 | 15.49 | 180 | 16.3 | .396 | 4,270 | 5,600 | 1,475 | 1.13 | 2.25 | 360 | 14.9 | .399 | 4,350 | 16.0 | .402 | 473 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 15.5 | .396 | 5,160 | 8,600 | 1,404 | 1.06 | 11.08 | 306 | 14.9 | .403 | 4,840 | 15.5 | .404 | 583 | 13.7 | 826 |
| 28 | Structural | 7.92 | 15.69 | 180 | 14.2 | .335 | 3,250 | 4,580 | 1,250 | .77 | 1.87 | 299 | 15.7 | .319 | 3,840 | 16.1 | .322 | 489 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 16.0 | .322 | 4,220 | 7,100 | 1,208 | .83 | 7.54 | 253 | 14.5 | .323 | 3,970 | 14.7 | .321 | 345 | 12.6 | 697 |
| 29 | Structural | 8.04 | 15.55 | 180 | 15.7 | .359 | 4,560 | 5,590 | 1,415 | 1.35 | 2.24 | 356 | 15.1 | .351 | 4,600 | 15.2 | .374 | 469 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.8 | .363 | 5,240 | 8,400 | 1,386 | 1.12 | 9.42 | 300 | 14.3 | .352 | 4,660 | 15.3 | .367 | 387 | 13.9 | 682 |
| 30 | Structural | 7.92 | 15.42 | 180 | 15.0 | .372 | 3,750 | 5,670 | 1,635 | .79 | 2.26 | 364 | 15.2 | .370 | 5,120 | 15.4 | .374 | 352 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.9 | .378 | 5,130 | 9,050 | 1,622 | .91 | 10.13 | 323 | 13.9 | .376 | 5,120 | 15.1 | .380 | 373 | 12.9 | 699 |
| 31 | Structural | 7.84 | 15.73 | 180 | 15.0 | .346 | 3,730 | 4,640 | 1,205 | 1.06 | 1.81 | 304 | 14.9 | .332 | 4,310 | 14.4 | .345 | 527 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.1 | .340 | 4,390 | 7,410 | 1,349 | .80 | 8.34 | 266 | 13.4 | .343 | 4,150 | 14.3 | .353 | 312 | 14.1 | 703 |

TABLE 14.—*Detailed data on individual structural timbers of air-dry Sitka spruce from Alaska and of small, clear specimens cut from them*—Con.

| Specimen No. | Type of specimen | Actual cross-section | | Span | Static bending | | | | | | | | Compression parallel to grain | | | Compression perpendicular to grain | | | Shearing strength parallel to grain | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Moisture content | Specific gravity | Fiber stress at elastic limit | Modulus of rupture | Modulus of elasticity | Work to elastic limit | Work to maximum load | Horizontal shear stress at maximum load | Moisture content | Specific gravity | Maximum crushing strength | Moisture content | Specific gravity | Fiber stress at elastic limit | Moisture content | Average of radial and tangential |
| | | *Inches* | *Inches* | *Inches* | *Per cent* | | *Lbs. per sq. in.* | *Lbs. per sq. in.* | *1,000 lbs. per sq. in.* | *In.-lbs. per cu. in.* | *In.-lbs. per cu. in.* | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | | *Lbs. per sq. in.* | *Per cent* | *Lbs. per sq. in.* |
| 32 | Structural | 8.25 | 15.97 | 180 | 20.9 | 0.410 | 4,090 | 6,020 | 1,720 | 0.89 | 2.75 | 398 | 16.0 | 0.415 | 4,970 | 16.3 | 0.419 | 249 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.6 | .401 | 6,250 | 9,720 | 1,663 | 1.31 | 13.89 | 347 | 13.6 | .396 | 5,590 | 11.4 | .405 | 515 | 12.0 | 1,031 |
| 33 | Structural | 8.05 | 15.68 | 180 | 22.0 | .457 | 5,020 | 7,010 | 1,770 | 1.31 | 3.33 | 457 | 16.2 | .477 | 5,790 | 13.1 | .503 | 745 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.7 | .458 | 6,830 | 11,330 | 1,654 | 1.57 | 15.27 | 404 | 12.9 | .444 | 6,200 | 12.9 | .492 | 685 | 12.1 | 1,316 |
| 34 | Structural | 8.01 | 15.68 | 180 | 19.2 | .332 | 3,040 | 4,620 | 1,300 | .65 | 2.00 | 302 | 15.2 | .330 | 4,150 | ------- | ------- | ------- | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.8 | .328 | 4,670 | 7,580 | 1,219 | 1.00 | 7.69 | 270 | 11.8 | .335 | 4,740 | 12.1 | .335 | 442 | 12.6 | 902 |
| 35 | Structural | 8.28 | 16.01 | 180 | 23.2 | .368 | 3,330 | 4,530 | 1,270 | .80 | 2.26 | 302 | 15.6 | .361 | 4,190 | ------- | ------- | ------- | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.1 | .370 | 4,950 | 7,810 | 1,122 | 1.23 | 6.61 | 278 | 12.1 | .379 | 4,880 | 11.8 | .364 | 477 | 11.0 | 1,000 |
| 36 | Structural | 8.20 | 16.09 | 180 | 19.7 | .337 | 2,950 | 4,350 | 1,070 | .74 | 2.27 | 290 | 14.9 | .336 | 3,890 | 11.5 | .346 | 399 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.4 | .348 | 5,020 | 7,620 | 1,290 | 1.09 | 4.88 | 272 | 12.1 | .349 | 4,960 | 11.5 | .358 | 639 | 11.5 | 854 |
| 37 | Structural | 8.16 | 16.30 | 180 | 14.6 | .357 | 3,880 | 4,860 | 1,265 | 1.09 | 2.25 | 330 | 15.0 | .345 | 4,150 | 14.8 | .350 | 387 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.2 | .398 | 4,940 | 8,740 | 1,246 | 1.10 | 9.80 | 311 | 13.9 | .384 | 4,500 | 15.4 | .405 | 587 | 12.8 | 853 |
| 38 | Structural | 7.97 | 15.84 | 180 | 15.2 | .348 | 3,220 | 4,450 | 1,375 | .69 | 1.42 | 293 | 14.4 | .342 | 4,420 | 15.5 | .341 | 375 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.5 | .337 | 4,760 | 8,240 | 1,408 | .88 | 10.20 | 294 | 14.0 | .335 | 4,530 | 15.2 | .336 | 403 | 13.7 | 659 |
| 39 | Structural | 7.99 | 15.86 | 180 | 19.9 | .368 | 3,160 | 3,890 | 1,490 | .61 | .99 | 255 | ------- | ------- | ------- | 15.0 | .365 | 368 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.2 | .380 | 5,500 | 8,050 | 1,481 | 1.14 | 5.11 | 288 | 13.5 | .374 | 4,960 | 11.1 | .357 | 510 | 11.0 | 990 |
| 40 | Structural | 7.89 | 16.22 | 180 | 20.3 | .354 | 2,840 | 3,650 | 1,175 | .63 | 1.02 | 246 | 14.7 | .364 | 4,010 | 14.9 | .362 | 425 | ------- | ------- |
| | Small, clear | 2.00 | 2.00 | ------- | 14.5 | .353 | 5,270 | 8,230 | 1,382 | 1.12 | 8.12 | 293 | 12.1 | .352 | 5,240 | 11.1 | .363 | 467 | 12.0 | 860 |

The allowable safe stress in bending recommended by the Forest Products Laboratory for western hemlock is 1,300 pounds per square inch for the Select grade for all thicknesses used under continuously dry conditions. This fact would establish 3,900 pounds per square inch as a desirable minimum value of modulus of rupture of western hemlock under test conditions for a select grade. Tables 11 and 15 show that the poorest western hemlock timber (No. 26), which might be graded as Select or S2, developed under test a modulus of rupture (3,950 pounds per square inch) just within the limits considered a desirable minimum.

These timbers, when tested were graded by the rules of the Pacific Lumber Inspection Bureau, which, however, did not include all the principles of strength grading. They were also originally graded according to the Forest Service rules set forth in Forest Service Bulletin 108 (*6*). These rules have since been superseded by the basic grades proposed in Department Circular 295 (*15*), on which the present American lumber standards grades of Select and Common are based (*22*). It was thought preferable, in connection with the individual structural timbers, to regrade them so far as possible in accordance with the latest principles and rules.

The results of this regrading, which followed the principles of Department Circular 295 (*15*), are presented in Tables 15 to 18. Unfortunately, the records of defects and their location are not complete enough to permit, in all cases, and several years after the tests were made, of accurate and final grading, particularly with respect to cross grain, checks, shakes, and decay. The grading given in the tables for each face, therefore, is that based on knots alone. In some cases it is known that other defects than knots controlled the strength, nevertheless, it is felt that the grading on the basis of knots alone is of considerable value in indicating the character of the material.

TABLE 15.—*Classification of green western hemlock structural timbers according to grade*

[The letters *a*, *b*, *c*, and *d* denote the successive faces of the timbers (clockwise) when viewed from the butt end]

| Specimen No. | Grade [1] of each face as determined by knots and size and location of limiting knot | | | | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| | Upper face (*a*) | Lower face (*c*) | Side face (*b*) | Side face (*d*) | |
| 1 | S1; clear | S1; clear | S2; 1½-inch sound knot at center of length of beam and about 2 inches from bottom edge. | S1; 1½-inch sound knot at center of length of beam and 7 inches from top edge. | Compression, tension, compression, tension. |
| 2 | S1; 1-inch rotten knot 31 inches from center of length of beam and 3 inches from edge. | do | S1; clear | S1; 1¼-inch sound knot 37 inches from center of length of beam and 7 inches from top edge. | Compression, splintering tension. |
| 3 | S1; 1¼-inch sound knot 37 inches from center and 2 inches from edge. | do | S1; 1-inch sound knot 12 inches from center of length of beam and 6½ inches from bottom edge. | S1; 1½-inch rotten knot 22 inches from center of length of beam and 4 inches from top edge. | Compression, spiral grain tension, horizontal shear. |
| 4 | S1; clear | do | S2; 1-inch sound knot 24 inches from center of length of beam and 3 inches from bottom edge. | S1; clear | Slight spiral grain tension, horizontal shear. |
| 5 | do | do | S1; ¾-inch sound knot 6 inches from center of length of beam and 11 inches from bottom edge. | do | Compression, slight spiral grain tension, splintering tension and horizontal shear. |
| 6 | S2; 1½-inch rotten knot 11 inches from center of length of beam and 4 inches from edge. | do | S2; 2-inch sound knot 8 inches from center of length of beam and 4 inches from top edge. | S1; 1¼-inch sound knot 6 inches from center of length of beam and 5 inches from top edge. | Compression, spiral grain tension, horizontal shear. |
| 7 | S1; clear | do | S1; 1-inch sound knot 5 inches from center of length of beam near top edge. | S1; clear | Compression, splintering tension. |
| 8 | do | do | S2; 2-inch sound knot 31 inches from center of length of beam and 6 inches from bottom edge; 2-inch sound knot 40 inches from center of length of beam and 4 inches from top edge. | S1; 1-inch sound knot 15 inches from center of length of beam and 2 inches from edge. | Compression, splintering tension, brash and splintering tension. |
| 9 | S1; small bark pocket 14 inches from center at edge. | do | S1; clear | S2; 2-inch sound knot 13½ inches from center of length of beam and 2 inches from top edge; 2-inch rotten knot 28 inches from center of length of beam and 4¾ inches from bottom edge. | Compression and brash tension. |

[1] S1, S2, S3, and S4 designate grades of timbers representing 87½, 75, 62½, and 50 per cent, respectively, of the strength of the clear wood (U. S. Dept. Agr. Cir. 295).

| | | | | | |
|---|---|---|---|---|---|
| 10 | S3; 2-inch sound knot 21 inches from center of length of beam and at edge. | S1; clear with some wane at end | ....do.... | S3; 2-inch sound knot 21 inches from center of length of beam and at top edge. | Compression, brash tension. |
| 11 | S2; about 1¼-inch sound knot 36 inches from center of length of beam and at the edge. | S2; about 1¼-inch sound knot 22 inches from center of length of beam and 3 inches from edge. | S2; 2-inch sound knot 36 inches from center of length of beam and extends to top edge. | S1; 1-inch sound knot 15 inches from center of length of beam and about 1 inch from bottom edge. | Brash tension. |
| 12 | S1; 1-inch rotten knot 16 inches from center of length of beam and 1½ inches from edge; 1-inch rotten knot 6 inches from center of length of beam and 5 inches from edge. | S1; clear.... | S1; clear except for 1 by 3 inch spike knot near support. | S2; 2-inch sound knot 15½ inches from center of length of beam and 2 inches from top edge. | Compression, simple tension. |
| 13 | S2; 1½-inch rotten knot 12 inches from center of length of beam and at edge. | S1; bark streak 1½ inches wide.. | S2; 1½-inch rotten knot 12 inches from center of length of beam and at top edge. | S2; 1½-inch sound knot 32 inches from center of length of beam at top edge. | Compression, simple tension, simple tension. |
| 14 | S1; clear.... | S1; clear.... | S1; clear.... | S2; 1½-inch sound knot 27½ inches from center of length of beam and 2 inches from top edge. | Compression, spiral grain tension, horizontal shear. |
| 15 | ....do.... | S1; clear except for pitch seam 12 inches long beginning 30 inches from center of length of beam. | S1; 2-inch sound knot 4 inches from center of length of beam and 7 inches from bottom edge. | S1; clear.... | Spiral grain tension, horizontal shear, buckling. |
| 16 | ....do.... | S1; 1-inch rotten knot 26 inches from center of length of beam and 1 inch from edge. | S1; 1-inch sound knot 27½ inches from center of length of beam and 2 inches from bottom edge. | ....do.... | Compression, spiral grain tension, horizontal shear. |
| 17 | ....do.... | S1; clear but shows some wane at end. | S1; 1-inch sound knot 38 inches from center of length of beam and 4 inches from bottom edge. | ....do.... | Slight tension, spiral grain tension and horizontal shear. |
| 18 | S1; any of three 1-inch sound knots, 25, 23, and 2 inches respectively from center of length of beam. | S1; clear except ½ by 18 inch bark streak beginning 4½ inches from center of length of beam. | S1; 1¼-inch sound knot 45 inches from center of length of beam and 9 inches from bottom edge; considerable bark. | S1; 1¼-inch sound knot 18 inches from center of length of beam and 3 inches from top edge. | Compression, spiral-grain tension and horizontal shear. |
| 19 | S1; 1-inch rotten knot 38 inches from center of length of beam and 1½ inches from edge. | S1; ¾-inch rotten knot 32½ inches from center of length of beam about 3 inches from edge. | S2; 2-inch rotten knot 30 inches from center of length of beam and 6½ inches from top edge. | S2; 1-inch sound knot 24 inches from center of length of beam at top edge. | Horizontal shear and brash tension. |
| 20 | S1; clear.... | S1; clear.... | S2; 2-inch sound knot 8 inches from center of length of beam and about 4 inches from upper edge. | S1; clear.... | Compression, horizontal shear, spiral-grain tension. |
| 21 | S3; 2-inch sound knot 11 inches from center of length of beam and 4 inches from edge. | ....do.... | S3; 2½-inch sound knot 7 inches from center of length of beam and 1 inch from top edge. | ....do.... | Cross-grain tension, horizontal shear, brash tension. |
| 22 | S1; clear.... | S1; clear but shows some wane near center. | S1; 1-inch sound knot 3 inches from center of length of beam and 5 inches from top edge. | S1; clear but shows some wane near center. | Spiral-grain tension, compression, buckling and splitting. |

TABLE 15.—*Classification of green western hemlock structural timbers according to grade*—Continued

| Specimen No. | Grade of each face as determined by knots and size and location of limiting knot | | | | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| | Upper face (*a*) | Lower face (*c*) | Side face (*b*) | Side face (*d*) | |
| 23 | S1; 1-inch sound knot 8½ inches from center of length of beam and at edge; 1-inch sound knot 6 inches from center of length of beam and 1 inch from edge. | S1; bark streak 2 inches wide. | S1; 1-inch rotten knot 30 inches from center of length of beam and 7⅜ inches from top edge; 1-inch sound knot 11 inches from center of length of beam and 5½ inches from bottom edge. | S1; 1-inch sound knot 8½ inches from center of length of beam and at top edge. | Compression, brash tension and simple tension. |
| 24 | S1; 1-inch sound knot 28 inches from center of length of beam and 1 inch from edge. | S1; clear | S1; 1¼-inch sound knot 5 inches from center of length of beam and 4½ inches from top edge. | S1; clear | Horizontal shear, brash tension. |
| 25 | S2; 1½-inch sound knot 38 inches from center of length of beam and 1 inch from edge. | S1; bark streak 1 inch wide by 30 inches long beginning 34 inches from center of length to beam. | S2; 1¼-inch sound knot 22 inches from center of length of beam and at top edge, also bark streaks. | S1; several bark streaks [2] | Horizontal shear. |
| 26 | S1; 1-inch sound knot 5 inches from center of length of beam and at the edge; 1-inch sound knot 24 inches from center of length of beam and at the edge. | S2; 1¼-inch sound knot at center of length of beam and 2 inches from edge. | S2; 1⅜-inch sound knot 9 inches from center of length of beam and 2½ inches from bottom edge. | S1; 1-inch sound knot 6 inches from center of length of beam and 5 inches from top.[3] | Horizontal shear, simple tension. |
| 27 | S2; 1¼-inch sound knot 36½ inches from center of length of beam and at edge. | S2; 1½-inch sound knot 39 inches from center of length of beam and 3 inches from edge. | S2; 1½-inch sound knot 37 inches from center of length of beam and 2 inches from bottom edge. | S1; 1-inch sound knot 43 inches from center of length of beam and 3 inches from top edge. | Compression, horizontal shear, spiral-grain tension. |
| 28 | S1; clear | S1; clear with some wane at end | S1; clear but some wane at end | S3; 2-inch bark knot 10 inches from center of length of beam and 1 inch from top edge.[4] | Horizontal shear, brash tension. |
| 29 | do | S1; clear | S2; 3-inch sound knot 1 inch from center of length of beam and 7 inches from bottom edge. | S1; clear except for a 1-inch sound knot 92 inches from center of length of beam.[5] | Slight spiral-grain tension, buckling, compression, horizontal shear. |

[2] A rotten knot and checks would probably make this timber unacceptable in any strength grade.
[3] Probably contained some shake, but not recorded.
[4] Serious decay would make this timber unacceptable in any strength grade.
[5] Rotten knots, checks, and cross grain would make this timber unacceptable in the S2 grade.

TABLE 16.—*Classification of air-dry western hemlock structural timbers according to grade*

[The letters *a*, *b*, *c*, and *d* denote the successive faces of the timbers (clockwise) when viewed from the butt end]

| Specimen No. | Grade[1] of each face as determined by knots and size and location of limiting knot | | | | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| | Upper face (*a*) | Lower face (*c*) | Side face (*b*) | Side face (*d*) | |
| 30 | S1; 1-inch rotten knot 19 inches from center of length of beam and at edge. | S1; ¾-inch rotten knot 12 inches from center of length of beam and 2 inches from edge. | S1; 1-inch sound knot 19 inches from center of length of beam and 12 inches from top edge. | S1; 1-inch rotten knot 19 inches from center of length of beam and at top edge. | Horizontal shear, brash tension, splintering tension. |
| 31 | S2; 1¼-inch rotten knot 32 inches from center of length of beam and at edge. | S1; clear except for 2-inch sound knot 72 inches from center of length of beam and 6 inches from edge | S2; 2-inch rotten knot 40 inches from center of length of beam and at top edge. | S2; 2-inch sound knot 43 inches from center of length of beam and 3 inches from bottom edge. | Slight spiral grain tension, horizontal shear, spiral grain and splintering tension. |
| 32 | S1; clear but contains large amount of advanced decay. | S1; clear | S1; clear but shows some checks and wane. | S1; 1-inch rotten knot 24 inches from center of length of beam and near top edge. | Buckling; horizontal shear, spiral grain tension; compression at probably 70,000 pounds total load. |
| 33 | S2; 2-inch sound knot 40 inches from center of length of beam and 6½ inches from edge. | S1; clear but contains some checks. | S1; 1-inch sound knot 19 inches from center of length of beam and 7 inches from top edge. | S3; 2½-inch sound knot 32 inches from center of length of beam and at top edge. | Horizontal shear, slight spiral grain tension, and splintering tension. |
| 34 | S2; about 1½-inch sound knot 36 inches from center of length of beam and at edge. | S1; clear | S2; 1½-inch sound knot 6 inches from center of length of beam and extending to within 1 inch of upper edge. | S2; about a 2-inch sound knot 36 inches from center of length of beam and at top edge. | Irregular grain tension, compression, horizontal shear and brash tension. |
| 35 | S1; clear but contains some checks. | S1; clear but contains some checks. | S1; contains streak of well advanced decay 2½ inches wide and 76 inches long. | S1; 1-inch sound knot about 18 inches from center of length of beam and 10 inches from bottom edge. | Diagonal grain tension. |
| 36 | S1; 1-inch sound knot 22 inches from center of length of beam and 4 inches from edge. | S1; clear but contains some wane and checks. | S3; 4-inch sound knot 44 inches from center of length of beam and about 2 inches from top edge; 3½-inch sound knot 28 inches from center of length of beam and 3 inches from top edge. | S2; 2-inch sound knot 40 inches from center of length of beam and about 5 inches from bottom edge; also check and wane. | Horizontal shear, brash tension and slight compression. |
| 37 | S1; clear | S1; clear | S2; 2-inch rotten knot 28 inches from center of length of beam and 6 inches from top edge. | S1; clear but shows some checks | Horizontal shear. |
| 38 | S3; 2½-inch sound knot 4 inches from center of length of beam at edge. | do | S1; 1-inch sound knot 2½ inches from center of length of beam about 3 inches from top edge. | S1; ½-inch rotten knot 29 inches from center of length of beam and 1½ inches from bottom edge. | Do. |

[1] S1, S2, S3, and S4 designate grades of timbers representing 87½, 75, 62½, and 50 per cent, respectively, of the strength of the clear wood (U. S. Dept. Agr. Circ. 295).

TABLE 16.—*Classification of air-dry western hemlock structural timbers according to grade*—Continued

| Specimen No. | Grade of each face as determined by knots and size and location of limiting knot | | | | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| | Upper face (a) | Lower face (c) | Side face (b) | Side face (d) | |
| 39 | S1; clear but shows some checks | S1; clear but shows some checks | S2; 2-inch rotten knot 18 inches from center of length of beam and 3 inches from top edge. | S1; 1½-inch sound knot 20 inches from center of length of beam and 9 inches from bottom edge. | Horizontal shear and slight spiral grain tension. |
| 40 | S3; 2-inch rotten knot 24 inches from center of length of beam and 2 inches from edge. | S1; clear except for two knots outside of center half of length. | S2; 1½-inch sound knot 29 inches from center of length of beam and about 1½ inches from top edge. | S1; 2-inch sound knot 10 inches from center of length of beam and 8 inches from bottom edge. | Slight spiral grain and brash tension. |
| 41 | S1; clear | S1; clear but shows checks | S2; 2-inch sound knot 42 inches from center of length of beam and 3½ inches from top edge. | S1; clear but shows some checks | Horizontal shear. |
| 42 | S2; 1½-inch sound knot 17 inches from center of length of beam and 2 inches from edge. | S2; about a 1¼-inch sound knot about 18 inches from center of length of beam and 3 inches from edge. | S1; 1-inch spike knot 30 inches from center of length of beam and extending to top face. | S2; 2-inch sound knot 21 inches from center of length of beam and 2 inches from top edge. | Slight tension, brash and simple tension, slight compression. |
| 43 | S2; 1½-inch sound knot 3 inches from center of length of beam and 7 inches from edge. | S1; clear but contains some bark streaks and checks. | S2; 2-inch sound knot 6 inches from center of length of beam and 3 inches from top edge. | S2; 1½-inch sound knot 24 inches from center of length of beam and at top edge. | Horizontal shear, brash and splintering tension. |
| 44 | S1; clear | S1; clear | S2; 2¼-inch sound knot 7 inches from center of length of beam and extending to bottom edge. | S1; ¾-inch encased knot 25 inches from center of length of beam and 5 inches from top edge. | Irregular grain tension, compression and buckling, horizontal shear. |
| 45 | S1; clear except shows some checks. | S1; clear except shows some checks. | S2; 2-inch sound knot 45 inches from center of length of beam and 2 inches from bottom edge. | S1; clear but shows some checks | Horizontal shear. |
| 46 | S1; clear | S1; clear but shows some wane | S1; 2-inch sound knot 44 inches from center of length of beam and 9 inches from top edge. | S1; clear but contains some checks and wane. | Horizontal shear, spiral grain tension. |
| 47 | S1; clear but shows some bark streak near end. | S1; clear | S1; clear but shows some checks. | S2; 2-inch sound knot 35 inches from center of length of beam and 13 inches from bottom edge. | Horizontal shear. |
| 48 | S1; 1-inch rotten knot 5 inches from center of length of beam and 1 inch from edge; 1-inch rotten knot 19 inches from center of length of beam and 4 inches from edge. | S3; 3-inch burl 60 inches from center of length of beam and 4½ inches from edge. | S2; 2-inch sound knot 19 inches from center of length of beam and 5 inches from bottom edge. | S2; 1-inch rotten knot 33 inches from center of length of beam and at top edge. | Horizontal shear, splintering tension. |
| 49 | S3; 3-inch sound knot 38 inches from center of length of beam and 4 inches from edge. | S3; 2-inch rotten knot 31 inches from center of length of beam and at edge. | S3; 2-inch rotten knot 31 inches from center of length of beam and at bottom edge. | S2; 1½ inch sound knot 22 inches from center of length of beam and 2 inches from top edge. | Brash and diagonal grain tension. |

| | | | | | |
|---|---|---|---|---|---|
| 50 | S2; 1½-inch rotten knot 40 inches from center of length of beam and 5½ inches from edge; checks. | S1; clear | S2; 2-inch sound knot 22 inches from center of length of beam 6½ inches from top edge. | S1; 1½ inch sound knot 37 inches from center of length of beam and 7 inches from bottom edge. | Horizontal shear, further development of horizontal shear, brash tension. |
| 51 | S1; clear except for bark streak at outer third. | do | S1; clear except for 1-inch rotten knot 65 inches from center and checks. | S1; 1-inch sound knot 34 inches from center of length of beam and 10 inches from bottom edge. | Horizontal shear, spiral grain tension. |
| 52 | S1; clear | S1; clear except 1-inch rotten knot near end. | S1; 1½-inch sound knot 18 inches from center of length of beam and extending to within 1 inch of top edge. | S1; 1-inch rotten knot 41 inches from center of length of beam and 8 inches from edge. | Horizontal shear, horizontal shear and brash tension. |
| 53 | do | S1; clear | S1; 1-inch sound knot 31 inches from center of length of beam and 11 inches from top face; checks. | S2; shake | Horizontal shear, further development of horizontal shear and buckling, irregular grain tension. |
| 54 | S1; clear except it shows some checks and wane. | S1; clear but shows some wane | S2; about 2½-inch sound knot 25 inches from center of length of beam and 9 inches from top edge. | S1; clear but contains some checks and wane. | Horizontal shear, horizontal shear in top half, spiral grain tension. |
| 55 | S1; clear except for 1-inch rotten knot near end. | S1; clear | S1; clear except for 1½-inch rotten knot 9 inches from top edge near end. | S1; 1-inch sound knot 22 inches from center of length of beam and 4 inches from bottom edge. | Diagonal grain tension. |
| 56 | S2; 1¼-inch sound knot 39 inches from center of length of beam 7 inches from edge. | S1; checks and bark | S3; 4-inch sound knot 14 inches from center of length of beam and about 2 inches from top edge; checks. | S1; 1-inch sound knot 24 inches from center of length of beam and 10 inches from bottom edge; checks. | Horizontal shear, spiral grain tension, compression, brash tension in portion above shear failure. |
| 57 | S3; 2-inch sound knot 3 inches from center of length of beam and [illegible] inches from edge. | S1; clear | S2; 2-inch sound knot 27 inches from center of length of beam and 12 inches from top edge. | S1; 1-inch sound knot 7 inches from center of length of beam and 13 inches from bottom edge. | Brash and spiral grain tension. |
| 58 | S2; 1½-inch sound knot 5 inches from center of length of beam and near edge. | S2; 1½-inch rotten knot 36 inches from center of length of beam and near edge. | S2; 2½-inch sound knot 4 inches from center of length of beam and about 5 inches from top edge. | S2; 1½-inch sound knot 33 inches from center of length of beam and at top edge. | Spiral grain tension, horizontal shear, splintering tension. |

TABLE 17.—*Classification of green Sitka spruce structural timbers according to grade*

[The letters *a*, *b*, *c*, and *d* denote the successive faces of the timbers (clockwise) when viewed from the butt end]

| Specimen No. | Grade[1] of each face as determined by knots and size and location of limiting knot | | | | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| | Upper face (*a*) | Lower face (*c*) | Side face (*b*) | Side face (*d*) | |
| 1 | S1; clear | S1; clear | S1; clear | S1; clear | Heavy compression, brash and spiral-grained tension. |
| 2 | do | do | S1; $1\frac{1}{2}$-inch sound knot 30 inches from center of length of beam, 7 inches from top edge. | do | Heavy compression at four places and slight compression at another place. |
| 3 | S1; 1-inch sound knot 35 inches from center at edge. | do | S1; $\frac{1}{2}$-inch sound knot 38 inches from center, 3 inches from bottom. | S1; $1\frac{1}{2}$-inch sound knot 18 inches from center, 8 inches from bottom. | Compression, brash and simple tension. |
| 4 | S1; clear | do | S1; clear | S1; clear | Compression, simple tension. |
| 5 | do | do | do | do | Compression, spiral tension. |
| 6 | do | do | S1; $1\frac{1}{2}$-inch sound knot 40 inches from center, 4 inches from bottom. | do | Compression, spiral-grained tension and horizontal shear. |
| 7 | do | do | S1; clear | do | Compression, horizontal shear and brash and spiral-grained tension. |
| 8 | S1; $\frac{3}{4}$-inch sound knot 1 inch from center and 1 inch from edge. | do | S1; 1-inch sound knot 64 inches from center and 4 inches from bottom. | S1; $1\frac{1}{2}$-inch sound knot 10 inches from center, 4 inches from top. | Compression, brash and spiral-grained tension. |
| 9 | S1; clear | do | S1; clear | S1; clear | Compression, brash and simple tension. |
| 10 | S1; $\frac{3}{4}$-inch sound knot 11 inches from center and 1 inch from edge. | do | S1; 1-inch sound knot 40 inches from center, 7 inches from bottom. | S1; $1\frac{1}{2}$-inch sound knot 11 inches from center, 8 inches from bottom. | Compression, horizontal shear. |
| 11 | S1; 1-inch sound knot 43 inches from center and 4 inches from edge. | S2; $1\frac{1}{2}$-inch sound knot 13 inches from center and 3 inches from edge. | S1; $1\frac{1}{2}$-inch sound knot 23 inches from center, 4 inches from bottom. | S1; 1-inch sound knot 24 inches from center, 7 inches from bottom. | Compression, brash and simple tension, horizontal shear. |
| 12 | S1; clear | S1; clear | S1; clear | S1; clear | Heavy compression, compression, splintering tension. |
| 13 | S1; $1\frac{1}{2}$-inch sound knot 53 inches from center and 1 inch from edge. | S1; 1-inch sound knot 31 inches from center and 1 inch from edge. | S1; $1\frac{1}{2}$-inch sound knot 31 inches from center, 2 inches from top. | S1; $1\frac{1}{2}$-inch sound knot 12 inches from center, 6 inches from bottom. | Compression, brash and simple tension. |
| 14 | S1; clear | S1; clear | S1; clear | S1; clear | Compression, horizontal shear, spiral-grained tension. |
| 15 | S1; $\frac{1}{2}$-inch sound knot 19 inches from center at edge | do | S1; $\frac{1}{2}$-inch sound knot 19 inches from center at upper edge; $\frac{1}{2}$-inch sound knot 12 inches from center and 6 inches from top. | do | Compression, simple tension, horizontal shear. |

| Speci-men No. | Upper face (a) | Lower face (c) | Side face (b) | Side face (d) | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| 16 | S1; 2½-inch sound knot 6 inches from center and 2 inches from edge. | do | S1; 1½-inch spike knot 8 inches from center, 1 inch from top edge. | do | Compression, horizontal shear along wind shake. |
| 17 | S1; clear | do | S1; clear | do | Compression, slight spiral-grained tension, horizontal shear. |
| 18 | do | do | S1; 1½-inch sound knot 26 inches from center, 4 inches from bottom. | do | Compression, horizontal shear and brash and spiral tension. |
| 19 | S2; 2-inch sound knot 16 inches from center and 4 inches from edge. | do | S1; 2½-inch sound knot 67 inches from center and at edge. | S1; 1½-inch sound knot 26 inches from center, 4 inches from bottom; 2-inch sound knot 50 inches from center and 1 inch from top. | Compression, brash and spiral tension. |
| 20 | S1; clear | S2; about 1½-inch knot 36 inches from center and about 1¼ inches from edge. | S2; 2-inch sound knot 2 inches from center, 6 inches from top edge. | S1; 2-inch sound knot 2 inches from center, 7 inches from top.[2] | Horizontal shear and spiral-grained tension; spiral-grained tension; compression. |

[1] S1, S2, S3, and S4 designate grades of timbers representing 87½, 75, 62½, and 50 per cent, respectively, of the strength of the clear wood. (U. S. Dept. Agr. Circ. 295.)
[2] Spiral grain of 1 in 4 would make this timber unacceptable in any of the structural grades.

TABLE 18.—*Classification of air-dry Sitka spruce structural timbers according to grade*

[The letters *a*, *b*, *c*, and *d* denote the successive faces of the timbers (clockwise) when viewed from the butt end]

| Speci-men No. | Grade[1] of each face as determined by knots and size and location of limiting knot | | | | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| | Upper face (*a*) | Lower face (*c*) | Side face (*b*) | Side face (*d*) | |
| 21 | S2; 2½-inch sound knot 71 inches from center and about 2¼ inches from edge. | S1; clear | S1; clear | S2; 1½-inch sound knot 36 inches from center and about 2½ inches from top edge. | Buckling, splitting and compression; simple tension; compression; brash and simple tension. |
| 22 | S1; 1½-inch sound knot 56 inches from center and at edge. | do | S1; 1½-inch sound knot 33 inches from center and about 4½ inches from top. | S1; 2-inch sound knot 51 inches from center and 2½ inches from top edge. | Spiral grain tension; slight compression under load block. |
| 23 | S1; clear | do | S1; clear | S1; clear | Horizontal shear, brash tension. |
| 24 | do | do | do | do | Compression, brash and spiral-grained tension. |
| 25 | S2; 1½-inch sound knot 20 inches from center and 1½ inches from edge. | do | S1; 2-inch sound knot 45 inches from center and at top edge. | do | Compression; splintering and spiral-grained tension. |

[1] S1, S2, S3, and S4 designate grades of timber representing 87½, 75, 62½, and 50 per cent, respectively, of the strength of the clear wood (U. S. Dept. Agr. Circ. 295).

TABLE 18.—*Classification of air-dry Sitka spruce structural timbers according to grade*—Continued

| Specimen No. | Grade of each face as determined by knots and size and location of limiting knot: Upper face (*a*) | Lower face (*c*) | Side face (*b*) | Side face (*d*) | Character of failure in bending in order of occurrence |
|---|---|---|---|---|---|
| 26 | S1; ½-inch sound knot 11 inches from center and 2 inches from edge; ½-inch sound knot 26 inches from center and 1 inch from edge. | S1; ½-inch sound knot 35 inches from center and 3 inches from edge. | S1; 1-inch sound knot 19 inches from center and 6 inches from top. | S1; 1-inch sound knot 26 inches from center and 5 inches from top. | Compression, simple tension, compression, simple tension. |
| 27 | S1; clear | S1; clear | S1; clear | S1; clear | Horizontal shear. |
| 28 | do | do | S1; 1½-inch loose knot 37 inches from center and 2½ inches from bottom edge. | S1; 1-inch sound knot 31 inches from center and 2 inches from bottom edge. | Brash tension, slight compression, splitting. |
| 29 | do | do | S1; clear | S1; clear | Horizontal shear. |
| 30 | do | do | do | do | Horizontal shear, slight tension. |
| 31 | S1; ½-inch sound knot 16 inches from center near edge. | do | S1; 1-inch sound knot 16 inches from center, ½ inch from top edge. | do | Compression, splitting and simple tension. |
| 32 | S1; clear | do | S1; 1-inch sound knot 12 inches from center, 2 inches from bottom. | do | Horizontal shear. |
| 33 | do | do | S1; clear | do | Compression, horizontal shear. |
| 34 | do | do | S1; 1-inch sound knot 38 inches from center, 6 inches from top edge. | S1; 1-inch sound knot 17 inches from center, 6 inches from bottom edge. | Horizontal shear. |
| 35 | do | do | S1; clear | S1; clear | Brash tension. |
| 36 | S2; 1½-inch sound knot 30 inches from center at edge. | S2; 2-inch sound knot 51 inches from center near edge. | S1; 1½-inch sound knot 26 inches from center, 4 inches from edge. | S1; 1-inch sound knot 32 inches from center at top edge. | Compression, horizontal shear and diagonal-grained tension. |
| 37 | S1; 1-inch sound knot 30 inches from center and 2 inches from edge. | S1; 1½-inch sound knot, 72 inches from center and at edge. | S1; ½-inch loose knot 53 inches from center, 6 inches from bottom edge. | S1; 1-inch loose knot 12½ inches from center and 2½ inches from top edge. | Tension, compression, splintering tension. |
| 38 | S3; 2-inch knot 30 inches from center near edge. | S2; 2-inch sound knot 76 inches from center and 5 inches from edge. | S2; 3-inch sound knot 32 inches from center and 5 inches from top. | S2; 2-inch sound knot 30 inches from center near edge. | Horizontal shear. |
| 39 | S2; 2-inch sound knot 72 inches from center and 1 inch from edge. | S1; clear | S1; clear except for 1-inch sound knot 70 inches from center and 2 inches from edge. | S1; 1-inch sound knot 19 inches from center and 5 inches from top edge. | Brash and simple tension. |
| 40 | S4; 3-inch sound knot 25 inches from center and 3 inches from edge. | S2; 1½-inch sound knot 40 inches from center and 4 inches from edge. | S1; 2-inch rotten knot 80 inches from center, 8 inches from bottom. | S2; 2½-inch sound knot 25 inches from center, 3 inches from top. | Horizontal shear, simple tension. |

In one other important respect the grading used differed from the rules of Department Circular 295. Rotten knots are not permitted in the S1, S2, and S3 grades of that circular (*15*), but in the grading shown in Tables 15 to 18 the rotten knots were considered as if they had been sound. Each timber containing one or more rotten knots is designated in the Tables 11 to 18 by means of a footnote reference.

Knots showing a slight amount of decay are prevalent in a number of species, such as western hemlock, and it is in the interest of utilization to permit them whenever it is feasible to do so. A practical way to grade timbers with rotten knots is to consider them the same as sound knots when the depth of the decay is less than half the diameter of the knot. It should be kept in mind, however, that the presence of rotten knots, even though they have no immediate effect on strength is, in general, undesirable in high-grade structural timbers.

It has been established from structural-timber tests that a given-sized knot causes only about half the reduction in bending strength when on the upper or compression side of a beam as when on the lower or tension face. Hence, in testing a beam different results could be obtained, depending on whether the most knots are turned up or down, assuming, of course, that the knot is the controlling defect. In this connection it has been the standard Forest Service procedure in testing to turn the timbers with the poorer side up, thus resulting in higher loads than would obtain if the timbers were reversed. The principal object of this procedure is to obtain information as to the effect of knots in compression as well as in tension. In service, of course, a beam is apt to be used either way, there being no assurance that the timber will be used most advantageously. For this reason the structural rules of Department Circular 295 and American lumber standards do not distinguish between the tension and compression faces of a beam. This practice is, of course, less efficient than grading a timber in accordance with its most advantageous placement in service, but is on the side of safety and, further, has simplicity to commend it.

## GLOSSARY OF TERMS USED

*Air dry.*—(See p. 35.) Air-dry condition is the normal condition, with respect to moisture, of wood exposed to the air, although this condition may have been obtained by artificial means. The term "air dried" means dried by exposure to the air, while "kiln dried" indicates artificial drying. Air dry is a very general term and may mean any degree of dryness from about 6 per cent moisture, which may be obtained in very dry climates, to over 30 per cent moisture, as in timber dried to reduce its shipping weight. The degree of dryness, which will be attained in timber depends upon species, size, and the conditions under which the material is dried, especially such as humidity, method of piling, shelter, and time of drying. Twelve by twelve inch Douglas fir timbers, when air seasoned in the Lake States, will fall to about 18 per cent moisture in two years if properly spaced to allow circulation. One-inch lumber of the same species, under the same conditions, will dry to 15 per cent moisture in considerably less time, and small-sized timber dried in very dry regions will in some cases reach 6 per cent moisture. The same species, in the same sizes, piled in the same manner under shelter out of doors, will not fall much below 12 per cent moisture in the North Central and Great Lake States. In the coastal region of southeastern Alaska, where the humidity is relatively high, the moisture content of thoroughly air-seasoned lumber would probably be higher.

*Dense.*—Dense, as applied to wood, means compact, heavy (when dry), containing much wood substance in small space. For example, hickory is a very dense wood. The specific gravity of the wood when oven dry is a measure of the density. This figure is based on the weight, exclusive of moisture, but including any substances, such as rosin not volatile at 100° C., the temperature at which the moisture specimens are dried.

*Elastic limit.*—(See pp. 36 and 38.) The elastic limit (sometimes called proportional limit) is that point where the distortion ceases to be in proportion to the load. For example, if a beam deflects one-sixteenth of an inch with a 50-pound load it will deflect one-eighth of an inch with 100 pounds, and so on, each additional load of 50 pounds causing an additional deflection of one-sixteenth of an inch until the "elastic limit" is reached, after which the deflections increase more rapidly than the increase in load. A timber stressed beyond the elastic limit will not resume its original form upon the removal of the load.

*Elasticity.*—Elasticity is the property (possessed by most materials) of changing form with the application of force and recovering at once upon release from the force. In any elastic material the amount of compression or deformation is proportional to the force applied, within the elastic limit. Air and other gases under compression are elastic. The most commonly recognized elastic material is rubber. Timber is elastic within comparatively narrow limits. The term "very elastic" as applied to wood is indefinite, because it may mean that the force required to produce a given deformation is great, and the recovery sudden as in an ivory ball (see "Modulus of elasticity"); or that the amount of distortion to the elastic limit is great as in a rubber ball, or that the wood possesses high elastic resilience, a combination of the two properties.

*Fiber-saturation point.*—(See definition p. 35.)

*Fiber stress at elastic limit.*—(See pp. 36, 38, and 73.)

*Green.*—Green is the condition of timber as taken from the living tree. Immediately upon being sawed from the tree lumber begins to lose moisture and otherwise change its condition. The rapidity of these changes is determined by the species, humidity, heat, and circulation of air.

*Mechanical properties.*—Mechanical properties are the properties of wood that enable it to resist deformations, loads, shocks, or forces. Thus the ability to resist shearing forces is a mechanical property of timber. (See "Strength" p. 74.)

*Modulus of elasticity.*—(See p. 37.) Modulus of elasticity is the ratio of stress per unit area to corresponding strain per unit length, the distortion or strain being within the elastic limit. Numerically, the modulus of elasticity of a material is the force in pounds required to stretch a sample of that material with a cross-sectional area of 1 square inch to double its length, on the assumption that the fibers would not be stressed beyond their elastic limit. Rubber has a very low modulus of elasticity, while that of steel is very high. It is, then, the measure of the stiffness or rigidity of a substance.

*Modulus of rupture.*—(See definition p. 36.)

*Radial.*—Radial means extending outward from a center or an axis. Thus a radial plane in a tree is one extending from the pith of the tree outward. The wide faces of a quarter-sawed board are radial surfaces.

*Rings.*—(See p. 34.) In timber grown in climates other than tropical well-defined concentric layers of wood can be seen on the cross section. These layers correspond closely to yearly increments of growth and for that reason are called annual rings. Each annual ring consists of a layer of spring wood and summer wood. It is difficult to distinguish spring wood and summer wood in some species.

*Shear.*—(See p. 39.) Shear is the name of the stress which tends to keep two adjoining planes or surfaces of a body from sliding, one on the other, under the influence of two equal and parallel forces acting in opposite directions. A force which produces shear (or shearing stress) in a material is called a shearing force.

*Spring wood.*—The lighter and more porous layer of wood in the annual rings of a tree is known as the spring wood, or early wood. As the name implies, it is produced in the spring growth, or in the earlier part of the growing season.

*Strain.*—The deformation or distortion produced by a stress or force is known as strain.

*Strength.*—The term "strength" as ordinarily used is a very indefinite one. It is usually thought of in connection with external loads or forces. Strength in its broad sense is a measure of the mechanical properties, or of the ability of a timber to resist stress or deformation. Thus, strength in shear, bending strength, compressive strength, hardness, stiffness, toughness. These last three properties are not always thought of in connection with the term strength, but are unconsciously included whenever they are important in a specific use. Seldom, if ever, do any two species contain all the various properties in the same degree. This accounts for the special uses of the different species. Much confusion often arises from comparing species for a special use on the basis of properties or strength values not of first importance in the specific instance.

*Stress.*—Stress is distributed force. Fiber stress is the distributed force tending to compress, tear apart, or change the relative position of the wood fibers. Stress is measured by the force per unit area. Thus a short column 2 inches square (4 square inches) and supporting a load of 2,000 pounds will be under a stress or fiber stress of 500 pounds per square inch.

*Summer wood.*—(See p. 34.) Summer wood is that denser layer of wood in the annual rings of a tree which is put on in summer or the latter part of the growing season.

*Tangential.*—Tangential, as applied in this bulletin, means tangent to or parallel to the curves of the annual rings in a cross section. Thus, a tangential surface is a surface perpendicular to the radius of a tree. A board in which the wide face is a tangential surface is also called flat sawn.

## WORKING STRESSES

The figures in Tables 2, 3, and 4 are most directly applicable to the comparison of species for uses requiring wood free from defects. For structural material of grades in which the size, location, and number of defects are limited with reference to their effect on strength, the relative strengths of the species are better represented by allowable working stresses used in design. Working stresses for Select and Common structural grades conforming to the basic provisions of American Lumber Standards are given in Table 19. They are technical in nature and have been arrived at from a consideration of the strength and variability of the clear wood, the relation of density to strength, the effect of defects in structural sizes, the effect of long-continued loading, and the inherent characteristics of the species, such as prevalence of knot clusters, tendency to check in seasoning, and prevalence of shakes. The figures in Tables 2, 3, and 4 are the average results of tests on clear wood of the different species; those of Table 19 are assigned values, based not only on tests, but on experience and judgment.

TABLE 19.—*Working stresses, in pounds per square inch, for timber conforming to the basic provisions for select and common structural material of American lumber standards* [1]

[As recommended by the Forest Products Laboratory, Forest Service, United States Department of Agriculture]

| Species | Fiber stress in bending [2] | | | | | | | | | | Compression perpendicular to grain | | | Horizontal shear [3] | | Compression parallel to grain (short columns having ratio of length to least dimension of 11 or less) | | | | | | Average modulus of elasticity [4] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Continuously dry | | Occasionally wet but quickly dried | | | | More or less continuously damp or wet | | | | Continuously dry | Occasionally wet but quickly dried | More or less continuously damp or wet | Not varied with conditions of exposure | | Continuously dry | | Occasionally wet but quickly dried | | More or less continuously damp or wet | | Not varied with conditions of exposure or with grade |
| | All thicknesses | | Material 4 inches and thinner | | Material 5 inches and thicker | | Material 4 inches and thinner | | Material 5 inches and thicker | | | | | | | | | | | | | |
| | Select grade | Common grade | Select grade | Common grade | Select grade | Common grade | Select grade | Common grade | Select grade | Common grade | Select and common grades | | | Select grade | Common grade | Select grade | Common grade | Select grade | Common grade | Select grade | Common grade | |
| Ash, black | 1,000 | 800 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 300 | 200 | 150 | 90 | 72 | 650 | 520 | 550 | 440 | 500 | 400 | 1,100,000 |
| Ash, commercial white | 1,400 | 1,120 | 1,070 | 910 | 1,200 | 960 | 890 | 760 | 1,000 | 800 | 500 | 375 | 300 | 125 | 100 | 1,100 | 880 | 1,000 | 800 | 900 | 720 | 1,500,000 |
| Aspen and large-tooth aspen | 800 | 640 | 580 | 490 | 650 | 520 | 440 | 370 | 500 | 400 | 150 | 125 | 100 | 80 | 64 | 700 | 560 | 550 | 440 | 450 | 360 | 900,000 |
| Basswood | 800 | 640 | 580 | 490 | 650 | 520 | 440 | 370 | 500 | 400 | 150 | 125 | 100 | 80 | 64 | 700 | 560 | 550 | 440 | 450 | 360 | 900,000 |
| Beech | 1,500 | 1,200 | 1,150 | 980 | 1,300 | 1,040 | 890 | 760 | 1,000 | 800 | 500 | 375 | 300 | 125 | 100 | 1,200 | 960 | 1,100 | 880 | 900 | 720 | 1,600,000 |
| Birch, paper | 900 | 720 | 670 | 570 | 750 | 600 | 530 | 450 | 600 | 480 | 200 | 150 | 100 | 80 | 64 | 650 | 520 | 550 | 440 | 450 | 360 | 1,000,000 |
| Birch, yellow and sweet | 1,500 | 1,200 | 1,150 | 980 | 1,300 | 1,040 | 890 | 760 | 1,000 | 800 | 500 | 375 | 300 | 125 | 100 | 1,200 | 960 | 1,100 | 880 | 900 | 720 | 1,600,000 |
| Cedar, Alaska | 1,100 | 880 | 890 | 760 | 1,000 | 800 | 800 | 680 | 900 | 720 | 250 | 200 | 150 | 90 | 72 | 800 | 640 | 750 | 600 | 650 | 520 | 1,200,000 |
| Cedar, western red | 900 | 720 | 710 | 600 | 800 | 640 | 670 | 570 | 750 | 600 | 200 | 150 | 125 | 80 | 64 | 700 | 560 | 700 | 560 | 650 | 520 | 1,000,000 |
| Cedar, northern and southern white | 750 | 600 | 580 | 490 | 650 | 520 | 530 | 450 | 600 | 480 | 175 | 140 | 100 | 70 | 56 | 550 | 440 | 500 | 400 | 450 | 360 | 800,000 |
| Cedar, Port Orford | 1,100 | 880 | 890 | 760 | 1,000 | 800 | 800 | 680 | 900 | 720 | 250 | 200 | 150 | 90 | 72 | 900 | 720 | 825 | 660 | 750 | 600 | 1,200,000 |
| Chestnut | 950 | 760 | 760 | 650 | 850 | 680 | 620 | 530 | 700 | 560 | 300 | 200 | 150 | 90 | 72 | 800 | 640 | 700 | 560 | 600 | 480 | 1,000,000 |
| Cottonwood, eastern and black | 800 | 640 | 580 | 490 | 650 | 520 | 530 | 450 | 600 | 480 | 150 | 125 | 100 | 80 | 64 | 700 | 560 | 550 | 440 | 450 | 360 | 900,000 |
| Cypress, southern | 1,300 | 1,040 | 980 | 830 | 1,100 | 880 | 800 | 680 | 900 | 720 | 350 | 250 | 225 | 100 | 80 | 1,100 | 880 | 1,000 | 800 | 800 | 640 | 1,200,000 |
| Douglas fir (western Washington and Oregon type) [5] | 1,600 | 1,200 | 1,233 | 983 | 1,387 | 1,040 | 948 | 756 | 1,067 | 800 | [6] 347 | [6] 240 | [6] 213 | 90 | 72 | 1,173 | 880 | 1,067 | 800 | 907 | 680 | 1,600,000 |

| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Douglas fir (dense) [5] | 1,750 | 1,400 | 1,349 | 1,147 | 1,517 | 1,213 | 1,037 | 882 | 1,167 | 933 | 379 | 262 | 233 | 105 | 84 | 1,283 | 1,027 | 1,167 | 933 | 992 | 793 | 1,600,000 |
| Douglas fir (Rocky Mountain type) | 1,100 | 880 | 800 | 680 | 900 | 720 | 620 | 530 | 700 | 560 | 275 | 225 | 200 | 85 | 68 | 800 | 640 | 800 | 640 | 750 | 560 | 1,200,000 |
| Elm, rock | 1,500 | 1,200 | 1,150 | 980 | 1,300 | 1,040 | 890 | 760 | 1,000 | 800 | 500 | 375 | 300 | 125 | 100 | 1,200 | 960 | 1,100 | 880 | 900 | 720 | 1,300,000 |
| Elm, slippery and American | 1,100 | 880 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 250 | 175 | 125 | 100 | 80 | 800 | 640 | 750 | 600 | 650 | 520 | 1,200,000 |
| Fir, balsam | 900 | 720 | 670 | 570 | 750 | 600 | 530 | 450 | 600 | 480 | 150 | 125 | 100 | 70 | 56 | 700 | 560 | 600 | 480 | 500 | 400 | 1,000,000 |
| Fir, commercial white | 1,100 | 880 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 300 | 225 | 200 | 70 | 56 | 700 | 560 | 700 | 560 | 600 | 480 | 1,100,000 |
| Gum, red, black, and tupelo | 1,100 | 880 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 300 | 200 | 150 | 100 | 80 | 800 | 640 | 750 | 600 | 650 | 520 | 1,200,000 |
| Hemlock, eastern | 1,100 | 880 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 300 | 225 | 200 | 70 | 56 | 700 | 560 | 700 | 560 | 600 | 480 | 1,100,000 |
| Hemlock, western | 1,300 | 1,040 | 980 | 830 | 1,100 | 880 | 800 | 680 | 900 | 720 | 300 | 225 | 200 | 75 | 60 | 900 | 720 | 900 | 720 | 800 | 640 | 1,400,000 |
| Hickory (true and pecan) | 1,900 | 1,520 | 1,330 | 1,130 | 1,500 | 1,200 | 1,070 | 910 | 1,200 | 960 | 600 | 400 | 350 | 140 | 112 | 1,500 | 1,200 | 1,200 | 960 | 1,000 | 800 | 1,800,000 |
| Larch, western | 1,200 | 960 | 980 | 830 | 1,100 | 880 | 800 | 680 | 900 | 720 | 325 | 225 | 200 | 100 | 80 | 1,100 | 880 | 1,000 | 800 | 800 | 640 | 1,300,000 |
| Maple, sugar and black | 1,500 | 1,200 | 1,150 | 980 | 1,300 | 1,040 | 890 | 760 | 1,000 | 800 | 500 | 375 | 300 | 125 | 100 | 1,200 | 960 | 1,100 | 880 | 900 | 720 | 1,600,000 |
| Maple, red and silver | 1,000 | 800 | 800 | 680 | 900 | 720 | 620 | 530 | 700 | 560 | 350 | 250 | 200 | 100 | 80 | 800 | 640 | 700 | 560 | 600 | 480 | 1,100,000 |
| Oak, commercial red and white | 1,400 | 1,120 | 1,070 | 910 | 1,200 | 960 | 890 | 760 | 1,000 | 800 | 500 | 375 | 300 | 125 | 100 | 1,000 | 800 | 900 | 720 | 800 | 640 | 1,500,000 |
| Pine, southern yellow [5] | ----- | 1,200 | ----- | 983 | ----- | 1,040 | ----- | 756 | ----- | 800 | (6) | (6) | (6) | ----- | 88 | ----- | 880 | ----- | 800 | ----- | 680 | 1,600,000 |
| Pine, southern yellow (dense) [5] | 1,750 | 1,400 | 1,349 | 1,147 | 1,517 | 1,213 | 1,037 | 882 | 1,167 | 933 | 379 | 262 | 233 | 128 | 103 | 1,283 | 1,027 | 1,167 | 933 | 992 | 793 | 1,600,000 |
| Pine, northern white, western white, western yellow, and sugar | 900 | 720 | 710 | 600 | 800 | 640 | 670 | 570 | 750 | 600 | 250 | 150 | 125 | 85 | 68 | 750 | 600 | 750 | 600 | 650 | 520 | 1,000,000 |
| Pine, Norway | 1,100 | 880 | 890 | 760 | 1,000 | 800 | 710 | 600 | 800 | 640 | 300 | 175 | 150 | 85 | 68 | 800 | 640 | 800 | 640 | 700 | 560 | 1,200,000 |
| Poplar, yellow | 1,000 | 800 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 250 | 150 | 125 | 80 | 64 | 800 | 640 | 700 | 560 | 600 | 480 | 1,100,000 |
| Redwood | 1,200 | 960 | 890 | 760 | 1,000 | 800 | 710 | 600 | 800 | 640 | 250 | 150 | 125 | 70 | 56 | 1,000 | 800 | 900 | 720 | 750 | 600 | 1,200,000 |
| Spruce, red, white, and Sitka | 1,100 | 880 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 250 | 150 | 125 | 85 | 68 | 800 | 640 | 750 | 600 | 650 | 520 | 1,200,000 |
| Spruce, Engelmann | 750 | 600 | 580 | 490 | 650 | 520 | 440 | 370 | 500 | 400 | 175 | 140 | 100 | 70 | 56 | 600 | 480 | 550 | 440 | 450 | 360 | 800,000 |
| Sycamore | 1,100 | 880 | 800 | 680 | 900 | 720 | 710 | 600 | 800 | 640 | 300 | 200 | 150 | 80 | 64 | 800 | 640 | 750 | 600 | 650 | 520 | 1,200,000 |
| Tamarack (eastern) | 1,200 | 960 | 980 | 830 | 1,100 | 880 | 800 | 680 | 900 | 720 | 300 | 225 | 200 | 95 | 76 | 1,000 | 800 | 900 | 720 | 800 | 640 | 1,300,000 |

[1] American lumber standards: Basic provisions for American lumber standards grades are published by the U. S. Department of Commerce in Simplified Practice Recommendation No. 16 (*22*); specifications for grades conforming to American lumber standards are published in the 1927 Standards of the American Society for Testing Materials, and in Amer. Ry. Engr. Assoc. Bul.

[2] Stress in tension: The working stresses recommended for fiber stress in bending may be safely used for tension parallel to grain.

[3] Joint details: The shearing stresses for joint details may be taken for any grades as 50 per cent greater than the horizontal shear values for the Select grade.

[4] Factors to be applied to average modulus of elasticity values: The values for modulus of elasticity are average for species and not safe working stresses. They may be used as given for computing average deflection of beams. When it is desired to prevent sag in beams values one-half those given should be used. In figuring safe loads for long columns values one-third those given should be used.

[5] Exact figures given: In order to preserve the exact numerical relations among working stresses for grades involving rate of growth and density requirements the values for Douglas fir (western Washington and Oregon type) and for southern yellow pine have not been rounded off, as have the values for the other species.

[6] Working stresses for the Common grade: The values given are for the Select grade. Working stresses in compression perpendicular to grain for the common grades of Douglas fir (western Washington and Oregon type) and southern yellow pine are 325, 225, and 200, respectively, for continuously dry, occasionally wet but quickly dried, and more or less continuously damp or wet conditions.

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