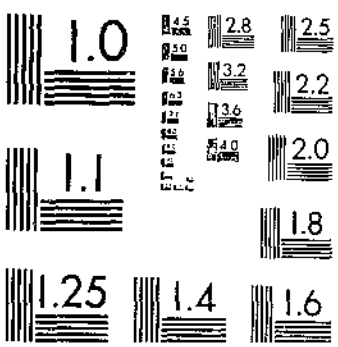
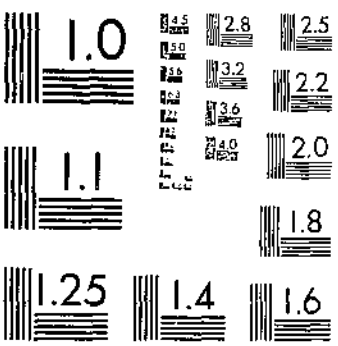
START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 285 MARCH, 1932

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

PROPERTIES OF WESTERN LARCH AND THEIR RELATION TO USES OF THE WOOD

By R. P. A. JOHNSON, *Engineer, Forest Products Laboratory*,[1] and M. I. BRADNER, *In Charge, Office of Forest Products, Region I, Branch of Research, Forest Service*[2]

CONTENTS

INTRODUCTION

Western larch [3] while well known in the "Inland Empire" [4] is not so well known in other sections of the United States. It is a comparatively new species in the lumber yards of New England, the

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

[2] The writers are indebted to S. V. Fullaway, formerly of the Forest Service, for much of the information on forest conditions, manufacturing practices, grade production, and distribution of lumber, and to E. M. Davis, Forest Products Laboratory, for the tables showing the annual ring growth, heartwood content, and characteristic defects of western larch. In addition, acknowledgment is made of assistance received from many other members of the Forest Products Laboratory staff, from the Western Pine Manufacturers' Association, and from the Potlatch Lumber Co.

[3] The standard names employed by the Forest Service for lumber and for the trees from which it is cut are used throughout this bulletin (24).[5] Other common names of the same species are given in the Appendix.

[4] Northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the northeastern tip of Oregon.

[5] Italic numbers in parentheses refer to Literature Cited, p. 91.

Mississippi Valley, and the Rocky Mountain region, where most of the cut leaving the "Inland Empire" is now marketed. The wood has a combination of properties that adapts it to a wide variety of uses. Until the properties of western larch are better known the marketing of the wood will be handicapped, especially in new fields. The purpose of this bulletin is to present the available data on the properties and characteristics of western larch for the assistance of users in determining the suitability of the species for specific uses.

Determination of the suitability of a wood for any purpose can not, however, be based on properties alone. Such things as grade, size, and dryness must also be considered. For example, a species selected on the basis of the properties alone may be sold on the local market in substandard sizes or insufficiently dried, and the advantages inherent in the clear wood of the species may under such conditions disappear or be reversed.

It would appear, therefore, that to determine the suitability of western larch for any use information on the characteristics of the lumber, as well as on the properties of the clear wood, should be presented. To a limited extent such data are presented in this bulletin. It is not practical, however, to present complete and final data on all the characteristics of lumber, for they differ with time and place and are subject to change. The inherent properties, on the other hand, do not change with time and place. A comparison based on the properties of clear wood is, therefore, as good in Spokane, Wash., as it is in Baltimore, Md., and, except for slight changes that may result from more complete data, will be as good 10 years hence as it is to-day. This is not true of comparisons of grades, manufacturing defects, moisture content, sizes, and other similar factors. They are constantly changing, and will differ with localities. Thus, the lumber of a species that is commonly sold wet at present may be marketed thoroughly dry next year, or it may commonly be marketed wet along the Atlantic and Pacific coasts and dry in the Middle West.

For most uses any one of a number of species of wood may be used with equal satisfaction provided provision is made to compensate for differences in properties. Such compensating provisions may be made by the use of preservatives or other treatment, choice of sizes, or variations in design. Preservative treatments tend to equalize decay resistance, choice of sizes can be made to compensate for differences in strength, and design can be used to compensate for many of the differences in properties. The determination of the most suitable species, therefore, consists largely of determining the cost of the lumber and construction plus the cost of the necessary compensational measures for the species available. Where compensating measures are not used it is necessary to balance the total cost in place against the service and degree of satisfaction that can be obtained with different kinds of wood.

THE LARCH-FIR MIXTURE

Western larch is associated with Douglas fir ("Inland Empire" type)[6] both in the forest and in the lumber markets. The stand of

[6] Owing to differences in properties, Douglas fir (*Pseudotsuga taxifolia*) has been separated in this publication according to the locality where grown into three types, namely, Douglas fir ("Inland Empire" type), Douglas fir (coast type), and Douglas fir (Rocky Mountain type).

each species within the botanical range of western larch is about equal. (Fig. 1.) In individual stands, however, the proportion varies from one extreme to another. It is the general practice to mix the two woods and sell them as a single product under the commercial name larch-fir. The average annual lumber cut from 1919 to 1928, inclusive, shows the larch-fir mixture to be in round numbers 60 per

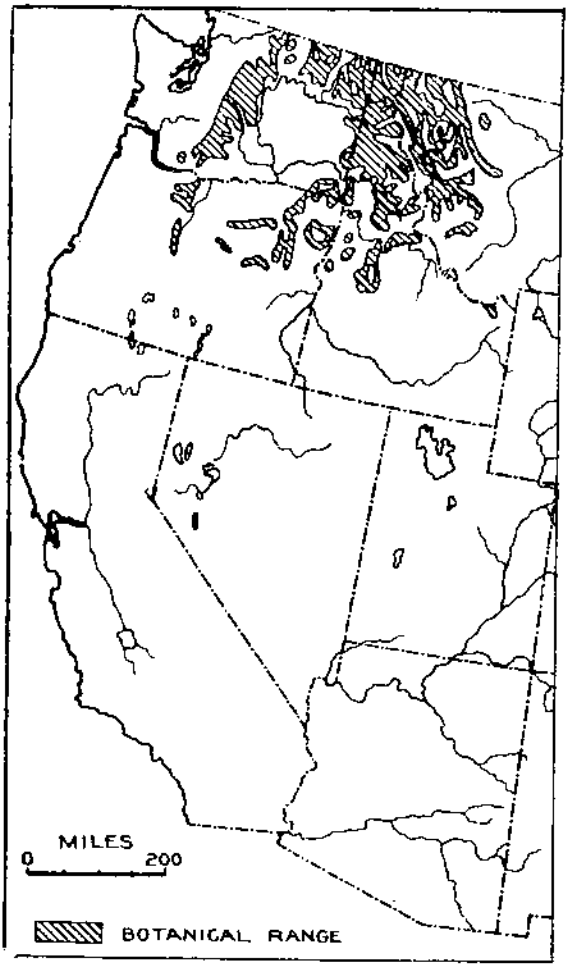


FIGURE 1.—Western larch (*Larix occidentalis*) botanical range

cent western larch and 40 per cent Douglas fir. The average proportion of western larch and Douglas fir ("Inland Empire" type) found in the different grades is given on page 49.

There are advantages and disadvantages in the mixing of species. The advantages lie in the savings in sorting, handling, and storage costs which accrue to the manufacturer. The disadvantages result from differences in properties, such as strength, color, and hardness, which are objectionable in some uses. In the common and dimension grades the advantages outweigh the disadvantages with the

manufacturer. Unless a decided preference develops for one of the woods in these grades, there is little chance of a change in the commercial practice of mixing the species. In the select grades there has developed a decided objection to the difference in the properties of the two species in the larch-fir mixture, especially color, percentage of sapwood, and hardness. The preference is for the western larch. Some manufacturers are meeting these objections by separating the species in the select grades. The continuation and extension of the practice of separating the species in select grades is necessary if western larch is to hold the reputation it has obtained in a number of uses.

The practice of mixing western larch with Douglas fir ("Inland Empire" type) makes it desirable to present the data in such form that the suitability of a mixture of the two species for any use may be determined. To accomplish this, western larch is taken as the basis of all comparisons of species. Data for Douglas fir ("Inland Empire" type) are also presented and compared with data on western larch. From the two sets of figures it will not be difficult to evaluate any mixture of larch-fir that may be encountered.

CHARACTER AND RANGE OF THE WESTERN LARCH FOREST

OCCURRENCE

Western larch grows chiefly in the drainage of the upper Columbia River. Its natural range extends from southern British Columbia to the western slopes of the Continental Divide of northern Montana and to the eastern slopes of the Cascade Mountains of Oregon (*24*). (Fig. 1.) It grows on mountain slopes, stream bottoms, valleys, and flats, preferring north and west exposures and elevations between 2,000 and 7,000 feet.

Western larch reaches its best development in northeastern Washington, northern Idaho, and northwestern Montana, where it often occurs in pure open forests, in valleys, and on slopes. (Fig. 2.) It is, however, usually associated with other species. In northern Idaho trees of the largest size are found at the lower elevations in mixture with western white pine, western hemlock, Engelmann spruce, and lowland white fir. Somewhat higher up it becomes an important part of the Douglas fir ("Inland Empire" type) forests, where it is associated with lodgepole pine, lowland white fir, alpine fir, and Engelmann spruce. The western larch-Douglas fir type occupies an intermediate position between the western yellow pine and subalpine types in northwestern Montana. The distribution of western larch has been increased by fires, and natural reproduction on burns is either in pure stands or in mixture with Douglas fir and lodgepole pine. The species is favored by burns because it requires a large amount of light and its seedlings can not obtain sufficient light to survive under the parent stand. Cutting and burning remove the advantage which the more tolerant associated species have in the forest.

CHARACTER

The western larch is one of the largest trees native to the region in which it grows. (Fig. 3.) It develops a straight, tall stem, occasionally attaining a height of 200 feet and a diameter breast high of 5 feet (*10*). The average height at maturity is 175 feet; the aver-

age diameter breast high is 20 inches. The trees average from five to six logs per tree. The average clear length of the stem varies from one and one-half logs in eastern Washington to three logs on the better white pine sites in Idaho. Stands per acre range from

FIGURE 2.—Dense stand of western larch. The tall, straight timber makes possible the production of a high percentage of clear lumber

about 2,000 feet, board measure, in the western yellow pine type of eastern Oregon, to 10,000 or 12,000 feet, board measure, in the larch-fir type of western Montana. Six to fifteen logs from an average stand will produce a thousand board feet of lumber. The average commercial stand of western larch is of good quality and yields a high percentage of select grades.

Western larch does not grow well in the shade. As a result the trees prune themselves of lower branches at an early age. The fire resistance of the western larch tree, which is due to the great thickness of its bark, is higher than that of any of the other Rocky Mountain

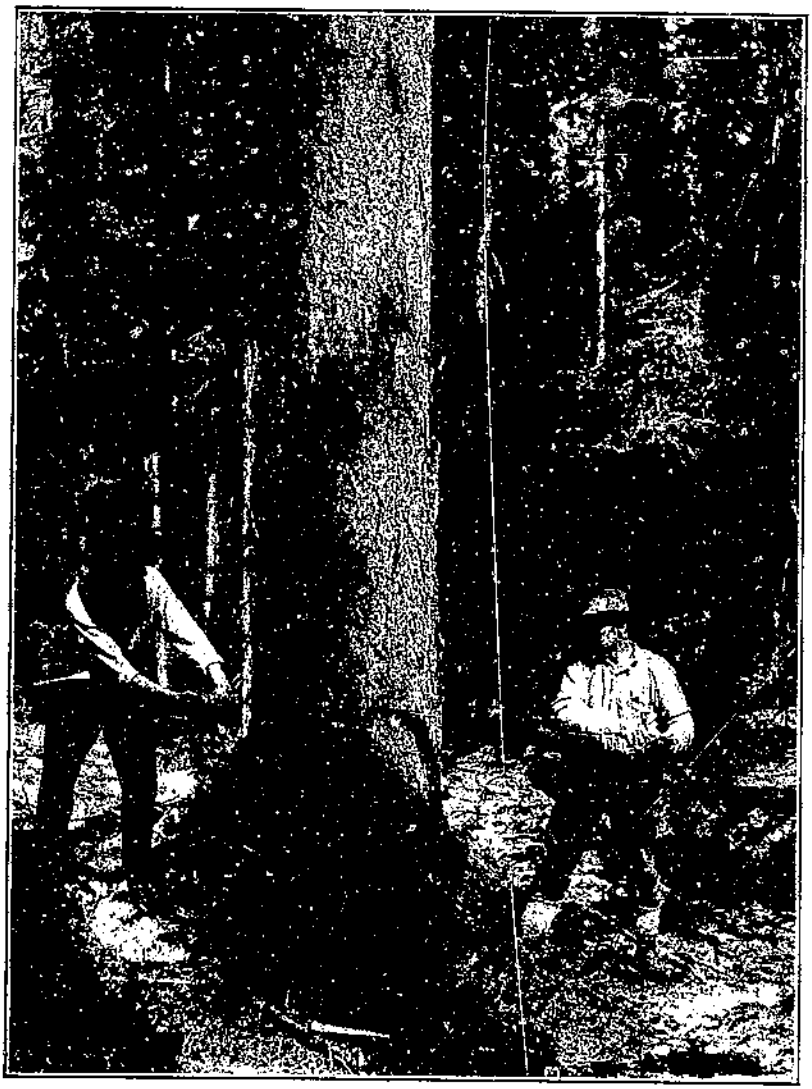


FIGURE 3.—Felling a western larch tree

conifers. This characteristic makes western larch a very suitable tree to reserve for seed so as to insure the stand against fire.

Western larch trees favorably located begin to bear seed at the age of 50 to 60 years and continue to bear good crops at intervals of five or six years. The germination of seed is prompt. The seedlings originate almost entirely from trees or stands left after cutting

or after burns, and germination and seedling growth take place generally on burned mineral soil or scorched duff surfaces.

Western larch trees are subject to the attack of a number of wood-destroying fungi, the most common of which is the chalky quinine fungus, *Fomes laricis*. The fungus causes a very destructive heart rot commonly known as brown trunk rot. Shake is a rather common and characteristic defect of the tree. It is confined, however, largely to the butt log. Consequently much of the shaky material is left in the woods as a result of the common practice of "long butting." Shake, rot, and other defects may cause a cull as high as 15 per cent in mature and overmature stands. The average run of large logs delivered at the mill in 1924 was 3.7 per cent defective.

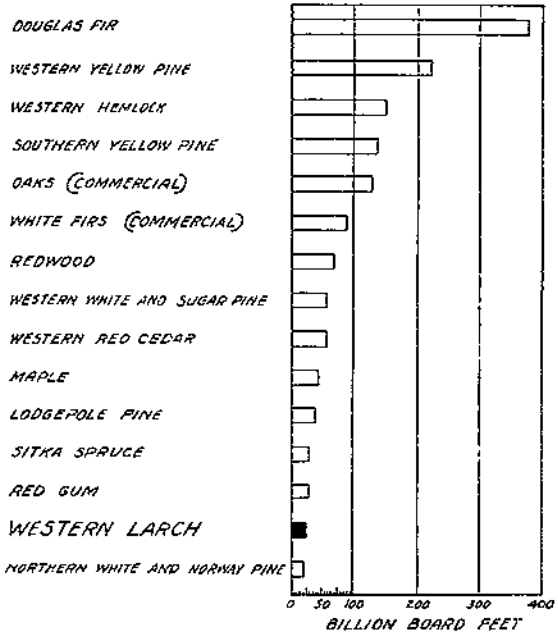


FIGURE 4.—Comparison of the present stand of western larch with that of 14 other species, based on 1923 estimates (*1*) revised for cut and growth to January 1, 1930. Other common names of the above species are given in the appendix

SIZE OF STAND

The total stand of western larch in the United States and Canada was estimated in 1923 for the United States Senate Select Committee on Reforestation (1) to be approximately 27,000,000,000 feet, board measure. Thirteen per cent of the western larch is located in the Canadian Province of British Columbia. The great majority, approximately 23,500,000,000 feet, is within the United States. Of this 23,500,000,000, 45 per cent is found in western Montana, 27 per cent in northern Idaho, 18 per cent in eastern Oregon, 8 per cent in eastern Washington, and the remaining 2 per cent is found in Idaho south of the Salmon River. The stand of Douglas fir in Idaho and Montana was estimated in 1923 to be approximately 30,000,000,000

feet, board measure, making a total of 53,500,000,000 feet of larch-fir in the United States.

Western larch makes up about 1 per cent of the total saw timber in the United States. The present stand of western larch is exceeded in volume by 3 hardwoods and by 10 softwoods. (Fig. 4.) An analysis of the timber resources of the "Inland Empire" shows that the stand of western larch is exceeded only by western yellow pine and Douglas fir ("Inland Empire" type). (Fig. 5.)

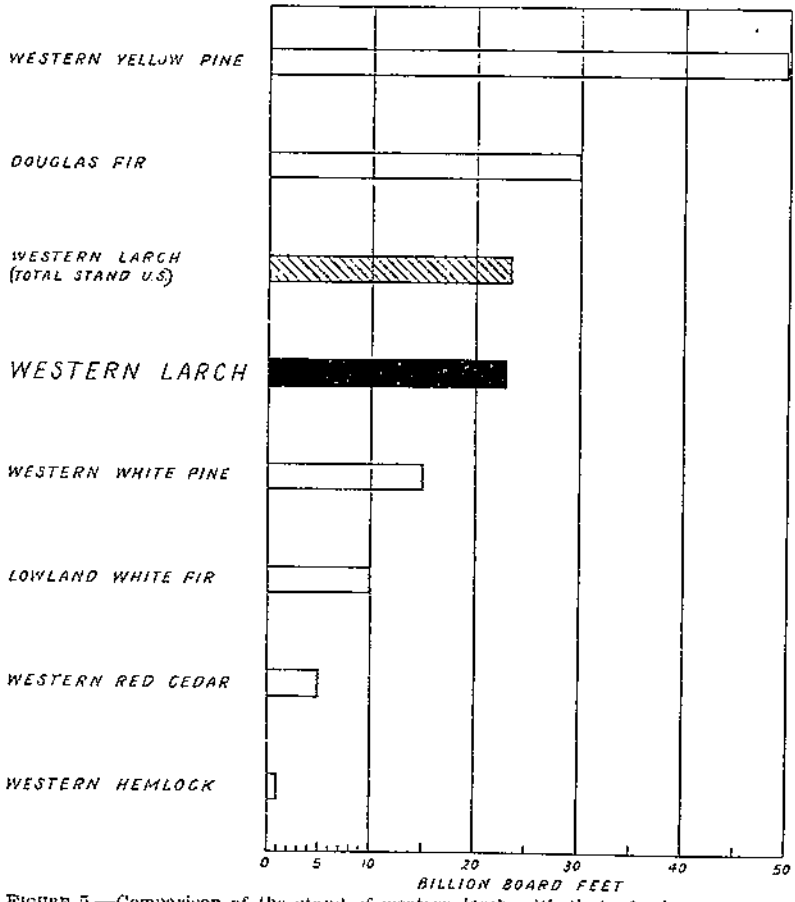


FIGURE 5.—Comparison of the stand of western larch with that of other species in the "Inland Empire." Other common names of the above species are given in the appendix

On the score of accessibility, western larch compares favorably with any of the other commercial species within the "Inland Empire" region. The western larch and larch-fir types of western Montana are in a large degree readily accessible at this time. Where larch is associated with the western white pine and western yellow pine, transportation facilities are continually improving as extensions are made to reach the pines. With the development of a greater demand for western larch at prices that will return a reasonable profit, a constant and adequate supply will be forthcoming.

CUT AND SUPPLY

The annual cut of western larch for 1929 was estimated to be 335,000,000 feet, board measure, log scale. This estimate includes the cut of western larch in the form of all products, reduced to board measure and is given on a log-scale basis to afford an easy comparison with stand figures. Of the total cut, 80 per cent is taken out in the form of saw logs; 7 per cent as hewed ties; 2 per cent as round, hewed, or split mine timbers; 1 per cent as posts, poles, and piling; and 10 per cent as cordwood. Montana furnishes approximately 39 per cent of the yearly cut, while Idaho, British Columbia, Washington, and Oregon contribute 28, 15, 13, and 5 per cent, respectively. In as much as larch and Douglas fir are commonly sold in mixture the corresponding production of Douglas fir is of interest. Within the larch-producing region it is roughly estimated that the annual

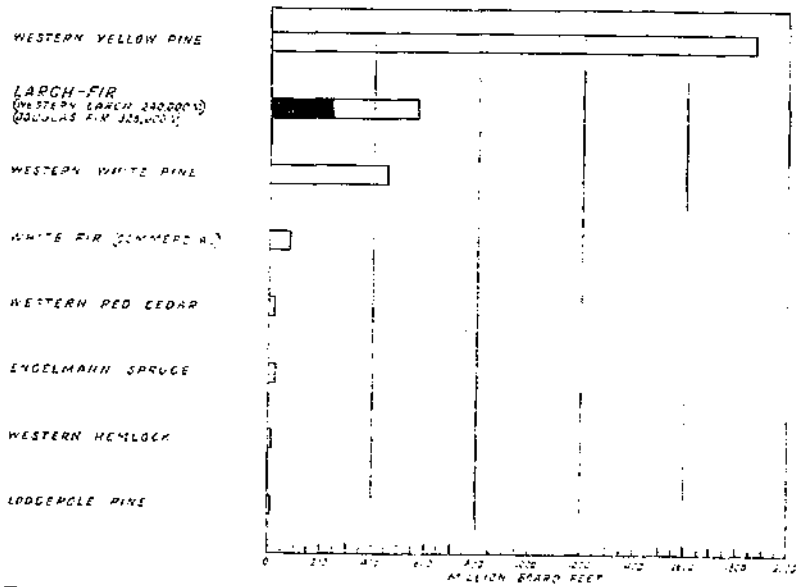


FIGURE 6.—The larch-fir mixture in 1926 ranked second in production of lumber in the "Inland Empire." Other common names of the above species are given in the appendix

cut of Douglas fir in 1929 amounted to 300,000,000 feet log scale. This means a yearly larch-fir cut of 635,000,000 feet, board measure. A comparison of the larch-fir lumber cut with the cut of the other principal lumber-producing species of the "Inland Empire" is shown in Figure 6.

There was a general increase in the production of western larch lumber from 1905 to 1920. (Fig. 7.) After the economic depression in 1921 the cut tended to stabilize around one-quarter of a billion board feet. It shows no tendency at present to shift materially from that figure. The cut of the species from 1905 to 1929 is shown by years in Figure 7.

The cut of western larch in 1928 was about 1 per cent of the total softwood lumber cut of the United States. In Idaho and Montana, where in 1928 80 per cent of the western larch lumber was cut, it con-

stituted 14½ per cent of the total lumber cut in those States. The remaining 20 per cent of the western larch cut came from Washington and Oregon. The 5-year average (1925 to 1929) cut, by States, was as follows:

State	Cut (thousand board feet)
Montana	119, 850
Idaho	88, 121
Washington	36, 353
Oregon	12, 146
Total	256, 470

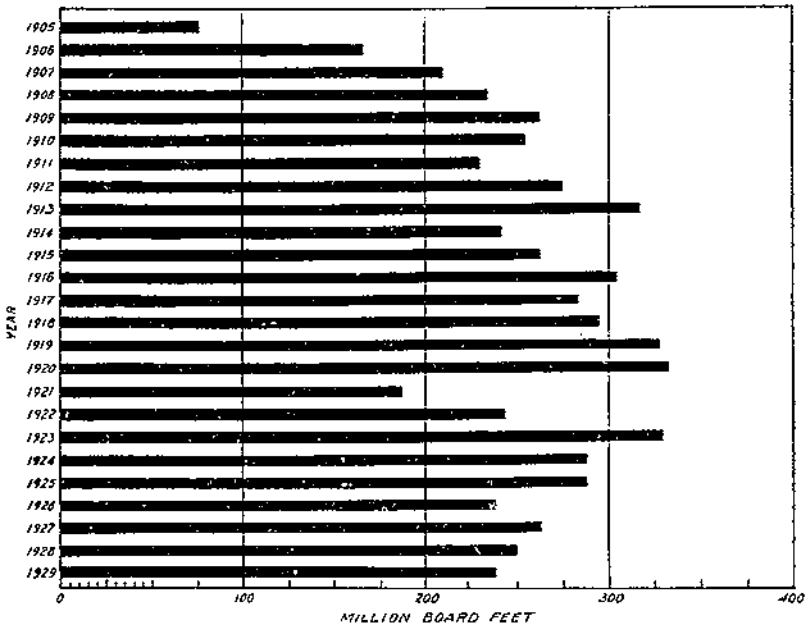


FIGURE 7.—Yearly lumber cut of western larch, 1905–1929

MERCHANDISING PRACTICES

DISTRIBUTION

The practice of using western larch as a filler in less-than-carload lots has been an important aid in enabling the species to enter new markets. Western larch first entered many of the eastern lumber yards, especially those in New England, as a filler in less-than-carload orders of western white and western yellow pine. The species found favor with many users, with the result that at present over one-fourth of the select grades of western larch are marketed in New England and in States along the Atlantic coast.

Sales of larch-fir direct to the consumer consist largely of ties and other railroad material, mine timbers, and some box and crating stock. At mills located within the larger centers of population, plant retail departments dispose of considerable larch-fir direct to the

user. Such local sales have resulted from the desire to have local consumption absorb the woods that have a low mill run value and are, therefore, less able to stand the freight charges to distant markets.

The bulk of the larch-fir yard lumber is used in the Mississippi Valley. The bulk of planks and timbers and miscellaneous items is used in the "Inland Empire." The distribution of the larch-fir cut to various consuming regions is shown in Table 1, which is based on the distribution of the cut produced by members of the Western Pine Manufacturers' Association. A general idea of the distribution of some of the more important products of larch-fir may be obtained from Table 2, which is an analysis of the distribution of the different larch-fir products shipped during a 12-month period by one mill. A surprisingly large percentage of the larch-fir cut is sold direct to the retailer, especially west of the Mississippi River.

TABLE 1.—*Distribution of larch-fir lumber*

[Based on 1924 shipments of members of the Western Pine Manufacturers' Association]

Grade	"Inland Empire" [1]	Rocky Mountains [2]	Mississippi Valley, west [3]	Mississippi Valley, east [4]	Atlantic coast [5]
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Selects	7	1	26	39	27
Nos. 1 and 2, common	11	9	41	34	5
No. 3, common	10	5	59	24	2
Nos. 4 and 5, common	10	2	58	28	2
Thick, common	31	10	2	56	1
Dimension	21	10	44	25	----------
Planks and timbers	59	11	21	8	1
Miscellaneous	63	8	26	3	----------
Battens and molding	2	----------	12	3	83
Lath: 5-year average	8	1	40	39	12

[1] Idaho, Montana, Oregon, Washington.
[2] Colorado, Wyoming, Utah, New Mexico, Nevada.
[3] The Dakotas, Minnesota, Iowa, Kansas, Nebraska, Missouri, Texas, Oklahoma, Arkansas.
[4] Illinois, Michigan, Wisconsin, Ohio, Indiana, and Southern States.
[5] Pennsylvania, Delaware, New Jersey, New York, Maryland, District of Columbia, and other Eastern States.

TABLE 2.—*Distribution of larch-fir products by regions*

[Based on shipments from 1 mill for 1924]

Region to which shipped	Products					
	Vertical-grain flooring	Surfaced, 2 sides and center, matched flooring	Ceiling or partition	Drop siding and rustic shiplap	Car siding and lining	Boards, square edged
	Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
"Inland Empire"	12	26	17	43	----------	24
Rocky Mountains	----------	----------	----------	(1)	100	11
Mississippi Valley, west	5	23	15	24	----------	46
Mississippi Valley, east	11	35	25	20	----------	17
Atlantic coast	72	16	43	13	----------	2
Total	100	100	100	100	100	100

[1] Less than 1 per cent.

PERCENTAGE OF CUT GOING INTO VARIOUS LUMBER ITEMS

More larch-fir goes into dimension, ties, and timbers than into all other items combined. About one-third of the total cut goes into No. 1 dimension, over a third of which is 2 by 4 inches in size.

Table 3 gives in detail the larch-fir shipments reported to the Western Pine Manufacturers' Association by association mills during 1928.

TABLE 3.—*Details of larch-fir shipments by members of Western Pine Manufacturers' Association, 1928*

Grade and size	Thousand board feet	Per cent
No. 1 Dimension:		
2 by 4 inches	10,520	
2 by 6 and 2 by 8 inches	9,512	
2 by 10 inches	3,158	
2 by 12 inches	3,626	
2 by 14 inches and wider	48	
Resawn	40	
Total	26,904	37.8
No. 2 Dimension:		
2 by 4 inches	1,681	
2 by 6 and 2 by 8 inches	977	
2 by 10 inches	210	
2 by 12 inches	479	
Resawn	519	
Total	3,866	5.4
No. 3 Dimension:		
2 by 4 inches	821	
2 by 6 and 2 by 8 inches	574	
2 by 10 inches	4	
2 by 12 inches	20	
Resawn	236	
Total	1,455	2.0
No. 1 Timbers:		
3 by 4 inches	11	
3 by 6, 4 by 4, and 4 by 6 inches	1,323	
3 by 8, 4 by 8 inches	71	
3 by 10 and 3 by 12 inches, 4 by 10 and 4 by 12 inches	1,513	
6 by 6 to 8 by 10 inches	440	
6 by 12 to 8 by 12 inches	22	
10 by 10 to 12 by 12 inches	46	
Larger than 12 by 12 inches	15	
Total	3,441	4.8
No. 2 Timbers	19	.0
Ties	1,306	1.8
No. 1 and 2 Common:		
4 inches	147	
6 inches	1,159	
8 inches	387	
10 inches	130	
12 inches	115	
⅝-inch	52	
Total	1,990	2.8
No. 3 Common:		
4 inches	1,732	
6 inches	2,702	
8 inches	2,279	
10 inches	831	
12 inches	536	
Mixed widths	62	
⅝ inch	42	
Total	8,180	11.5
No. 3 and Better Common:		
4 inches	1,249	
6 inches	2,491	
8 inches	1,558	
10 inches	489	
12 inches	646	
Mixed widths	3	
Total	6,436	9.0
No. 4 Common	8,049	11.3
No. 5 Common	443	0.6
Short Common	494	0.7
Select Common	514	0.7
C and Better Vertical-grained Flooring:		
4 inches	601	
3 inches	103	
Total	704	1.0
C and Better Flat-grained Flooring:		
4 inches	789	
6 inches	412	
Total	1,201	1.7
C and Better Drop Siding or Rustic:		
4 inches	28	
6 inches	1,181	
Total	1,209	1.7
C and Better Ceiling:		
4 inches	336	
6 inches	297	
⅝ inch	574	
Total	1,207	1.7
C and Better Finish:		
4 inches	200	
6 inches	156	
8 inches	122	
10 inches	107	
12 inches	48	
13 inches and wider	2	
Thick	393	
Total	1,029	1.5
D Vertical-grained Flooring:		
4 inches	39	
3 inches	6	
Total	45	0.1
D Flat-grained Flooring:		
4 inches	295	
6 inches	227	
Total	522	0.7

TABLE 3.—*Details of larch-fir shipments by members of Western Pine Manufacturers' Association, 1928*—Continued

Grade and size	Thousand board feet	Per cent	Grade and size	Thousand board feet	Per cent
D drop Siding or Rustic:			D Finish—Continued.		
4 inches	10		10 inches	5	
6 inches	458		12 inches	1	
			Thick	11	
Total	468	0.7			
			Total	215	0.3
D Ceiling:					
4 inches	51		D and Better Finish:		
6 inches	44		All widths	637	
8 inch	72		Thick	286	
Total	167	0.2	Total	923	1.3
D Finish:					
4 inches	152		Short Select	72	0.1
6 inches	38		Miscellaneous	435	0.6
8 inches	8		Total, all grades	71,309	100.0

DESCRIPTIVE PROPERTIES OF WESTERN LARCH

GENERAL DESCRIPTION OF THE WOOD

The wood of western larch closely resembles that of Douglas fir (coast type). Described in standard terms (*16*), the wood is moderately heavy, strong, moderately hard, moderately high in shock resistance, stiff, and has a moderately high shrinkage. It is moderately decay resistant, slightly resinous, has no distinctive odor or taste, and has alternate bands of hard and soft wood. These characteristics are all relative and can be applied equally well to the coast type of Douglas fir, except that Douglas fir is resinous and very stiff. The paint-holding characteristics of the two species are likewise very similar.

Western larch, however, has a number of distinctive characteristics. The heartwood is a dark reddish brown, and the sapwood a light straw color and very narrow (*12*). The annual rings in western larch are exceptionally narrow and uniform in width. This characteristic is sufficiently pronounced to produce a distinctive figure which the lumber trade describes as "wire grained." The wood is exceptionally slow in giving up and taking on moisture. Its slowness in giving up moisture has resulted in much of the wood being marketed before it was properly seasoned, although if exposed long enough to uniform conditions western larch will eventually reach about the same moisture content as will other woods. On the other hand, once properly seasoned, its slowness in picking up moisture is a distinct advantage. A much more detailed description of these and other properties and characteristics of species follows.

HEARTWOOD CONTENT OF LUMBER

The heartwood content of western larch is high because the sapwood is usually only from one-half to three-fourths of an inch thick and consequently is largely cut off with the slab. A study made by the Forest Products Laboratory on western larch boards 8 inches wide showed the sapwood to occupy less than 5 per cent of the area

of the best face. From 60 to 70 per cent of the boards studied, depending on the grade, contained no sapwood. A somewhat higher percentage of sapwood was found in narrower boards, and a somewhat smaller percentage in wider boards.

The Douglas fir ("Inland Empire" type) has a wider sapwood ring than western larch. Generally the sapwood ring in a Douglas fir log is over 1 inch wide (*12*). On an average sapwood occupied about 12 per cent of the best face of the Douglas fir ("Inland Empire" type) lumber studied. Over 90 per cent of the Douglas fir ("Inland Empire" type) boards contained two-thirds or more of heartwood. The amount of heartwood in the larch-fir mixture, though containing less heartwood than western larch, compares favorably with most commercial species.

GROWTH RINGS

Western larch is one of the slowest growing commercial softwoods; consequently, the annual rings are very narrow and uniform in width. Studies by the Forest Products Laboratory show that 1-inch western larch lumber averaged 25 rings to the inch, Douglas fir ("Inland Empire" type) averaged 18, Douglas fir (coast type) 13, virgin commercial longleaf pine 20, and mixed virgin and second-growth commercial shortleaf pine 8 rings per inch. Ninety-two per cent of the western larch pieces studied had over 13 rings per inch. In thicker stock the average number of rings may be slightly less than for 1-inch lumber, but the difference is not great, for the annual growth is narrow and uniform from close to the pith to the bark. The ring growth of the "Inland Empire" type of Douglas fir is wider and less uniform than that of western larch.

SUMMER-WOOD CONTENT

Western larch has pronounced alternate bands of hard summer wood and softer spring wood. The summer wood is darker in color than the spring wood and contrasts sharply with it. The summer-wood bands of western larch are narrow and contrast with the spring wood much like those in the commercial type of Douglas fir known as old-growth yellow fir. The summer wood in southern yellow pine is wider, more easily measured, and contrasts more pronouncedly with spring wood than that of western larch. The summer wood of eastern and western hemlock and white fir does not contrast so sharply with spring wood as that of western larch. The high percentage of summer wood in western larch is largely responsible for the weight, strength, and hardness of the wood.

FIGURE

The figure of western larch is pronounced. It is similar to that in Douglas fir, is not so pronounced as that in the southern pines, but is more pronounced than that of western hemlock and white fir. The narrow and uniform width of the growth rings has a marked influence on the figure, tending to soften the contrast resulting from the differences between the summer wood and spring wood. The characteristic figures of edge-grained and flat-grained material are shown in Plate 1.

HOW TO DISTINGUISH WESTERN LARCH FROM OTHER WOODS

The wood of western larch is comparatively easy to distinguish from the wood of all species except Douglas fir (all types), tamarack, southern cypress, and the southern yellow pine. Even the wood of these species can usually be distinguished from that of western larch by the unaided eye. Structural characteristics visible under the microscope make it possible to positively distinguish western larch from all species except tamarack (*12*). The distinguishing characteristics of western larch are the reddish-brown color of the heartwood, the narrow and evenly spaced annual rings, the contrast between summer wood and spring wood, narrow sapwood ring, the yellowish-white color of the sapwood, and the lack of pronounced odor or taste.

Douglas fir (all types) is the wood with which western larch is most likely to be confused. Confusion may occur not only because the two woods are very similar in appearance but also because western larch is sold in mixture with Douglas fir ("Inland Empire" type) and finds its way into many of the same markets and uses as Douglas fir (coast type). The easiest and most general method of distinguishing western larch from Douglas fir (all types) is by the difference in the color of the heartwood. Western larch heartwood has a marked brownish color in contrast with the reddish or yellowish color of Douglas fir. In addition western larch has a narrower sapwood ring, and as a result the lumber contains less sapwood. The annual rings of both species are relatively narrow and comparatively uniform in width. The rings in western larch, however, are more uniform in width and narrower than those of Douglas fir; this is especially true of the "Inland Empire" type of Douglas fir. The knots in western larch are generally smaller, tighter, and sounder than those of Douglas fir. Douglas fir has a distinct odor when freshly cut, while western larch is odorless. Lumber graders often use the greater weight of western larch as an aid in distinguishing it from the Douglas fir ("Inland Empire" type). None of these characteristic differences, however, is as reliable a basis for distinguishing the wood as is the structural difference visible under a microscope.

The wood of tamarack can not, with our present knowledge, be positively distinguished from that of western larch. Tamarack lumber in bulk, however, can usually be roughly distinguished from that of western larch by its wider and less uniform growth rings and more pronounced summer wood. Fortunately it is not often necessary to distinguish between these species, for they go into different markets and uses, and there is small chance of the lumber being mixed. In addition, the cut of tamarack is small, and it is commonly distributed in mixture with other woods, especially eastern hemlock. The mixture is easily distinguished from the larch-fir mixture.

The color of western larch sufficiently resembles that of southern cypress to cause occasional confusion. The wood of southern cypress, however, can be distingushed from that of western larch by the rancid odor, by the less uniform width of growth rings, and the wider sapwood of the southern cypress. In addition, the summer wood of southern cypress is usually less pronounced and does

not contrast so sharply with the spring wood. With a good magnifying glass western larch can be positively distinguished from southern cypress by the resin ducts which are present in western larch but not in cypress. Necessity for distinguishing between the species occurs when the two species go, as they occasionally do, into the same uses in the same markets. The confusion of the woods results from the use of names such as mountain cypress for western larch, as well as from similarity of color and general appearance of some select-grade material.

Western larch and the hard pines differ sufficiently in appearance so that only occasionally are specimens of one species likely to be mistaken for those of the other. The principal cause of confusion is the presence in both of pronounced alternate bands of hard and soft wood, combined with a general brownish color. The summerwood bands of western larch, however, are narrower and less pronounced than those of hard pines, and the brown of the heartwood is reddish in western larch and yellowish or orange brown in the hard pines. The wood of the hard pines is readily distinguished from western larch by the more resinous character, wider annual rings, more pronounced summer wood, and wider sapwood of the hard pines.

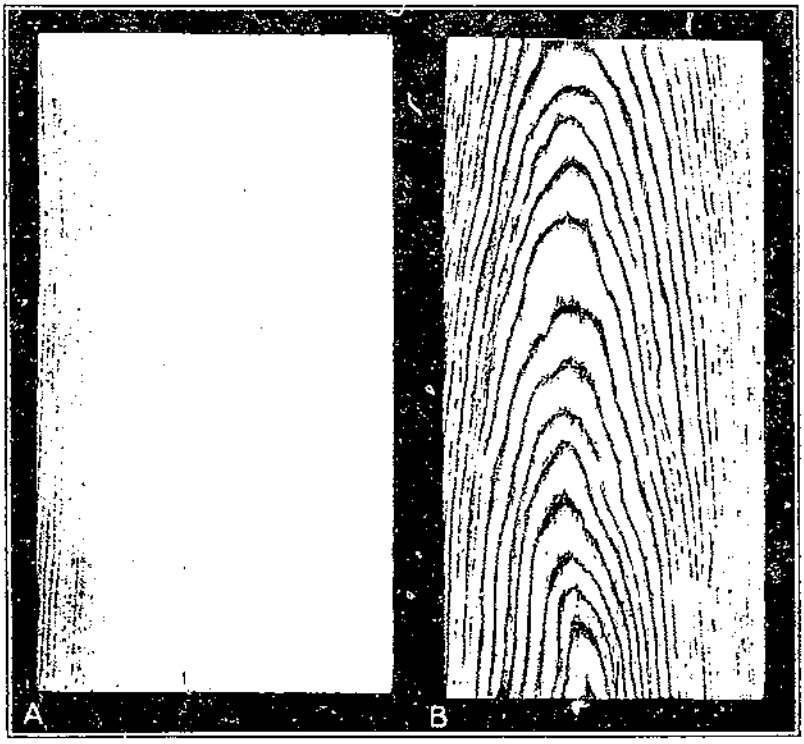
The comparisons just made of the wood of western larch with that of other species are intended as an aid in identifying western larch lumber in the bulk. The positive identification of individual specimens is more difficult. It quite often requires the use of the microscope which will reveal structural differences not visible to the unaided eye.[7] (Pl. 2.)

GRAIN AND TEXTURE

Western larch has been described as a "wire-grain" wood because of its uniformly narrow bands of hard and soft wood. (Pl. 1, A.) Western larch is also known as a "straight-grained" wood; that is, the wood is comparatively free from spiral grain and entirely free from interlocking grain. The amount of cross grain in western larch depends to some extent upon the taper of the logs and the methods employed in manufacturing, for cross grain is produced in sawing as well as in growth. The taper in western larch logs is usually less than 1 inch in 10 feet of length (*5*); consequently the amount of cross grain developed in sawing is small. Cross grain is objectionable because of its injurious effect on strength (*33*) and its tendency to cause warping.

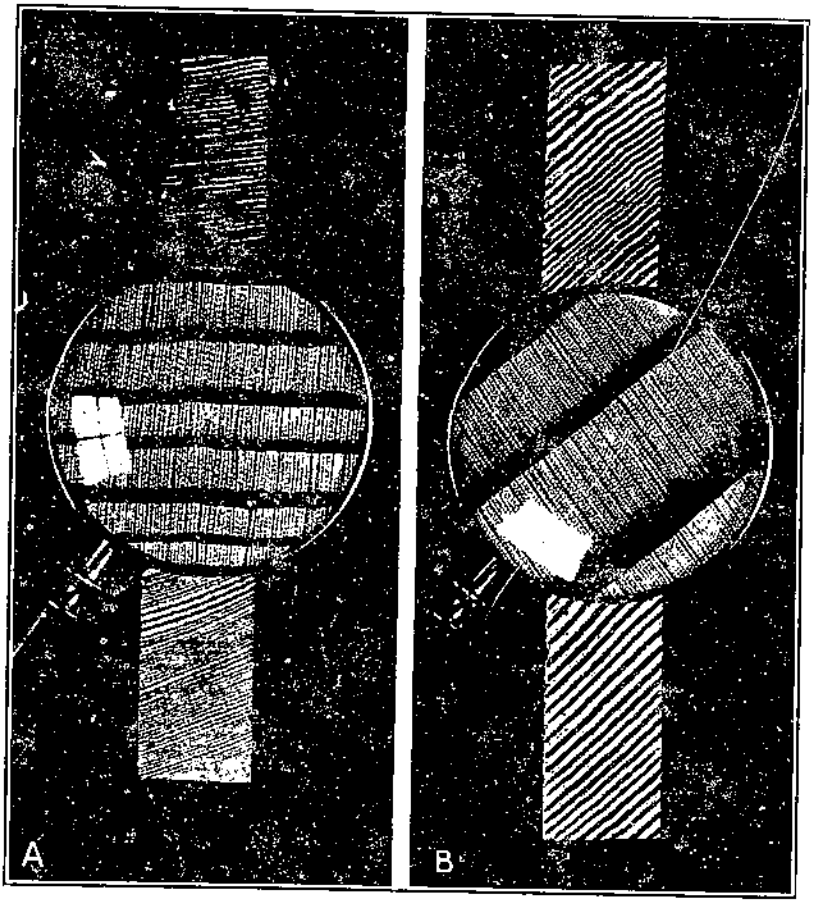
In texture the wood of western larch is composed of pronounced alternate bands of summer wood and spring wood. The wood cells in the spring wood are larger and much thinner walled than in the summer wood. (Pl. 2.) As a result the summer wood is much harder, heavier, and darker than the spring wood. The contrast between summer wood and spring wood is not so pronounced as in southern yellow pine or in Douglas fir (all types), but is more pronounced than in the hemlocks, spruces, and true firs. The alternate bands of western larch are narrower and more uniform in width than in any of the species mentioned. The characteristically narrow bands

[7] Where the necessity for positive identification exists samples may be submitted for identification to the Forest Products Laboratory, Madison, Wis.



M 19254

Characteristic figures of western fir. A, Edge-grain figure. The narrow uniform bands are sometimes termed "wire grain." B, Flat-grain figure. The narrow unevenly spaced bands of hard and soft wood material for the figure to be shown to best advantage in flat-sawn western fir.



M17509F M17510F

End sections of western larch and Douglas fir as they appear when highly magnified. A, Western larch. The pronounced alternate bands of dark summer wood and light spring wood and scattered small resin ducts shown by white spots are characteristic of the species; B, Douglas fir. The some pronounced summer-wood and spring-wood bands as in western larch are also in Douglas fir, but they are generally wider in the Douglas fir

of western larch reduce the tendency to deflect nails that is sometimes encountered in species with wide and pronounced summerwood bands.

MECHANICAL AND PHYSICAL PROPERTIES

Wood users generally evaluate a species in terms of other species. Tough like ash, strong like oak, cuts like white pine, are typical examples. Since this is the common and familiar method of judging the value of species, a comparison of the properties of western larch with those of other well-known woods is made in this publication. Western larch is represented as 100 points in order that comparisons may be made with other species by a glance at the table or figures. As previously pointed out, such comparisons are of the average inherent properties of the clear wood and hold only when other things, such as defects, moisture content, size, and the like, are equal.

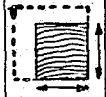
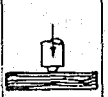
Average values alone are not always adequate for the selection of species, for individual pieces may vary widely from the average. Knowledge of the probable extent of the variation from the average is therefore often of value. There is about a 50–50 chance that any individual piece of western larch selected at random will not vary from the average more than the percentage shown in the bottom line of figures in Table 4 (*15*). In other words, in any shipment about half of the material will not vary from the average more than the percentage shown. For example, the probable variation in bending strength, bottom line of column 6, Table 4, is 12 per cent. It is estimated, therefore, that the bending strength of one-half of the pieces of western larch will fall between 88 and 112.

The strength values for western larch are based on approximately 2,500 tests. The test specimens were obtained from three localities scattered throughout the range of the species in the United States. Additional tests of western larch would probably not change the average values more than 3.1 per cent in shock resistance and 1.3 per cent in specific gravity. Change in other properties would fall between these two extremes. The probable change in the other species as a result of additional tests will in no case exceed 5 per cent in toughness and 2.1 per cent in specific gravity. In many of the species where from two to three times as many tests have been made as in western larch the probable changes in the average value would be even smaller than in western larch (*15*).

In addition to the testing done at the Forest Products Laboratory considerable testing of western larch has been done by the Canadian Forest Products Laboratory (*13, 23*).

Values in Table 4, with the exceptions of the white oaks and eastern spruce, are for a single botanical species. The figures for commercial white oak are the average of six species that are marketed under the name white oak. These six species of oak are so closely related that they can not be distinguished from one another by an examination of the wood alone. Red spruce and white spruce are also closely related species, very similar in their properties, and are not separated commercially. They are sold under the commercial name of eastern spruce.

TABLE 4.—*Average mechanical and physical properties of the clear wood of western larch compared with other species* [1]

Species of wood [2]	Specific gravity based on weight when oven dry and volume when green	Weight per cubic foot		Composite or index values [3] (western larch taken as 100 points) for—						Strength at 12 per cent moisture content	
		Green	At 12 per cent moisture content	Shrinkage	Bending strength	Compressive strength (endwise)	Stiffness	Hardness	Shock resistance	Modulus of rupture	Compression parallel to grain
											
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		Pounds	*Pounds*	*Points*	*Points*	*Points*	*Points*	*Points*	*Points*	*Lbs. per sq. in.*	*Lbs. per sq. in.*
Larch, western (Larix occidentalis)	0.48	48	36	100	100	100	100	100	100	11,790	7,480
Cedar, western red (Thuja plicata)	.31	27	23	59	67	71	71	59	64	7,800	5,120
Cypress, southern (Taxodium distichum)	.42	50	32	81	89	89	89	81	94	10,010	6,390
Douglas fir (Pseudotsuga taxifolia) (coast type)	.45	38	34	94	101	103	118	92	100	12,270	7,650
Douglas fir (Pseudotsuga taxifolia) ("Inland Empire" type)	.41	37	31	87	90	87	104	91	89	11,450	6,800
Douglas fir (Pseudotsuga taxifolia) (Rocky Mountain type)	.40	35	30	80	84	80	93	81	83	9,650	6,140
Hemlock, eastern (Tsuga canadensis)	.38	50	28	76	81	76	79	80	83	8,950	5,490
Hemlock, western (Tsuga heterophylla)	.38	41	29	93	83	81	94	78	90	9,990	6,200
Oaks, commercial white (average of six species) [4]	.59	63	47	120	111	89	97	170	154	13,990	7,060
Pine, loblolly (Pinus taeda)	.50	54	38	98	104	100	109	97	115	13,000	8,200
Pine, longleaf (Pinus palustris)	.55	50	41	96	119	118	124	119	127	15,490	9,060
Pine, northern white (Pinus strobus)	.34	36	25	64	71	64	78	55	68	8,920	4,910
Pine, shortleaf (Pinus echinata)	.49	51	38	99	109	100	111	106	137	13,350	7,860
Pine, western white (Pinus monticola)	.36	35	27	91	78	72	90	55	80	9,650	5,720
Pine, western yellow (Pinus ponderosa)	.38	45	28	75	73	66	73	64	72	9,320	5,340
Redwood (Sequoia sempervirens) [5]	.41	55	30	50	101	100	88	92	86	10,800	6,600
Spruce, eastern (average of red and white)	.37	34	28	98	79	72	84	61	83	9,920	5,720
Tamarack (Larix laricina)	.49	47	37	99	94	92	96	83	105	11,700	7,170
Percentage estimated probable variation of an individual piece	8.0			12	12	14	18	16	20		

[1] This table is for use in comparing species either in the form of clear lumber or in grades containing like defects, except structural material. Structural material which conforms to American lumber standards should be compared by means of allowable working stresses, values for which are presented in Table 16.

[2] Other common names of the above species are given in the Appendix.

[3] For derivation of composite values see Markwardt (*15*).

[4] Bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak.

[5] The trees on which these values are based were somewhat higher in density than the general average for species. It is, therefore, probable that future tests which are now under way will slightly lower the present figures, although it is not expected that this will necessitate any change in the working stresses recommended for structural timbers as given in Table 16.

WEIGHT AND SPECIFIC GRAVITY

Western larch is a heavy softwood. In an air-dry condition (12 per cent moisture content) it weighs on an average 36 pounds per cubic foot. (Fig. 8.) Green, it will average 48 pounds per cubic foot. The weight of air-dry material varies with the density, regional climatic conditions, and size of the stock. In the North Central States the average moisture content of thoroughly air-dry western larch is about 12 per cent, and the average weight of thoroughly air-dry yard stock will therefore be 36 pounds per cubic foot. Because of variations in density, however, the average weight of the air-dry stock may vary from about 33 to 39 pounds per cubic foot. In a hot, dry climate, like that of the Southwest, the weight of thoroughly air-dry yard stock may drop as low as 32 pounds per cubic foot in a piece of low density because of the low moisture content common to

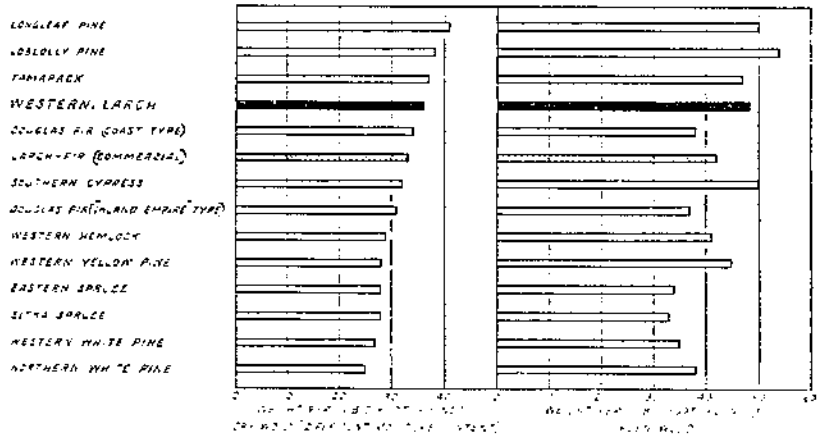


FIGURE 8.—Average weight per cubic foot of green and dry western larch compared with other species. The green weight may vary widely from the averages shown because of the wide range in the moisture content of green wood

that region. In a humid climate, on the other hand, the weight may run as high as 41 pounds per cubic foot in pieces of high density. Seasoned structural timbers average about a pound heavier per cubic foot than yard stock because they do not come to so low a moisture content as does yard lumber. Green western larch varies over a much wider range in moisture content than air-dry stock because of the large variations of the moisture in the living tree. Green western larch will seldom drop below 37 pounds per cubic foot but may occasionally go as high as 75 pounds per cubic foot.

A comparison of the weights per cubic foot of green and air-dry western larch and those of other species is shown in Figure 8. The weight of thoroughly air-dry western larch is between that of southern yellow pine, which is slightly heavier, and that of Douglas fir (coast type), which is slightly lighter. Douglas fir of the "Inland Empire" type is about 5 pounds to the cubic foot lighter than western larch. The practice of mixing western larch and Douglas fir of the "Inland Empire" type reduces the weight of the common grades of the larch-fir mixture from 2 to 4 pounds per cubic foot, depending on the percentage of Douglas fir present. The weight

of the larch-fir mixture shown in Figure 8 is based on a 50-50 mixture. In the select grades the weight of the species in mixture will seldom be more than a pound lighter than western larch because of the small percentage of the select grades obtained from Douglas fir ("Inland Empire" type). The weight of the larch-fir mixture in a green condition is materially lower than the weight of green western larch, especially in the common grades.

The specific gravity is another and useful measure of the weight of western larch. When oven dry, western larch has an average specific gravity of 0.48; that is, a cubic foot of western larch at practically zero moisture content weighs 0.48 of the weight of a cubic foot of water at 39.2° F. The specific gravity is therefore a measure of the amount of wood substance, and aside from actual tests is the best indicator of the strength as well as of a number of other properties of wood.

A survey was made by the Forest Products Laboratory of the range in specific gravity of western larch. Nine hundred and seventy-two samples were selected at random from shipments of western larch as they left the mills. The samples were collected at three mills and included material of the select and common grades and of a number of different mill products. The result of the survey is illustrated in Figure 9, which shows how a lumber pile of western larch would look if it were sorted and piled in accordance with its specific gravity. A smooth curve is drawn through each of the tiers. This curve is a variability curve. Similar variability curves are used throughout this bulletin to show the range in properties of western larch. The value of such a curve is that it gives a better idea of the general run of the species than can be obtained from average values alone. For example, Figure 9 shows that 1 per cent, or one piece in a hundred, of the western larch has a specific gravity of only 0.34, or 76 per cent of the average specific gravity, and 1 per cent of the pieces have a specific gravity of 0.58, which is about 29 per cent higher than the average specific gravity. Also, the lightest pieces have only about one-half the specific gravity of the heaviest. The curves at the end of the bars in subsequent figures may be considered as representing the end view of piles of lumber sorted in accordance with the property under consideration, just as in Figure 9.

A rough general comparison of the properties of western larch with those of other species can be made quickly by comparing their specific gravities. Figure 10 is a comparison of the average and range in specific gravity of western larch and six well-known species. The data on which the comparison is based was obtained from specimens selected at random from material as it left the mills. The average values and the range in values differ slightly from the data in Table 4 because of differences in method of selection and test. For example, the average specific gravity of western larch is shown as 0.48 in Table 4, based on selected samples from selected trees, and 0.45 in Figures 9 and 10, based on random selection of material as it went on the market.

BENDING STRENGTH

The clear wood of western larch has a high bending strength. Bending strength is a measure of the load-carrying capacity of clear wood when used as a beam. The bending strength of western larch

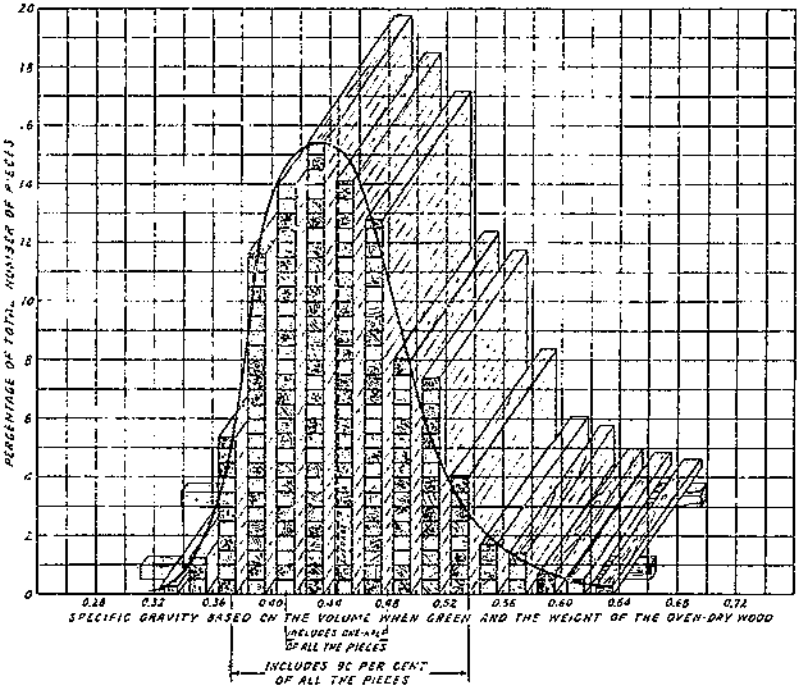


FIGURE 9.—Variations in specific gravity of western larch. The figure shows the form a pile of western larch would take if the pieces were sorted into groups in accordance with the specific gravity. It is based on results of determinations made on 972 samples selected at random from lumber as it left the mills

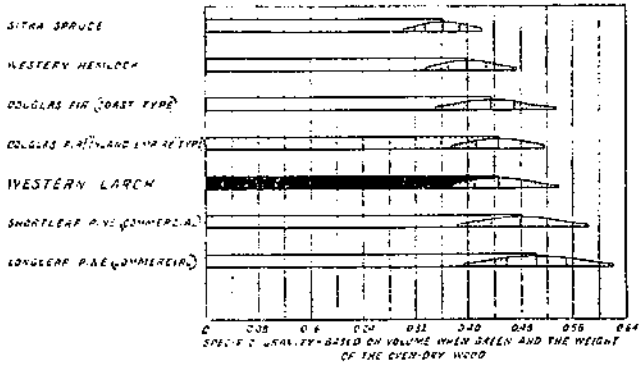


FIGURE 10.—Average specific gravity and range in specific gravity of western larch compared with other species of wood; based upon a random selection from siding, finish, common boards, dimension, flooring, chip-lap, and other items of lumber as shipped from the mills. Average shown by the end of the horizontal bar and range by the curve. One-half of all material of a species of wood fell within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average, and 20 per cent below average; while 10 per cent, 5 per cent above and 5 per cent below, fell outside the range shown by the curve

averages about the same as that of Douglas fir (coast type) but is not quite so high as that of southern yellow pine. It averages higher than that of southern cypress, tamarack, or Douglas fir of the "Inland Empire" type. The bending strength of larch-fir mixture in the common grades is therefore lower than that for western larch. The select grades contain only a small percentage of Douglas fir or contain only western larch.

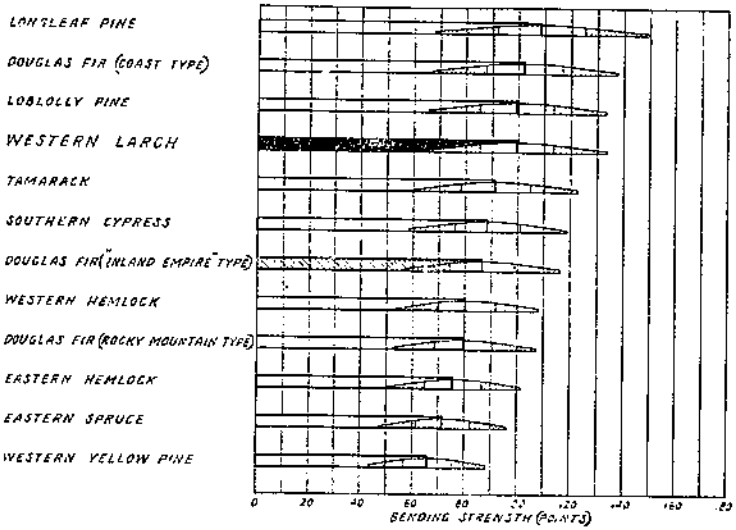


FIGURE 11.—Average and range in bending strength of clear wood of western larch as compared with that of other species of wood. The comparison shown here is for clear lumber. The effect of defects, difference in dressed dimensions, moisture content, or drying conditions may equalize or reverse the relative values as charted. Western larch taken as 100 points. Average is shown by the end of the horizontal bar and range by the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

A direct comparison of the bending strength of western larch with other species is made in Table 4 and Figure 11. The comparison is of value in judging the suitability of species for uses requiring comparatively small, clear pieces, such as ladder steps, automobile decking, cross arms, wagon tongues, and automobile body parts.

Bending strength is one of several properties required in structural timbers for mines, bridges, and factories. Such structural material contains defects, and the bending strength of individual pieces is dependent more on the size, number, and location of the defects than on the strength of the clear wood. The suitability of western larch for structural purposes is therefore best determined from the working stresses (p. 58), which are based on comparable grades and which take into consideration the influence of the defects permitted by basic requirements of American lumber standards for structural material (*28*).

COMPRESSIVE STRENGTH (ENDWISE)

Western larch ranks high among our native softwoods in the compressive strength (endwise) of its clear wood. Compressive strength endwise is a measure of the load-carrying capacity as a post or short column; that is, one whose length does not exceed 11 times its least dimension. The compressive strength of western larch averages lower than that of longleaf pine and about the same as that of Douglas fir (coast type) and loblolly pine, and higher than that of

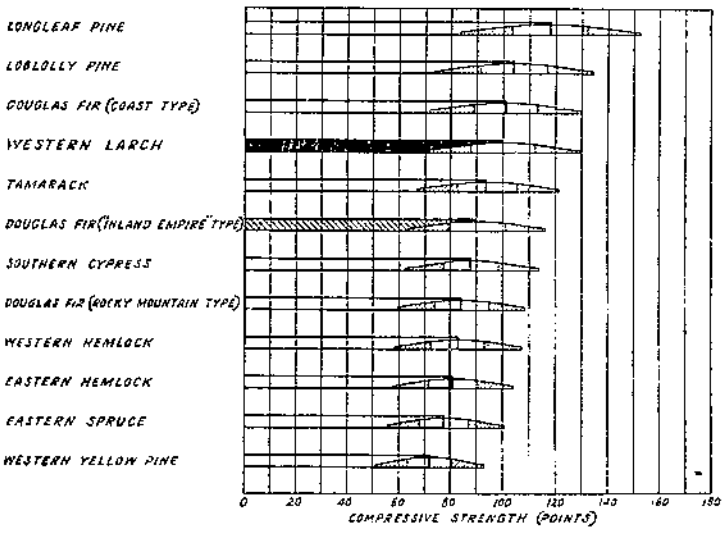


FIGURE 12.—Average and range in compressive strength (endwise) of clear wood of western larch as compared with that of other species of wood. The comparison shown here is for clear lumber. The effect of defects, difference in dressed dimensions, or moisture content, may equalize or reverse the relative values as charted. Western larch taken as 100 points. Average is shown by the end of the horizontal bar and range by the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between crosshatched areas; 40 per cent in range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

southern cypress, the hemlocks, or the spruces. Douglas fir ("Inland Empire" type) averages about 13 per cent lower than western larch, and larch-fir mixture therefore has a lower compressive strength.

Compressive strength (endwise) is one of the most important properties required in mine props, porch columns, and posts that support girders of bins or buildings. In columns whose length is in excess of 11 times the least dimension, compressive strength (endwise) becomes less important and stiffness more important. A comparison of compressive strength (endwise) of western larch with other species is made in Table 4 and Figure 12. The comparison is directly applicable to small, clear pieces used as posts. A comparison of large-sized structural posts containing defects is best made on the basis of the working stresses given on page 58.

HARDNESS

Western larch does not mar, dent, or scratch readily. It is a hard softwood. Of our important commercial softwoods, only the southern yellow pines are harder than western larch. Douglas fir (all types) is softer, and the soft pines have only about half the hardness of western larch. (Fig. 13.) Western larch is, however, not nearly so hard as the denser hardwoods, such as the oaks, beeches, maples, and yellow birch. The larch-fir mixture of the common grades will average lower in hardness than western larch, for Douglas fir ("Inland Empire" type) is 9 per cent softer. The average hardness of the mixture will not vary greatly in the select grades from that of

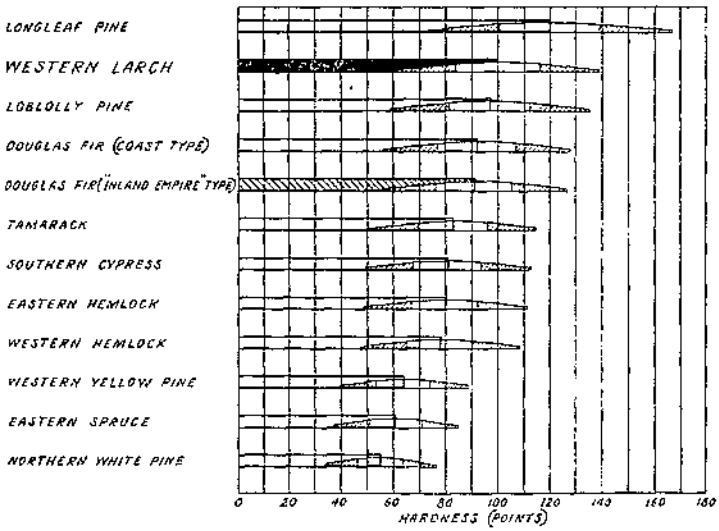


FIGURE 13.—Average and range in hardness of clear wood of western larch as compared with that of other species of wood. Comparison is applicable to lumber of all grades which contain only sound wood. Western larch taken as 100 points. Average is shown by the end of the horizontal bar and range by the curve. One-half of all the material of a species of wood will fall within the range shown by the blank space between the crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average, and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

western larch. The small difference in the average hardness of the larch-fir mixture and western larch is not, however, a true measure of the resistance of the two to wear. Even a small percentage of the softer Douglas fir in a larch-fir mixture results in uneven wear. Western larch by itself is therefore preferable to a larch-fir mixture for surfaces that are to be subjected to heavy wear.

There is a pronounced difference in the hardness of the summer wood and spring wood of western larch. The summer wood is the dark portion of the annual-growth layer and is much denser, heavier, and harder than the lighter-colored spring wood. Western larch has very narrow but distinct layers of hard and soft wood. The alternate bands of hard and soft wood in the southern pines and in that type of Douglas fir known commercially as red fir are much wider than in western larch. The wood of the white pines is more uniform in hard-

ness than western larch in that they have no pronounced layers of hard and soft wood. Variations of hardness within the annual-growth rings should be considered as well as the average numerical hardness in making comparisons. Alternate bands of hard and soft wood tend to cause uneven wear and to deflect nails. In this respect, western larch is between Douglas fir and the hemlocks.

The hardness of western larch, other things being equal, makes it more resistant to wearing, crushing, or mashing than the softer softwoods. On the other hand, its hardness makes it more difficult to cut, shape, and nail, but makes it finish smoother and polish better than the softer softwoods.

CAPACITY TO WITHSTAND SHOCKS (TOUGHNESS)

Toughness or shock resistance is not the most important property in most of the uses into which western larch goes. Where very tough woods are required the heavier hardwoods, such as the hickories, ashes, and oaks, generally are used because they are so much higher in shock resistance than the best of the softwoods as to practically eliminate the latter. In a number of uses into which western larch goes, toughness is desired along with other more important properties. For example, strength in bending and compression (endwise) are the most important properties required in mine timbers. Toughness is desired because, other things being equal, the tougher the wood the more warning it gives of failure. Likewise, toughness is a desired property in other structural material. It is also important in such uses as ladder rails, wagon tongues, and automobile-body parts, for which softwood species are largely supplied.

Western larch has the same average toughness as Douglas fir (coast type). It is not so tough as southern yellow pine or tamarack but is tougher than southern cypress, eastern spruce, or Douglas fir ("Inland Empire" type). The lower toughness of the Douglas fir ("Inland Empire" type) results in the average toughness of the clear wood in the common grades of the larch-fir mixture being less than that of western larch. Detailed comparisons of the average and range of toughness of western larch with other softwoods are made in Figure 14.

STIFFNESS

Western larch is a stiff wood. It bends or deflects less under loads than tamarack, southern cypress, the hemlocks, or the spruces. It is not, however, so stiff as Douglas fir of either the "Inland Empire" or coast types, nor is it so stiff as the southern yellow pines. The difference in stiffness between western larch and the Douglas fir of the "Inland Empire" type is so small that the stiffness of the larch-fir mixture will not differ materially from that of western larch. The average and range of stiffness in clear wood of western larch are compared with that of other species in Figure 15. The comparisons hold almost as well for lumber as they do for clear wood, for defects have little influence upon the stiffness. The comparisons are, therefore, applicable to all grades.

Stiffness is an important requirement for many uses. It is the most important requirement in joists and studding for dwellings. Stiffness largely determines the load-carrying capacity of long col-

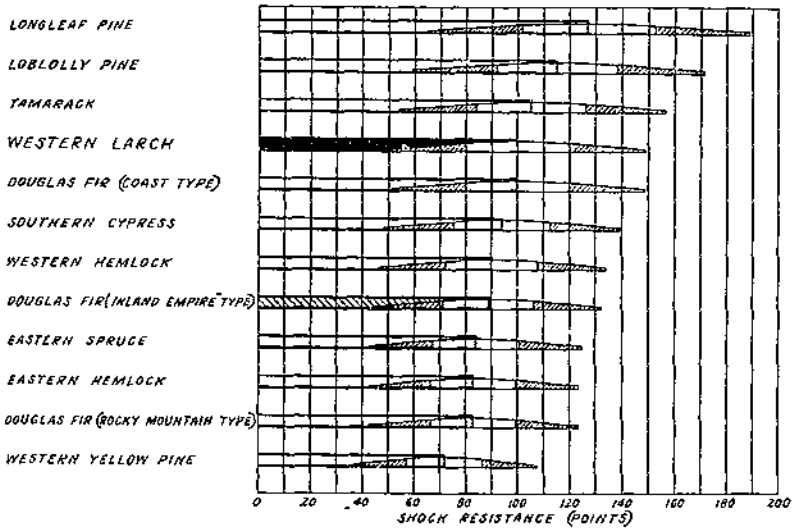


FIGURE 14.—Average and range in shock resistance of clear wood of western larch as compared with that of other species of wood. The comparison shown is for clear lumber. Western larch taken as 100 points. Average is shown by the end of the horizontal bar and range by the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

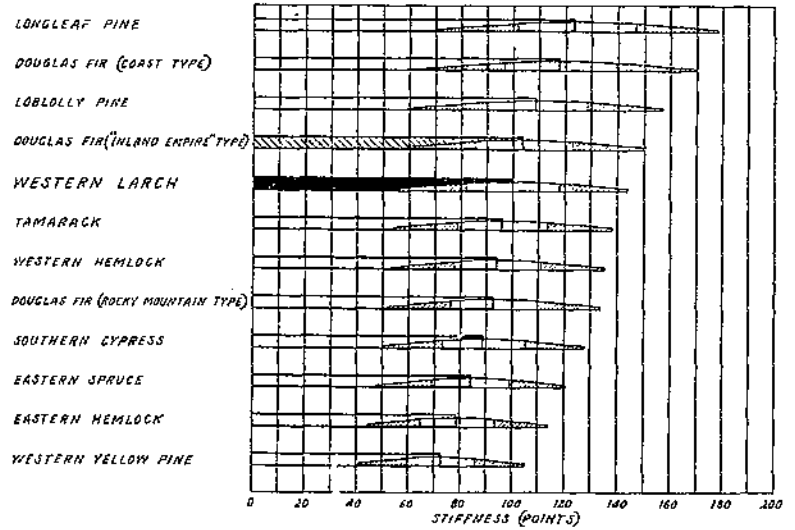


FIGURE 15.—Average and range in stiffness of clear wood of western larch as compared with that of other species. The comparison is based on clear wood but is applicable to lumber almost as well, provided the dressed size and moisture content are comparable since defects have little or no influence on stiffness. Western larch taken as 100 points. Average is shown by the end of the horizontal bar and range by the curve. One-half of all material of a species of wood will fall within the range shown by the blank space between crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

umns; that is, columns which fail by bending rather than by crushing. Side rails of ladders and footboards of bleachers are examples of other uses in which stiffness is an important requirement.

SEASONING

The satisfactory use of western larch is predicated upon proper seasoning of the wood. No single factor has operated more to discredit the real merits of western larch than has poor and inadequate seasoning.

Western larch is free from such serious drying difficulties as staining, collapse, or honeycombing. The comparatively slow rate at which the species dries and the tendency of material 10 inches and wider to cup, check, and split are the principal difficulties in drying western larch. The slow drying rate of the wood often results in western larch being marketed before it is thoroughly dried. The tendency of wide widths to check or split during air seasoning has resulted in manufacturers cutting three-fourths of the select grades into widths 4 inches and under, and about three-fourths of the common grades into thickness 2 inches and over. About one-half of the common grades are 6 inches or less in width, and practically none are wider than 12 inches. Such cutting practice has reduced trouble from cupping, checking, and splitting, but the real solution is to be found in proper kiln drying.

All sizes and grades of western larch can be satisfactorily kiln-dried. Boards 1 inch thick and 10 to 23 inches in width, green from the saw, were kiln-dried at the Forest Products Laboratory to a moisture content of 6 per cent in seven days with the drying schedule shown in Table 5. Higher kiln temperatures than those in Table 5 will shorten the drying time even more. Such increased temperatures, however, require greater care if excessive casehardening is to be prevented. Schedules for kiln-drying western larch in thicknesses ranging from 1 to 3 inches are available in publications of the Forest Products Laboratory (*35*).

TABLE 5.—*Experimental kiln schedule for drying inch western larch*

Time in kiln	Relative humidity	Temperature of air	Condition of lumber
Hours	*Per cent*	° *F.*	
0	100	165	Green; 60 per cent moisture.
3	90	165	Drying begins.
24	80	165	Free water evaporating.
48	80	165	Do.
72	80	165	Do.
92	80	165	Fiber-saturation point reached.
98	64	165	Drying and shrinkage.
120	47	165	Danger of casehardening and checking.
144	30	165	Danger of casehardening and checking.
168	30	165	Take out; 6 per cent moisture.

The best results can be obtained by kiln-drying western larch and Douglas fir in separate charges since western larch requires a longer schedule than Douglas fir in the select larch-fir grades. Separate drying, moreover, results in increased kiln output because of the faster drying of Douglas fir. Drying in separate charges is also

accomplished with less degrade because each species can be treated according to its drying requirements.

All western larch products intended for use where they must stay in place well should be kiln-dried to insure satisfactory service. The relatively large shrinkage of the wood makes it necessary to dry as near as practical to the moisture condition the wood will have in use. Interior finish in heated buildings in the North Central States, for example, will average about 7 per cent moisture content or lower. In unheated buildings interior finish will seldom average above 12 per cent. An average moisture content of 8 to 10 per cent is therefore required to reduce shrinkage to a minimum. Such low moisture-content values can not ordinarily be obtained in the "Inland Empire" by air seasoning.

About one-fourth of the western larch lumber produced is now kiln-dried. Within the locality that produces the bulk of the western larch lumber dry kilns are now the exception rather than the rule. Among the manufacturers that are equipped to kiln-dry the bulk of their daily cut, four produce practically 15 per cent of the total cut of western larch lumber. There is now, however, a very decided tendency within the "Inland Empire" to increase kiln capacity.

Western larch requires a much longer time to thoroughly air season than most softwoods. (Fig. 16.) Moisture determinations made on stock after 34 months' air seasoning in the "Inland Empire" showed values too high to be satisfactory for wood going into interior and dry locations. The moisture content of several hundred samples selected at random from winter shipments of western larch that had been in the yards 12 to 34 months had approximately one-third more moisture than the average of several thousand specimens similarly selected from 10 of the leading softwood species. Similar determinations on summer shipments showed the average moisture content of western larch decidedly higher than that of the other softwoods studied. Time in the seasoning pile can not, therefore, be relied upon by either producer or consumer for a satisfactory indication of the adequacy of seasoning.

The slow drying characteristics of western larch and the tendency of wide material to cup, check, and split present a perplexing problem in air seasoning. Checking, splitting, and warping are due to uneven shrinkage, and all may be reduced by methods of piling. Shading the ends of the stock will decrease the end checking and splitting. Warping can be reduced by piling methods that hold stock firmly in place and in alignment during drying. Surface checking can also be prevented by slowing down the drying rate. The slow drying characteristics of the western larch, however, make it problematical whether methods of piling to reduce degrade, which slow up drying, are commercially feasible. Where air drying must of necessity be practiced the moisture content should be frequently observed to be sure that the material is dry enough for use, and the seasoning should be studied to determine the piling methods that will give a satisfactory drying rate and still prevent excessive degrade.

The benefits from good seasoning are operating to improve the seasoning of western larch. The advantage of reduced shipping weights, especially with a wood as heavy as western larch, and the

advantages of decreasing degrade are evident and appeal directly to manufacturers. To these the consumer can add another indirect but more powerful appeal by an insistent demand for thoroughly seasoned wood. The consumer should make this demand to protect himself from unsatisfactory service from wood otherwise admirably adapted to his use. The improved seasoning which will result from such a demand will benefit the consumer, the producer, and the species.

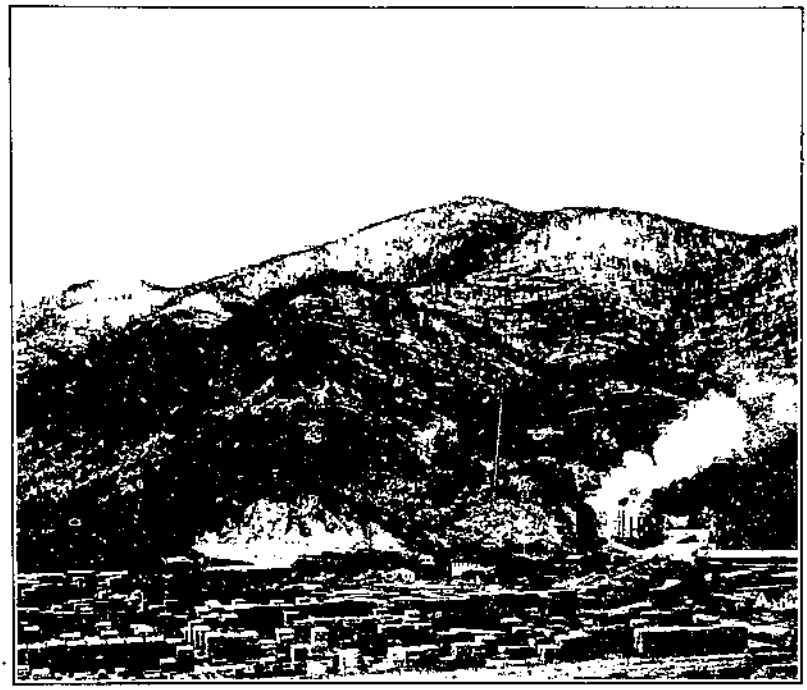


FIGURE 16.—Air seasoning western larch in the "Inland Empire." About half the output of this mill is larch-fir

SHRINKAGE

Western larch shrinks more in drying from a green to an oven-dry condition than do any of the principal softwoods but less than many of the heavier, commercially important hardwoods. The average shrinkage of tamarack, the southern yellow pines, and eastern spruce is only slightly less than that of western larch. The difference in shrinkage between the foregoing species and western larch is not important for most practical purposes. There is a significant difference, however, between the shrinkage of western larch and Douglas fir (all types), southern cypress, the hemlocks, and the soft pines.

The larch-fir mixture shrinks less than western larch because the shrinkage of Douglas fir ("Inland Empire" type) is only 87 per cent of that of western larch. In the common grades the shrinkage of larch-fir will average about 93 per cent of that of western larch; in the select grades about 98 per cent since 90 per cent of the selects are western larch.

A comparison of the average and range of shrinkage of western larch with that of several other softwoods is shown in Figure 17. The comparison is based on the total shrinkage from a green to an oven-dry condition measured on specimens 1 inch thick, 4 inches wide, and 1 inch along the grain, which is a standard size used with all species in order to obtain comparable values. The comparatively large shrinkage of western larch is not primarily the cause of trouble resulting from changes in dimensions because several species with higher shrinkage than larch are used for exacting purposes with satisfactory results. Where change in dimension is of sufficient size to cause trouble it is usually the result of inadequate seasoning or

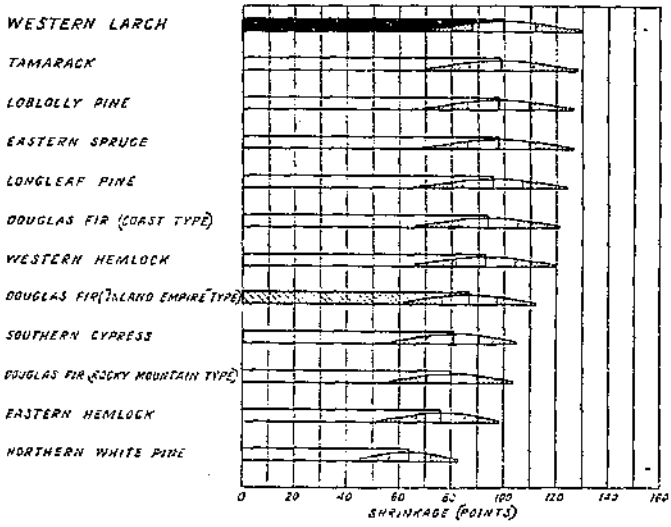


FIGURE 17.—Average and range in the total shrinkage from a green to an oven-dry condition of small, clear pieces of western larch as compared with that of other species of wood. Western larch taken as 100 points. Average is shown by the end of the horizontal bar and range by the curve. One-half of all material of a species of wood will fall within the range shown by blank space between crosshatched areas; 40 per cent in the range shown by the crosshatching, 20 per cent above the average and 20 per cent below the average; while 10 per cent, 5 per cent above and 5 per cent below, will fall outside the range shown by the curve

of storage conditions. When the wood dries in place the changes in dimension are, of course, relatively large and may result in unsatisfactory service. Such changes cause the shrinkage of western larch to appear larger as compared to other woods than it is. On the other hand, when the wood is used dry the slowness with which it picks up moisture reduces the tendency to change dimension and makes the relative shrinkage appear smaller than it is. The shrinkage of western larch, although relatively high, does not prevent the use of western larch for flooring, interior trim, and other purposes where only small changes in dimension are permissible.

Under most conditions differences in the shrinkage of western larch and other species are not so important as the moisture condition of the wood at time of use. For example, the shrinkage of northern white pine is about two-thirds that of western larch, but western larch shrinks over twice as much in drying from 18 to 6 per

cent as it does in drying from 12 to 6 per cent moisture. Shrinkage troubles with western larch, as with other species of wood, can be largely controlled by proper seasoning, but it follows that proper seasoning is more important with high-shrinkage woods than with small-shrinkage woods.

The average shrinkage to be expected in western larch lumber between any given moisture conditions can be obtained from Figure 18. For example, to determine the average change in dimension of 1 by 4 inch, edge-grained, western larch flooring between 6 and 12 per cent moisture, which are the approximate winter and summer moisture-equilibrium conditions of flooring in heated buildings in New England and the Lake States, a line through 6 per cent moisture meets the edge grain or radial shrinkage curve at 3 per cent. A similar line through 12 per cent meets the edge-grain curve at 2 per cent. The difference between the two values is 1 per cent. One per cent of 3⅝ inches (actual width of nominal 4-inch flooring) is about one-twenty-eighth of an inch. A similar determination for flat-grained flooring shows a change in dimension of about one-fifteenth of an inch. The curves of Figure 18 are based on measurements made on short sections of boards selected from a commercial run of lumber (*19*). The shrinkage in the width of flat-sawn western larch lumber from a green to oven-dry condition is about 7 per cent of the original green width. The shrinkage in width of edge, or vertical-grained, western larch lumber is 4 per cent of the green width. Most of the shrinkage in western larch takes place below 28 per cent moisture. The small amount of shrinkage (about one-half of 1 per cent) that takes place above 28 per cent moisture content is of little practical importance. Some shrinkage does occur in lumber at high moisture-content values (40 per cent); it is very small, however, only a small fraction of 1 per cent, and is due to the drying of the outside fibers while the interior of the piece is still in the green condition.

ABILITY TO STAY IN PLACE

Ability to stay in place is a desirable property in all lumber. It depends on a combination of the shrinkages and the tendency of the wood to warp. Shrinkage is a measure of the change in dimension. Warping is the tendency of wood to change in shape. From the log to the finished product warping and change in dimension are a source of loss and trouble.

In so far as shrinkage is concerned, previous comparisons have shown that western larch changes in dimension more than most of the softwoods, but not so much as the denser or heavier hardwoods. The change in dimension of thoroughly seasoned western larch is not sufficient to cause complaint in such uses as interior trim and finished flooring, but would be objectionable in such uses as patterns.

No numerical evaluation can be made of warping tendencies, either for comparison of species or for determination of amounts. The tendency of western larch to warp, however, can be judged to some extent by its past behavior and general reputation. The species has given some trouble in seasoning from cupping, especially in boards of widths in excess of 10 inches (p. 27). Because of its straight grain, little trouble has been experienced with western larch from

warping of the twisting type. Once properly seasoned, western larch stays in place well. The dry wood has a reputation among retailers of "yarding" well; that is, it is easy to pile, stays straight in the pile, and the degrade in storage is small. Its reputation among users for staying in place is good with those who use it for framing, subfloors, sheathing, and other rough usages, indicating that the wood will not work out of place sufficiently to be objectionable in such uses.

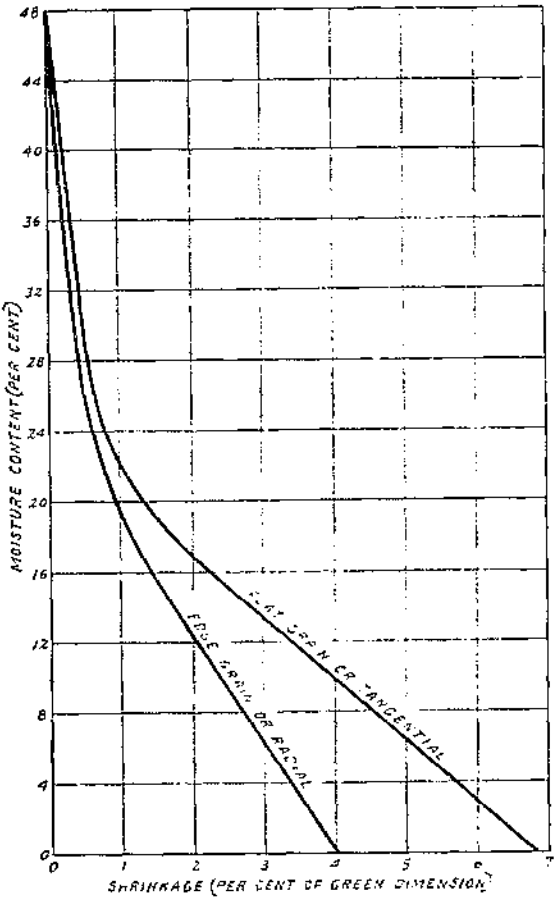


FIGURE 18.—Shrinkage of flat and edge grained western larch. Based on tests of heartwood specimens in the form of 1-inch boards cut from commercial run of lumber. An estimate can be made with the aid of this chart of the amount of change in dimension that will take place with changes in the moisture content of the wood

EASE OF MACHINING AND WORKING

Smooth surfaces are easy to obtain with western larch, but the effort or power required is relatively high for a softwood. The smoothness of the surface is probably due to the hardness, density, and uniform narrow annual-growth ring of wood. The hardness and the alternate bands of hard and soft wood are responsible for

the amount of power and effort required to work the wood. The smoothness of the dressed surfaces is quite noticeable in the piling or handling of the lumber. The boards slide on one another more readily than boards of the other western softwoods. A tendency of quarter-sawed stock to sliver on edge or for edges to feather is also noticeable in handling. The alternate bands of hard and soft wood are largely responsible for this tendency. In occasional shipments the feathering of edges of quarter-sawed stock has been sufficient to be objectionable. When feathering is sufficiently pronounced to be objectionable it is probably the result of working the wood while it is still wet. Dull knives or poor machining may also be responsible for feathering.

In ease of working and machining, western larch is between Douglas fir (all types) and longleaf pine. The Douglas fir (all types) is softer and easier to cut, saw, and shape but does not dress so smoothly. Longleaf pine and shortleaf pine are harder and require more effort to cut, saw, and shape, while loblolly pine requires about the same. The narrow and uniform width of growth rings of western larch have a favorable influence on its workability, reducing the adverse influence of alternate bands of hard and soft wood. Its hardness increases the tendency of knots to break or crack in planing. This is evident in the lower grades, where broken knots are more prevalent than in the Douglas fir ("Inland Empire" type). On the other hand, the clear wood of western larch dresses to a smoother surface and breaks back less in crosscutting than Douglas fir, that is, the sawed surfaces are cleaner cut and the edges of ends less slivery. The hemlocks, true firs, and spruces are all easier to cut than western larch, but the edges and surfaces are not so good.

The moisture content has a pronounced influence on the ease with which a wood works. Wet or green wood cuts and saws easier than dry wood but does not finish to so smooth a surface. Wood has a tendency to fuzz when planed before it is thoroughly dry. The grain also may rise or loosen. The tendency to fuzz, however, is not so pronounced in western larch as in softer woods, but the tendency of the grain to rise or loosen is greater than in more uniformly textured woods.

When saws or planes stick in working western larch the sticking is caused by galactan rather than by resin. Galactan is a water-soluble extractive, which occasionally exudes on the surface of western larch. Galactan has a less pronounced effect on workability than the resin in such woods as Douglas fir (all types) and the southern yellow pines. Water is used to eliminate trouble from galactan just as kerosene is used with resinous woods. Galactan seldom causes trouble at the planer but does at times gum the saws. Trouble from this source occurs principally with green wood.

NAIL-HOLDING CAPACITY

One of the desirable properties of western larch is its high nail-holding power. Not only does the wood hold nails well when they are first driven into it, but it retains its nail-holding power well under varying moisture conditions. All woods lose heavily in nail-holding

power when the nails are driven into wet wood that later dries. Some species retain only about 10 per cent of their original nail-holding power under such severe conditions. It is, therefore, poor practice to nail into wet western larch or any species when the wood will later dry in use.

Western larch ranks near the top of the softwood group in nail-holding power (*17*). (Fig. 19.) It is between longleaf and loblolly pine in nail-holding power and is higher than Douglas fir (coast type), the hemlocks, soft pines, or the spruces. It is higher, for example, than red gum, a hardwood used extensively in automobile bodies, where nail and screw holding properties are important requirements. There are no data available on the nail-holding power of the "Inland Empire" type of Douglas fir: therefore, a comparison can not be made between western larch and larch-fir mixture. Judg-

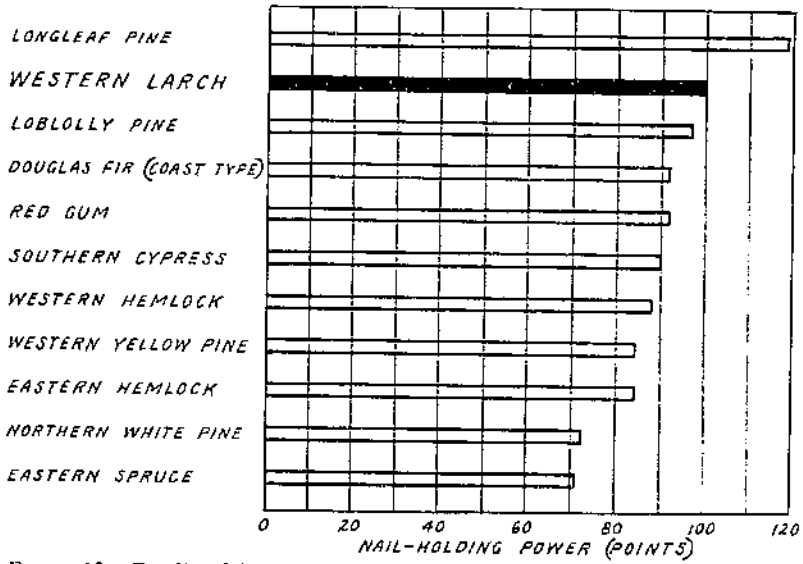


FIGURE 19.—Results of tests on holding power of nails driven into and pulled at once from dry, clear wood of western larch as compared with that of other species of wood. Western larch is taken as 100 points

ing from the specific gravity of the two species, however, it appears probable that the nail-holding power of Douglas fir ("Inland Empire" type) is between 10 and 15 per cent lower than that of western larch.

The foregoing comparisons and those shown in Figure 19 are based on pulling tests of 7-penny cement-coated nails driven into flat-grained and edge-grained faces. Other tests indicate that the comparisons will hold for other sizes and types of nails.

Data on only a small number of species are available for comparison with western larch for retention of nail-holding power as the wood dries out. The comparison of retention of nail-holding power is complicated by the influence of time. Tests made on the resistance to withdrawal of nails driven into green wood and pulled after the wood had thoroughly air-dried showed western larch retained its nail-holding power well.

The high nail-holding power and high retention of holding power in drying of western larch are a desirable combination of properties, especially in such uses as in boxes and crates, which change from damp to heated storage, in freight cars, which are subjected to a wide range of climatic conditions, and in automobile bodies, which are alternated between heated garages and direct exposure to the elements.

SPLITTING

The prevention of splitting in seasoning, nailing, and handling western larch requires special attention. In air seasoning, splitting is partly controlled by manufacturing narrow widths in preference to wide ones; in kiln-drying, by the use of special drying schedules

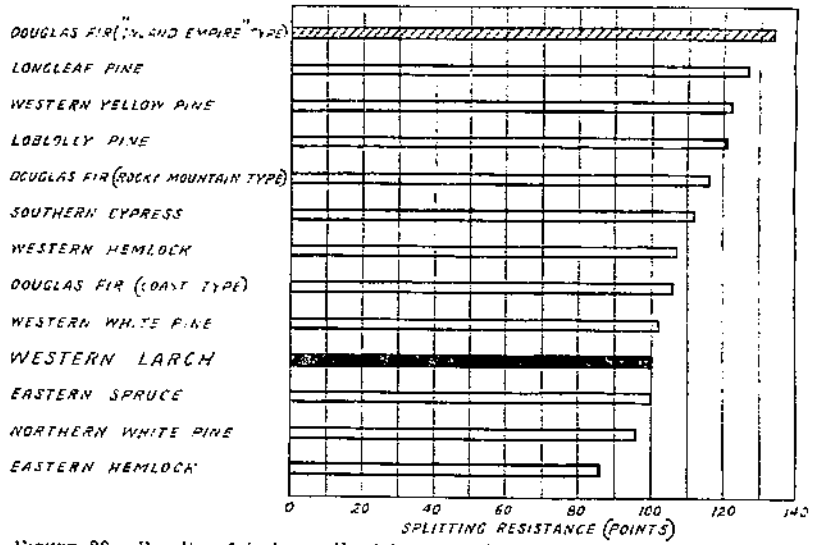


FIGURE 20.—Results of tests on the inherent splitting resistance of clear wood of western larch as compared with that of other species. Western larch taken as 100 points. Splitting resistance is a measure of the resistance to splitting from action of wedges and bolts but is not a direct measure of the tendency to split in nailing because hardness, width of annual rings, and texture also influence the splitting in nailing

(p. 27); and in nailing, by the use of blunt or smaller nails than are used with lighter, softer, and more uniform textured woods. The tendency of western larch to split in seasoning and handling is due to the low inherent resistance of the wood to splitting combined with its comparatively high shrinkage. The high hardness of the wood combined with its low inherent splitting resistance is responsible for the tendency of western larch to split in nailing.

Western larch is easy to split with wedge or ax. (Fig. 20.) The inherent resistance to splitting of western larch is about the same as that of spruce and the white pines, and is lower than that of Douglas fir (all types) and southern yellow pine. Douglas fir ("Inland Empire" type) has a high inherent resistance to splitting; consequently, the average splitting resistance of the larch-fir mixture in the common grades is about the same as that of the southern yellow pines and is higher than that of Douglas fir (coast type). In the select grades, where the percentage of Douglas fir ("Inland Em-

pire" type) is small, the average splitting resistance is about the same as that of Douglas fir (coast type). The foregoing comparisons are based on wood free from shakes, season checks, or other defects.

Western larch does not split in nailing so much as would be expected from a study of its hardness and inherent splitting resistance. This was shown by a recent study at the Forest Products Laboratory in which a large number of nails were driven into a small number of specimens selected to represent the range in specific gravity and ring growth to be found in western larch and five other softwoods. The percentage of splits in western larch was slightly less than in Douglas fir (coast type) or in western hemlock, but slightly greater than in southern yellow pine, southern cypress, or white fir, and several times greater than that in northern white pine. Wide-ringed material split more under the nails than narrow-ringed material, which accounted to some extent for the favorable showing made by western larch. Edge-grained material split less than flat-grained material or material in which the grain was intermediate between flat and edge. The heavy specimens of a species split more than the light ones of the same species. These are factors which should be considered in comparing the splitting resistance of western larch with other species. The comparisons, however, should all be considered as tentative until a more comprehensive study can be made of the tendency of woods to split in nailing.

GLUING CHARACTERISTICS

Glued joints as strong as the wood in shear and tension perpendicular to grain can readily be made with western larch. Such joints can be produced with both flat-grained and edge-grained material by the use of the schedules of Table 6 with vegetable, animal, or casein glues. The characteristic failures of western larch glued with vegetable glue are shown in Plate 3. The photograph, which is also typical of failures with animal and casein glues, shows how the wood tore apart while the glue held, indicating that satisfactory joints were obtained.

TABLE 6.—*Gluing schedules for western larch*

Kind of glue	Proportion of glue to water by weight [1]	Glue spread	Temperature of the wood	Pressure	Closed assembly time [2]
		Lbs. per 1,000 sq. ft.	*°F.*	*Lbs. per sq. in.*	*Minutes*
Animal [4]	1:2¼	65–70	70	125–175	35– 1
	1:2¼	70–75	80	125–175	2 – 5
	1:2¼	75–80	90	125–175	7 –18
	1:2¼	75–80	90	125–175	10 –20
Casein [5]	1:1½	70–75	70–90	150–200	0 –12
	1:2	75–80	70–90	150–200	5 –20
Vegetable [3]	1:2½	60–70	70–90	100–170	0 –20
	1:2¼	70–80	70–90	100–150	1 –25

[1] The recommended proportions of glue and water are suitable for both lumber and veneer gluing, but ordinarily it is better to use a thicker glue mixture with lumber than with veneer.

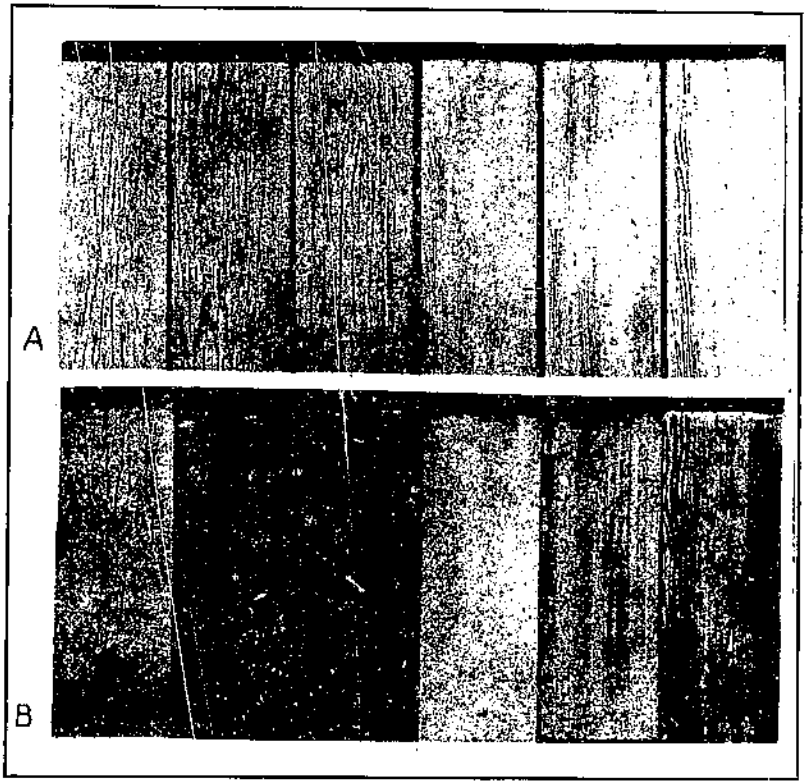
[2] Wood pieces laid together as soon as spread with glue.

[3] Weight of wet glue mixture.

[4] An animal glue equivalent to about a No. 1 2 in the National Association of Glue Manufacturers' grades. Other grades may be used if suitable adjustments in the proportions of glue and water are made.

[5] Some commercial glues require more or less water than given here in order to obtain the same consistency of mixture.

Chief joint as strong as the wool in sheep and lambs not sheared. The grain can readily be made with western hand. The illustration shows how the wool when tested to failure tore apart while the grip held. The failures are typical of those obtained with vegetable, animal, and cereal glues. A, Flat grained western lamb; B, edge grained western lamb



M5637F M8195F

A, Edge and flat grained painted panels of western larch after two years exposure at Madison, Wis., facing south and inclined 45° to the vertical. This is equivalent to about three years exposure in a vertical position facing south and perhaps four or five years facing north. Wood checking is evident in the flat grain on the left, and the paint is flaking from the summer-wood bands. Repainting should not be delayed. (Holes shown in panels on left are the result of gunfire and are not defects); B, same specimens as shown in A after four and one-half years exposure. The first and fourth panels from the left received one coat and the second and fifth panels two coats at the end of three years exposure. Note difference in checking as a result of four and one-half years exposure in the third specimen which is flat grain and the sixth which is edge grain

The animal-glue schedules of Table 6 are recommended (*26*) for use with the sapwood of eastern red cedar, southern yellow pine, and western yellow pine, as well as western larch. More restrictive schedules are recommended for the heartwood of eastern red cedar, heartwood of southern cypress, and many of the hardwoods.

The average strength of glued joints made at the Forest Products Laboratory with western larch was high for a softwood. Joints made with vegetable or animal glue in accordance with the schedules of Table 6 averaged over 1,600 pounds per square inch; with casein glue, over 1,800 pounds per square inch. Under extremely adverse conditions, animal glue joints averaged over 1,200 pounds per square inch.

PAINTING AND FINISHING CHARACTERISTICS

Western larch exposed to the weather should be painted at relatively frequent intervals. In this respect western larch is classed with Douglas fir (coast type) and southern yellow pine. These three woods, largely because of their high density combined with their distinct alternate bands of hard and soft wood, do not hold paint so long as the lighter and more uniform textured softwoods. The paint on western larch fails by flaking from the summer-wood bands. (Pl. 4.) Repainting, however, is generally advisable before flaking takes place in order to protect the wood from checking and to prevent cupping. The white pines, cedars, southern cypress, and redwood hold paint the longest of any of the woods studied at the Forest Products Laboratory. The spruces, true firs, hemlocks, and western yellow pines were between this group and western larch.

The Forest Products Laboratory is studying the painting characteristics of 17 native softwoods, including western larch. The study has been in progress for seven years and is conducted on panels exposed on test fences at widely scattered points throughout the United States. The test panels include flat-grained and edge-grained material and both white-lead and lead-zinc paint are used. Details of the work and the conclusion drawn from the study are available at the laboratory (*6*).

The species comparisons just made are based on the behavior of paint on clear wood. A special study of knotty western larch showed that paint did not discolor around knots and that knots held paint well, there being no early flaking of paint from knots. (Pl. 5, A.) Shellac or other knot sealers are therefore unnecessary and should not be applied over the knots in western larch. The indications from this study are that paint on knotty western larch will maintain a better general appearance than on woods with high resin content.

Ordinarily western larch that is freely exposed to the weather should be repainted at intervals of about three years. The time, however, varies greatly with exposure, climatic conditions, with edge-grained and flat-grained material, and with quality and type of paint. If surfaces facing south are shaded by trees or buildings, repainting may not be needed oftener than once in four or five years. On the other hand, under adverse climatic conditions, where at times there is much sunshine, little rain, and periods of low humidity, it may be necessary to renew coating oftener than every three years.

Prepared paints containing a moderate proportion of zinc oxide can be used to better advantage on western larch than they can on

heavy softwoods that contain more resin, because resins seem to affect adversely the durability of paints containing zinc oxide.

Edge-grained material requires repainting less often than flat-grained material. (Pl. 4.) While this is true of practically all softwoods, the difference is much more pronounced in western larch than in lighter and more uniform textured woods. On an average the paint coatings lasted about half again as long on edge-grained larch as they did on flat grained in the tests at Madison, Wis. Again, the time varies widely with climate, location, and type and quality of paint. Where flat-grained boards are used, especially out of doors, they should be placed with the sapwood side rather than the heartwood side exposed to the weather. This will largely prevent the development of loose and raised grain.

The durability of paint on western larch can be increased at least one year by applying one coat of exterior aluminum paint (7) to bare wood before painting with ordinary house paint. Such a coating, consisting of one coat of aluminum primer and two coats of white or light-colored paint, costs about the same as a standard 3-coat job but lasts longer because flaking of the coating from the summer wood is retarded. When the added durability is considered, the cost of the coating with aluminum primer and two top coats of ordinary paint is usually less than the cost of a 2-coat paint job, even if skillfully applied. With paint of a dark color one coat over aluminum primer is sufficient.

The results of the painting study are not directly applicable to interior conditions. The painting of interior woodwork is primarily for appearance or sanitation rather than for protection of the wood. Normally, checking of wood or flaking of paints from summer-wood bands does not occur on interior trim. Repainting time for interior trim is therefore normally the result of the soiling of the paint by dust, soot, grease, or the like. The hazard from such causes varies with the use, as does also the amount of soiling or marring which can take place before repainting is necessary. Generally, lighter and more uniform-textured woods are preferred to western larch for smooth-paint and enamel finishes. Where western larch is used it is generally given a natural or stain finish, although it will take and hold paint and enamel finishes. (Fig. 21.)

Beautiful effects can be obtained on western larch with spirit stains or natural finishes. (Fig. 22.) On the other hand, fuming is not recommended for use on western larch, for fuming has little effect on the wood. Three-coat finishes consisting of one coat of penetrating stain, one coat of white shellac, and one coat of interior varnish were applied to western larch specimens, a number of commercial shades of oak stains being used. Brown and dark mahogany primers with one coat of interior varnish and no shellac were also tried. The wood took all stains well, and the figure of the flat-grained material was brought out in greater relief. Light, bright tones were obtained with natural finishes consisting of one coat of silex filler lightly sanded, plus one coat of interior varnish rubbed with very fine steel wool, plus a second coat of varnish which when dry was rubbed with pumice stone and rubbing oil. This finish may be waxed if desired.

Two other types of finishes which gave good results in tests at the Forest Products Laboratory and which are applicable to either the natural or stained wood are: (1) One coat of white shellac, rubbed with fine steel wool and finished with two coats of prepared wax; (2) one coat of shellac followed by two coats of interior varnish, each coat except the last being lightly rubbed with steel wool.

A very high polish can be obtained with finish (2) by rubbing the final varnish coat with pumice stone and oil and polishing with an agent composed of 2 parts of white shellac and 1 part raw linseed oil. Finish (2) may also be polished by rubbing with pumice stone and oil and polishing with prepared wax. These materials properly applied present a pleasing and durable finish.

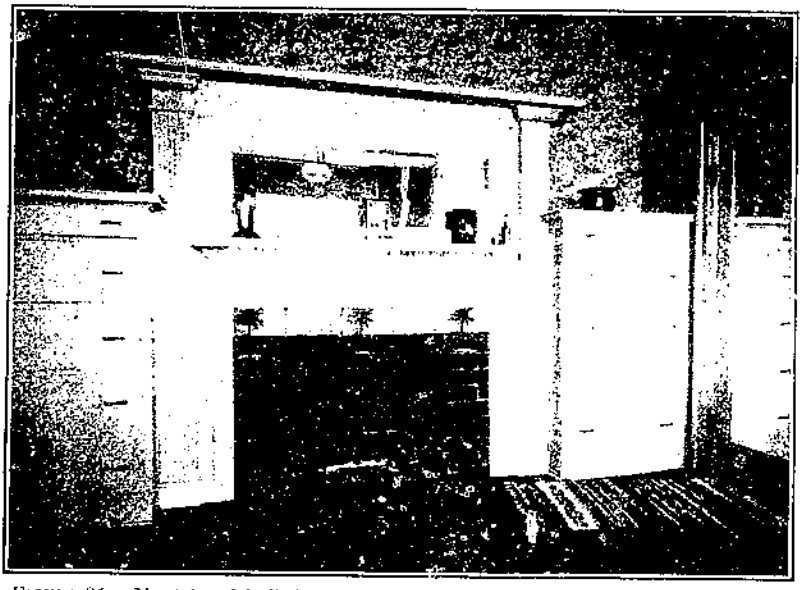


FIGURE 21.—Mantel and built-in fixtures of western larch finished in white enamel

RESISTANCE TO DECAY, WEATHERING, AND INSECTS

The heartwood of western larch is moderately decay resistant. It is used satisfactorily without preservative treatment where the decay hazard is not high. Like other woods, however, the life of western larch is doubled or tripled by a good preservative treatment. Not only is the heartwood of western larch moderately decay resistant, but the decay resistance of heartwood is largely retained in the lumber because of the small amount of sapwood it contains. The sapwood of all species rots readily under conditions favorable to decay. The decay resistance of any lumber is, therefore, dependent not only on the resistance of the heartwood, but on the percentage of sapwood present. In judging the suitability of western larch lumber for uses requiring decay resistance, consideration should, therefore, be given to the fact that repairs and maintenance may be smaller with western larch lumber than with lumber of species with more decay-resistant heartwood but a higher percentage of sapwood. (Fig. 23.)

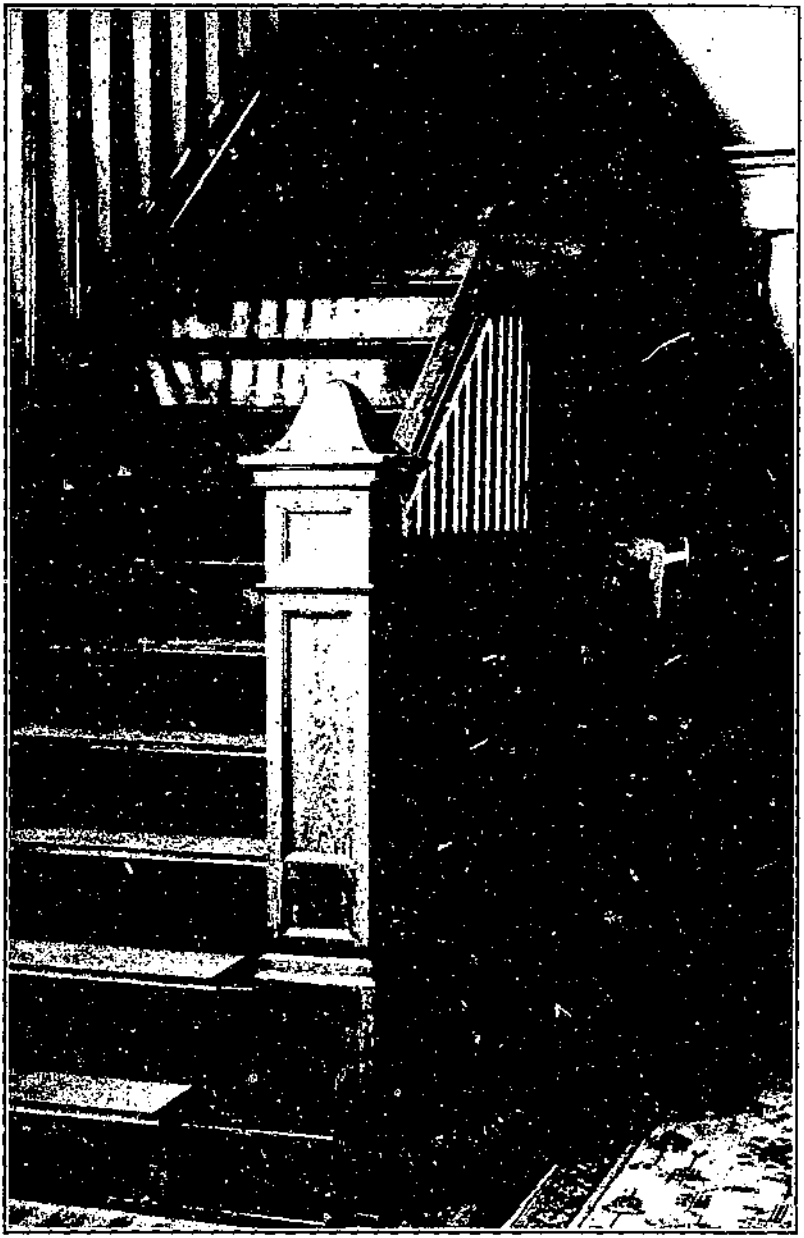


FIGURE 22.—Western larch stairway and panel strips showing effect obtainable with natural and stain finishes

Numerical comparisons of the decay resistance of western larch with other species are not satisfactory. Such comparisons based on service records can not be exact for removal for decay is always a matter of judgment. In addition, life in service varies widely with locality and use.

A general comparison based on service records where available, supplemented by general experience, indicates that the heartwood of western larch is very similar in decay resistance to that of Douglas fir (all types), southern yellow pine, and tamarack. Western larch is classed as lower in decay resistance than the heartwood of the

FIGURE 23.—Western larch highway guard-rail posts. The moderate decay resistance of the heartwood and the narrow sapwood ring of western larch are advantageous where posts are to be used untreated

cedars, chestnut, and southern cypress, but higher than the hemlocks and spruces. The average life to be expected of untreated western larch under conditions favorable to decay, as indicated by service records on untreated crossties in the "Inland Empire," was a little over seven years. Douglas fir ("Inland Empire" type) installed in the same track had practically the same average life. Western larch treated with zinc chloride had an average life of 14 years.

All woods weather when exposed to the elements. Weathering in western larch, especially if the wood is exposed before thoroughly seasoned, takes place in a comparatively short time. Unpainted western larch panels showed some checking three weeks after exposure. At the end of four years the weathering in the western larch panels was more pronounced than in Douglas fir (coast type) or southern yellow pine and considerably more pronounced than in

the cedars and southern cypress. The difference between species is much more pronounced in flat-grained than in edge-grained material. The weathering of western larch can be prevented by thoroughly seasoning the wood before exposing it to the weather and by protecting it with paint. The paint should be applied as soon after exposure as possible, and a good paint coating should be maintained.

All native species are susceptible to the attack of termites, or white ants, but some are more resistant than others. The prevention of damage from termites is best accomplished by preservative treatment and special care in construction (*22*), not by selection of resistant species.

REACTION TO PRESERVATIVE TREATMENT

Wood-preserving plants report that from a treating standpoint there are two types of western larch. One type treats very much like coast-type Douglas fir, the other like the Rocky Mountain type of Douglas fir. The western larch with treating characteristics like the Rocky Mountain type of Douglas fir is reported to come from higher altitudes and to have wider growth rings and to be more difficult to treat than the western larch from lower altitudes, which has the characteristic narrow growth rings of uniform width. Good penetration in crossties is obtained with the narrow-ringed type of western larch when the ties are incised.

Very little experimental work has been done on the preservative treatment of western larch. Most of the information available has been obtained from a study of the experiences of commercial treating plants with the species. Commercial plants are treating a large number of western larch crossties.

HEAT-INSULATION PROPERTIES

No tests are available on the heat conductivity of western larch. Tests made on other species indicate that the heat conductivity of wood is proportional to its specific gravity (*3*, *21*, *30*). Western larch would, therefore, be expected to conduct heat somewhat better than Douglas fir (coast type), but not quite so well as southern yellow pine.

Differences in the heat conductivity of species are, however, of small practical significance in most uses of lumber. The heating requirements of buildings are dependent more on tightness of construction and method and amount of insulation used than on the species (*20*). Western larch and other species all have high insulating properties as compared with most other structural materials.

PERMEABILITY BY LIQUIDS

Liquids penetrate western larch with difficulty. This fact is shown by the difficulty encountered in forcing preservatives into the wood. While the impermeability of the wood is a handicap to preservative treatment, it is a distinct asset in some uses, such as tight cooperage, silos, and tanks. The wood is very similar to Douglas fir (coast type) in this respect. Liquids penetrate western larch less readily than western yellow pine but more readily than Douglas fir ("Inland Empire" type).

TENDENCY TO IMPART ODOR OR FLAVOR

The wood of western larch is slightly resinous, falling between the spruces and Douglas fir in this respect. Western larch, however, is without distinctive odor or flavor. In so far as is known, western larch does not impart odor or flavor to food or liquids and normally can be used for boxes, barrels, and tanks without danger of contaminating the contents.

TENDENCY TO LEACH OR EXUDE EXTRACTIVES

Although western larch is slightly resinous, it has only a small tendency to exude resin. In this respect western larch is between the spruces and Douglas fir. Western larch does, however, exude a water-soluble gum known at galactan, which is sometimes mistaken for pitch. Galactan exudations are confined largely to material from butt logs; consequently, much of the material rich in galactan is left in the woods because the butt logs are often too heavy to float or are too shaky to be cut into profitable lumber.

The wood of western larch has no tannin or water-soluble material that will leach out and stain paint or plaster.

CHEMICAL PROPERTIES

The principal chemical difference between western larch and the other softwoods is in the nature of the extractives the wood contains. The basic chemical composition of the wood itself is very similar to that of other species of softwood. The wood is peculiar chemically in that it contains galactan, a water-soluble gum. Galactan can be hydrolyzed into galactose, and can be oxidized into mucic acid. Galactose, which is a sugar, has no commercial value at present. The very small amounts, a few pounds, now used by universities and chemical laboratories are obtained from milk sugar. Mucic acid obtained from galactan has been used commercially in place of tartaric and phosphoric acid in the manufacture of baking powder.

The galactan in western larch makes the wood suitable as raw material for the production of ethyl alcohol. Higher yields of ethyl alcohol are obtained with western larch than with other softwoods because both wood and galactan can be hydrolyzed to sugar that can be fermented for the production of alcohol. The species, however, has not been used commercially for this purpose, principally because practically all ethyl alcohol is obtained commercially from raw materials other than wood.

FIRE RESISTANCE

Western larch, like all other species, will ignite and burn at temperatures prevalent under fire conditions in structures. The difference in the ignition temperature of western larch and other species is small as compared to the difference in ignition point of untreated wood and wood which has received an effective fire-retardant treatment. Differences within species with reference to oil, density, and resin are as significant from a fire-resistance standpoint as differences between species. When fire resistance is required in untreated

wood it should be selected for high density and low oil and resin content. High fire resistance, however, is best obtained by giving the wood a fire-retardant treatment.

CHARACTERISTIC DEFECTS[8] OF WESTERN LARCH

Natural, seasoning, and machining defects are found in western larch as in all other woods. Natural defects are developed in the growing tree. Their occurrence can be controlled only by selection of trees and grading and selection of logs and lumber. They, therefore, show up in lumber as a permanent characteristic of the wood. Seasoning and machining defects, on the other hand, are developed in the lumber, not in the tree, and are therefore subject to control. Improved machinery, methods, and practices may change the size, character, or number of such defects and may even eliminate some of them. Although the frequency with which these seasoning and machining defects occur is, in some cases, influenced by the properties or characteristics of the wood, they can not be said to be truly characteristic of any species. In the following discussion such defects should only be considered as indicative of what may be expected under current practice.

The frequency with which the more important defects occur in western larch is shown in Table 7, which is based on a study of the defects in 14 of the principal commercial softwoods made at a number of representative mills. The occurrence of defects is shown separately for the select and common grades and for the mill run.

TABLE 7.—*Character and occurrence of defects in western larch*[1]

Defects[2]	Frequency of occurrence in—			Defects[2]	Frequency of occurrence in—		
	Select grades	Common grades	Log run		Select grades	Common grades	Log run
	Per cent	*Per cent*	*Per cent*		*Per cent*	*Per cent*	*Per cent*
Knots	60.1	96.3	82.4	Pitch	9.2	4.2	5.1
Check	54.5	68.4	63.6	Shake	2.7	7.7	5.8
Torn grain	19.4	19.8	19.6	Pitch streak	2.5	2.9	2.8
Split	8.8	24.8	18.6	Stain	1.9	1.7	1.8
Puncture	17.5	6.5	10.7	Chipped grain	3.3	.3	1.4
Pitch pocket	10.2	9.1	9.5	Decay	.5	3.5	2.8

[1] Based on 1,435 specimens 1 by 8 inches in size, studied by the Forest Products Laboratory.
[2] The defects are defined in American lumber standards (28).

NATURAL DEFECTS

KNOTS

Knots in western larch, as in other species, are the most numerous and most important of the defects. They are characteristically small, and most of them are encased. Knot holes and decayed and loose knots are fewer in western larch than in most softwoods, but knot clusters are more frequent. (Pl. 5, B.)

The knots in western larch averaged smaller in size than in any other important commercial softwood studied. The average size

[8] American lumber standards (28) defines and classifies defects. The discussion of characteristics in this bulletin is based on those standard definitions.

of knot in the mill run of western larch was less than one-half inch in diameter. On an average there were about 12½ knots in each 1 by 8 inch by 12 foot board. Most of the knots were black, but only about 1 in 50 was loose or rotten. The small size of the knots was especially evident in the common grades, where the knots averaged only one-half inch in diameter. The knots in the larch-fir mixture were about the same size as those in western larch, but there were more of them. Southern yellow pine knots, on an average, were about twice as large as those in western larch, but there were only about one-third as many. In Douglas fir (coast type) the knots were somewhat larger than in western larch, and there were about half as many. The small size and high quality of the knots in western larch make the common grades of the species suitable for a large variety of uses.

SHAKE

Shake occurs in western larch lumber with about the same frequency that it does in northern white pine, redwood, and shortleaf pine. The practice of long butting is largely responsible for the small amount of shake found in lumber. Six and one-half per cent of the western larch boards studied contained shake. In the select grades three-fourths or more of the shake was fine[9] or small.[10] On the other hand, over half of the shake in No. 3 common was through.[11]

The larch-fir mixture had less shake than western larch because the Douglas fir ("Inland Empire" type) contained shake in only 4½ per cent of the boards studied.

PITCH POCKETS

The pitch pockets in the western larch studied were smaller and less numerous than in other resinous woods. On an average about 1 western larch board in 10 had a small [12] or medium [13] pitch pocket. There were practically no large pitch pockets. Douglas fir (coast type) averaged about one pitch pocket to every 4 boards, while the hard pines averaged a pitch pocket to about every 3 or 4½ boards, depending on the species. The true firs, hemlocks, and southern cypress have no pitch pockets. Douglas fir ("Inland Empire" type) had a pitch pocket in about every sixth board. The larch-fir mixture, therefore, had more pitch pockets than western larch but not so many as Douglas fir (coast type) or the hard pines.

PITCH

Pitch occurs in western larch with about the same frequency that it does in Douglas fir (coast type). The pines, as a group, contain more pitch. In the western larch studied, about 1 board in every 20 contained pitch. Pitch occurred more frequently in the select

---

[9] A fine shake is one with a barely perceptible opening.
[10] A small shake is one with an opening not over one thirty-second of an inch wide.
[11] A through shake is one extending from one surface through the piece to the opposite surface or adjoining surface.
[12] A small pitch pocket is not over one-eighth inch in width and not over 4 inches in length or not over one-fourth inch in width and not over 2 inches in length.
[13] A medium pitch pocket is one not over one-eighth inch in width and not over 8 inches in length or not over three-eighths inch in width and not over 4 inches in length

than in common grades. Where pitch occurred it was principally of the light [14] or medium [15] rather than of the heavy [16] or massed [17] variety. Only about 1 western larch board in each 150 contained heavy or massed pitch, and these were boards in the No. 3 Common grade. The larch-fir mixture contained more pitch than did the western larch. The difference, however, was small, for only about 1 Douglas fir ("Inland Empire" type) board in 13 contained pitch.

PITCH STREAKS

Very few pitch streaks are found in western larch, fewer in fact than in any of the softwoods that are subject to pitch. The results of a survey by the Forest Products Laboratory show about 1 western larch board in 40 contained a pitch streak and that about two-thirds of the pitch streaks were small.[18] Pitch streaks occurred about twice as frequently in Douglas fir ("Inland Empire" type) as in western larch. Other resinous woods, depending on species, contained from three to seven times as many pitch streaks as western larch.

DECAY

Western larch lumber has relatively little decay. Out of 1,435 western larch boards studied only about 1 in 35 showed decay. All of the decay was of the incipient [19] variety, except in No. 3 Common where about one-third of the decay was advanced.[20] About twice as much decay was found in the Douglas fir ("Inland Empire" type) lumber as in western larch lumber. This was true also of the hard pines, western hemlock, and white fir. Western yellow pine was the only important commercial softwood whose lumber, as shipped from the mill, showed less decay than western larch. The small amount of decay found in western larch lumber is indicative of the sound, vigorous nature of the timber.

SEASONING DEFECTS

Western larch has a high percentage of checks and splits and a low percentage of stain. The prevalence of these defects is a reflection of the high shrinkage, low-splitting resistance, and narrow sapwood ring of the species. The extent of these defects is determined partly by seasoning practices and is, therefore, subject to control. They nevertheless indicate a natural tendency of the species and the necessity for exercising special care in seasoning.

CHECKS

Checks are the most prevalent of the seasoning defects. Over half of the western larch boards examined showed checks. The percentage was higher than that shown by any of the other softwoods

[14] Light pitch is a slightly evident presence of pitch.
[15] Medium pitch is a slightly more evident trace of pitch than is the light.
[16] Heavy pitch is the very evident presence of pitch shown by its color and consistency.
[17] Massed is a clearly defined accumulation of solid pitch in a body by itself in a piece of lumber.
[18] A small pitch streak is one not over one-twelfth the width by one-sixth the length of the surface on which it occurs.
[19] Incipient decay is an early stage of decay in which disintegration has not proceeded far enough to soften or otherwise change the hardness of wood perceptibly.
[20] Advanced decay is the older stage of decay in which disintegration is readily recognized because the wood has become punky, soft, and spongy, stringy, ring shaped, pitted, or crumbly.

studied. Douglas fir ("Inland Empire" type) showed about three-fourths as much checking as western larch, while Douglas fir (coast type) and southern yellow pine showed only about one-third as much. About three-fourths of the checking was end checks. Small checks [21] came next in frequency.

SPLITS

Splitting is a common defect in western larch. The same properties that are responsible for the prevalence of checking are also responsible for the prevalence of splitting. About one in every five western larch boards examined was split. Except in No. 3 Common the splits were all short [22] or medium [23]. The larch-fir mixture showed slightly less splitting than western larch. With one exception the other species studied showed less splitting than western larch. Douglas fir (coast type) showed about two-fifths as much and western white pine about the same amount of splitting.

STAIN

The stain in western larch is practically negligible. The small amount (about 1 piece in 60) that does occur is of light [24] variety. Douglas fir ("Inland Empire" type) showed about twice as much stain as the western larch. Redwood and eastern hemlock showed about the same amount, and all other species studied showed considerably more.

MANUFACTURING DEFECTS

The occurrence of manufacturing defects is only slightly influenced by species properties or characteristics. Comparison of the occurrence of manufacturing defects in western larch with those in other species is, therefore, not warranted.

Torn grain occurs more frequently in western larch than any other manufacturing defect. It is usually the result of a tearing or chipping of grain on one side of a knot. Since knots are more numerous in western larch than in most softwoods, the amount of torn grain is greater.

Skips, burns, punctures, and scant boards occur in all grades but are relatively unimportant as compared with the natural and seasoning defects. The frequency with which they occur under present manufacturing practice is shown in the discussion of the grades. These defects reflect the care used in manufacturing rather than the species characteristics.

GRADES AND THEIR CHARACTERISTICS

Rules applying to the classification, manufacture, and grading of western larch are published by the Western Pine Manufacturers' Association (*42*). The grade names and the broad divisions into grades shown in the official rules are in accord with the American lumber standards (*28*). The sizes of the rough and dressed lumber also follow closely the American lumber standards. Variations from

---

[21] A small check is a perceptible opening not over 4 inches long.
[22] A short split is one whose length does not exceed either the width of the piece or one-sixth of its length.
[23] A medium split is one whose length exceeds the width but not one-sixth of the length.
[24] Light stain is a slight difference in color which will not materially impair the appearance of the piece if given a natural finish.

these standards are indicated in the grading rule books and are in all cases either slightly thicker or wider than the standards. According to the grading rules of the Western Pine Manufacturers' Association, Douglas fir ("Inland Empire" type) is considered of similar character and quality to western larch and is permitted in all grades of western larch.

The grading rules of the Western Pine Manufacturers' Association describe the grades by listing a number of typical examples under definitions that give the general characteristics of the grade. Written rules, however, have their limitations and can not cover all the possible types and variations to be found in the lumber of any grade. The examples given in the rule books do not, therefore, include all of the different types of boards to be found in a grade.

The description of grades given in this bulletin includes not only the limitations shown in the association rule book but also a detailed record of the defects found in the grade as marketed. This record presents the percentage of boards in which each defect was found. Since association grading rules are changed slightly from time to time, grade descriptions can not be considered unchangeable. Likewise the data on defects found in the grades are subject to change as a result of changes in grade descriptions, improved seasoning and dressing practice, and the collection of additional data.

GRADE YIELD AND PRODUCTION

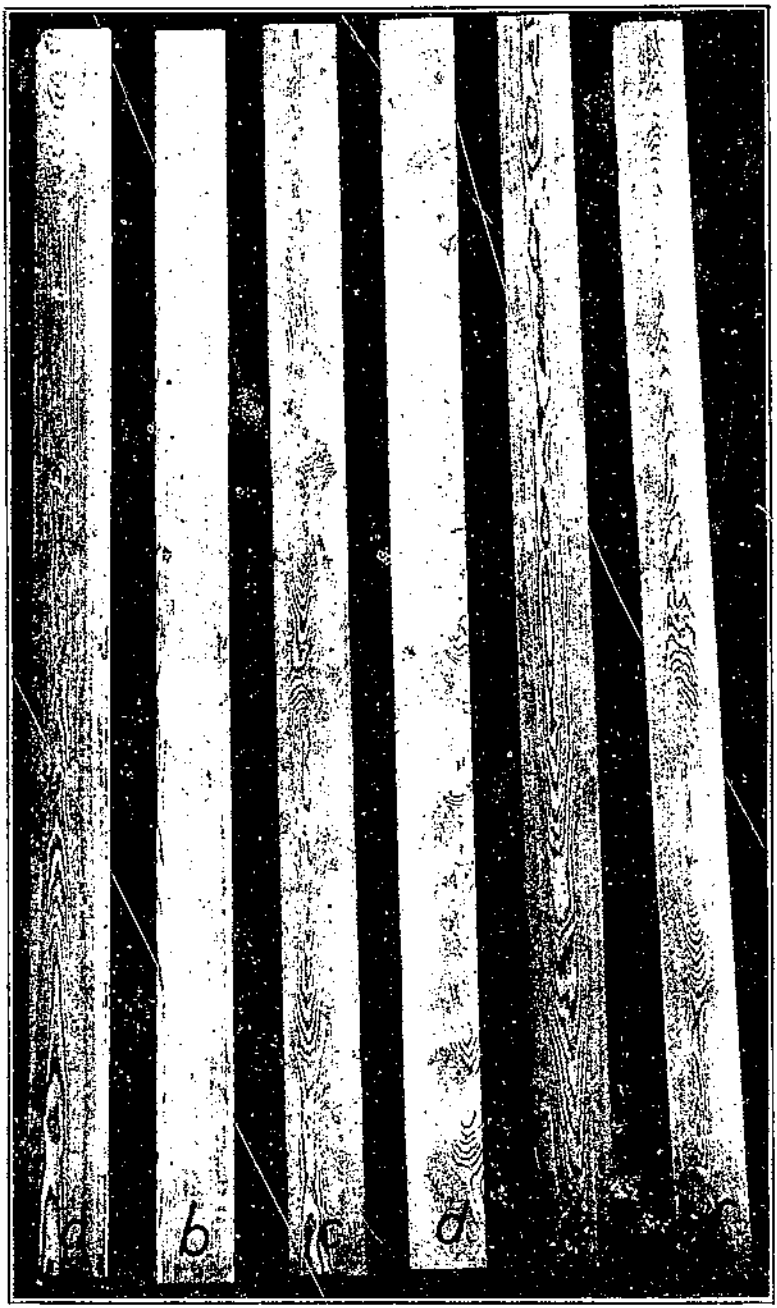
The standard grading rules of the Western Pine Manufacturers' Association list the following grades of larch-fir lumber: Selects—C and better, and D; Common—Nos. 1, 2, 3, 4, 5; Dimension and timbers—Nos. 1, 2, 3.

The proportion of each grade produced by the present-day methods of manufacturing western larch and Douglas fir ("Inland Empire" type) is presented in Table 8. The grade-production percentages, which are given separately for western larch and Douglas fir, were obtained by means of detailed mill-scale studies. The larch-fir grade production figures given in the last column of the table are based on average shipments of the Western Pine Manufacturers' Association during a 5-year period which included the year the mill-scale studies were made. These figures check closely with the average obtained from the mill-scale study. They differ, however, from the figures shown in Table 9 which were obtained at a later date and which show a decided increase in the percentage of selects produced. The percentage of grades produced differs considerably, of course, among mills due in part to the manufacturing policy, the market cut for, and the quality of the log run.

The Western Pine Manufacturers' Association's grade-production figures based on a 5-year average (1924 to 1928, inclusive) are shown in Table 9. It may be noted that a number of the separate grades as classified under the standard grading rules are combined in actual practice. In the select grades the recognized grades of C and Better and D Select are sometimes marketed as D and Better. Mill-scale studies show that this grade is about two-thirds D Select and one-third C and Better Select. In the common grades of larch-fir lumber the general practice is to market No. 1 and No. 2 Common together or to sell all the better grades of common as No. 3 Common and Bet-

M 2 E 30 F

A, The knots of western larch hold pretty well. The boards shown here have been exposed at Madison, Wis., about two years. Small cracks at the knots are the only evidence to indicate the presence of the knots in the seasoned boards. B, Checks in western larch boards. While not frequent in occurrence they occur more often in western larch than in other commercial softwoods



M12138F

Typical C and better western larch boards surfaced on two sides. The principal natural defects found in this grade are small or pin knots one-half inch or under in diameter and occasionally a small pitch pocket. The knots are tight, comparatively few in number, and scattered, as shown in *a*, *b*, and *c*. The grade contains a large proportion of boards like *d*, *e*, and *f*. The grain of *d*, *e*, and *f* is slightly raised, and *e* has a small puncture. Such boards give the grade, as a whole, a clear appearance. A single serious defect of any type is sufficient to prevent a board from entering the grade

ter. Mill-scale studies show that No. 2 Common and Better is practically a straight No. 2 grade with only an occasional No. 1 Common board. No. 3 and Better, however, is about one-half No. 3 Common and one-half Better. Table 9 shows also that certain classes of material have been separated from the regular recognized grade and sold as separate items. The marketing of timbers and planks as a separate class of material under the dimension group of grades is an example of this practice.

TABLE 8.—*Percentage of western larch and Douglas fir in larch-fir mixture*

Grade	Larch grade production by mills [1]					Average of all mills [1]		Western larch in mixture [2]	Douglas fir in mixture [2]	Average of all mills [1]	Larch-fir [3]
	Mill No. 1	Mill No. 2	Mill No. 3	Mill No. 4	Mill No. 5	Larch	Douglas fir			Larch-fir	
B and Better Selects	6.21					3.25	0.16	97.0	3.0	1.78	5.5
C Selects	.76	2.84	1.95		0.19	1.25	.13	94.0	6.0	.71	
D Selects	7.73	7.02	10.13	4.84	11.25	8.04	1.84	87.0	13.0	5.16	1.9
Total	14.70	9.86	12.08	4.84	11.44	12.54	2.13			7.65	7.4
Average								90.0	10.0		
No. 1 Common	.05		.03			.05	.02	79.0	21.0	.04	5.6
No. 2 Common	3.97	23.94	10.55	3.50	18.75	11.15	15.07	53.0	47.0	13.00	
No. 3 Common	9.22	18.38	8.67	2.96	18.79	12.40	15.59	54.0	46.0	13.94	19.2
No. 4 Common	1.01	4.88	4.16	.69	4.58	2.59	4.15	48.0	52.0	3.33	9.9
No. 5 Common	.13	.26	.09	.01	.17	.14	.23	48.0	52.0	.18	
Total	14.38	47.46	23.50	7.49	42.29	26.33	35.06			30.49	34.7
Average								53.0	47.0		
No. 1 Dimension and timbers	62.29	32.44	59.20	79.33	42.86	53.20	53.40	60.0	40.0	53.24	57.0
No. 2 Dimension and timbers	2.03	.04	3.90	7.11	3.33	2.01	2.45	55.0	45.0	2.26	
No. 3 Dimension and timbers	.09		.05	1.23	.08	.10	.18	45.0	55.0	.14	
Ties	6.47	10.20	1.27			5.77	6.74			6.22	
Total	70.88	42.68	64.42	87.67	46.27	61.11	62.80			61.86	57.0
Average								60.0	40.0		
Moldings	.01					.02	.01				.9
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00			100.00	100.00
Average								60.0	40.0		

[1] Based on a Forest Service mill-scale study.
[2] Based on percentage figures in columns 7 and 8 and on a mixture of 60 per cent larch and 40 per cent Douglas fir, which is the average ratio of the 10-year cut from 1919 to 1928.
[3] Based on shipments of the Western Pine Manufacturers' Association. Average over a 5-year period (1920-1924).

TABLE 9.—*Western larch grade production* [1]

(Basis 581,202,000 board feet)

Grade	Per cent	Per cent	Grade	Per cent	Per cent
No. 1 Dimension	35.6		No. 1 and 2 Common	2.7	
No. 2 Dimension	5.4		No. 3 and Better Common	5.1	
No. 3 Dimension	2.6	40.3	No. 3 Common	11.8	
Ties	1.1		No. 4 Common	8.6	30.5
Timbers and planks	4.6		No. 5 Common	.4	
C and Better Select	7.4		Short Common	1.0	
D and Better Select	.8		Select Common	.9	
D Select	2.2	10.6	Miscellaneous	9.6	9.6
Beveled siding					
Short selects	.2				

[1] Based on shipments of the Western Pine Manufacturers' Association. Average over a 5-year period (1924 to 1928, inclusive).

The combined grades of larch-fir give the consumer a high value. Western Pine Manufacturers' Association price figures, averaged over a 3-year period, 1926 to 1928, inclusive, show that D and Better grade sells for about $1.22 per thousand board feet less than it would if it were sold as two separate grades. The consumer, however, often can not or does not use the C and Better material in the combined grade to the best advantage. The practice of combining grades, therefore, tends to cause the consumer to use better grades than he requires, which is poor utilization. Manufacturers will eventually recognize that the combining of grades is not necessary in order to sell western larch and that they are losing money by it. The D and Better and No. 1 to 3 Common and Better combinations now so common on the market will, therefore, probably gradually be withdrawn.

HEARTWOOD CONTENT

Table 10 shows the heartwood content of each grade of western larch by classes. Very little western larch of any grade had less than three-fourths heartwood.

TABLE 10.—*Heartwood content of western larch boards*

Heartwood	Per cent of total number of boards of grade—			
	C and Better	D Select	No. 2 and Better	No. 3 Common
Per cent of cross section:				
0–54		0.4	1.0	0.4
55–64	1.1	.2	.5	1.5
65–74	1.5	.8	1.0	1.3
75–84	5.2	4.8	7.2	4.3
85–99	32.4	33.8	29.2	23.8
100	59.8	60.0	61.1	68.7
Total	100.0	100.0	100.0	100.0
Average heartwood	94.8	95.1	94.3	95.5
Basis.....boards	269	477	209	462

WIDTH OF RINGS

Table 11 shows the width of rings in each grade of western larch by classes.

TABLE 11.—*Width of ring in western larch boards*

Rings per inch (number)	Per cent of total number of pieces of grades—				
	C and Better	D Select	No. 2 and Better	No. 3 Common	All grades
4				0.2	0.1
5–6			0.5	1.5	.6
7–8			2.9	5.6	2.3
9–12	0.4	1.5	4.8	10.4	4.8
13–17	7.0	7.3	15.4	18.6	12.2
18–22	17.0	17.2	19.2	19.0	18.1
23+	75.6	74.0	57.2	44.7	61.9
Total	100.0	100.0	100.0	100.0	100.0
Average	27.2	26.9	24.1	21.6	24.7

GRADE DESCRIPTIONS

SELECT GRADES

The select grades for western larch listed in the grading rules of the Western Pine Manufacturers' Association include C and Better and D. Lumber of these grades has, as a whole, a good appearance and is suitable for both natural and paint finishes. Items, such as ceiling, flooring, partition, wainscoting, molding, window and door casings, window and door frames, and finish, are manufactured from these grades.

Mill-scale studies indicate (Table 8) that only about 12½ per cent of D and Better larch is actually produced. This is a rather low production in view of the fact that western larch is capable of producing a higher percentage of material in the select grades than any other tree species in the "Inland Empire" region. Well-informed lumbermen estimate that the usual run of western larch logs should yield 27 per cent of the D and Better product. One Canadian mill, which produces over 25,000,000 feet of western larch annually, reports a 30 per cent production of the select grades.

There are two reasons for the present small production of western larch select grades. The excellent qualities of the western larch select grades for flooring, ceiling, and interior finish have not been generally recognized, and the relatively small price spread between grades has led to the conclusion, as a rule without any definite basis, that it does not pay to use refined methods with western larch. Ordinarily the log is sawed to get out the C and Better product, and at some mills the D Selects, which naturally develop in cutting such a high-quality log, are saved. However, at a good many plants select stock of the D grade is mixed with the common grades and sold as No. 3 and Better or No. 2 and Better. Much of the D product of the log now goes into low-class products, such as dimension, timbers, and ties. Such practices keep down the mill-run value of the species and also greatly hinder the producer who is attempting to cut and market the maximum amount of the select grades. If one can buy a grade of No. 3 Common and Better and obtain a good percentage of D grade or purchase dimension of the D grade at a price slightly over that for the common dimension, it becomes difficult to market the grade of D Select, particularly at a reasonable price. Such manufacturing and selling evils are now common practice in the western larch trade and decrease the profits obtainable from this wood.

The selling of western larch and Douglas fir ("Inland Empire" type) lumber in mixture as a single product, larch-fir, has a very decided effect upon the selling value and marketing of the western larch select grades. The Western Pine Manufacturers' Association reports show (Table 8) the 5-year average yield of larch-fir selects to be about 7.5 per cent. This compares closely with the grade production figure of 7.6 per cent for the two species, which was obtained by intensive mill-scale studies. The mill-scale data in Table 8 give very positive proof that the larch-fir select grade problem is primarily a western larch problem. Of the D and Better larch-fir produced, about 90 per cent is western larch, while the C and Better grade is made up of almost 97 per cent western larch. The Douglas fir, particularly the sapwood, is different in color from the western larch

and mars the uniformity of appearance which is so important in flooring and finish where natural finishes are employed. Difference in hardness of species is also objectionable in these items. A few of the more progressive manufacturers are excluding all Douglas fir from the C and Better grade. Although there is but little western larch sapwood, it would be well to exclude it from the C and Better grade. (Pl. 6.)

In D Select grade for interior uses where a natural finish is customary, it would also be a decided trade advantage if all sapwood were excluded. Such a practice should be entirely feasible, since sapwood could go into D Select products for outside uses where paint conceals the contrasting color of the western larch heartwood and sapwood. A straight run of larch selects should, moreover, command a higher price than one which includes some fir.

C AND BETTER SELECT

According to the standard grading rules of the Western Pine Manufacturers' Association, C and Better larch consists of C and all the better products of the log. The grade permits only a limited amount of small defects or blemishes. Small knots, limited in number and well scattered over the piece, are permitted in practically all of the items manufactured. In the absence of such knots or where the knots are very few in number, such defects as slightly raised or torn grain, small season checks, and very small pitch pockets are permitted. A serious combination of the above defects will not be allowed in any one piece, nor any defect that will destroy the high quality and appearance of the grade.

The defects in the grade as marketed by five mills in 1928 are shown in Table 12. The defects were of such a size and character that they did not detract greatly from the appearance or utility of the boards.

TABLE 12.—*Character and occurrence of defects in western larch C and Better grade*[1]

Kind of defect	Frequency of occurrence	General character
	Per cent	
Check	39	Three-fourths are end checks, remainder small.
Knots	35	Average about one-fourth inch in diameter. Half black, all tight. Knots over one-half inch in diameter found in about 1 board in 30.
Puncture	16	Small. Made by peavies, pike poles, etc.
Pitch pockets	16	Two-thirds very small. Few medium. None large.
Torn grain	9	Slight.
Burns	6	
Pitch	5	All light.
Wane	4	
Skip	4	
Split	3	
Shake	2	Relatively unimportant. Occur in only occasional boards.
Bark pocket	2	
Stain	2	
Wormholes	1	

[1] Based on 272 specimens of western larch 1 by 8 inches in size, studied by the Forest Products Laboratory.

Common regional practice is to cut for C and Better western larch at the head saw. Of the total amount of select material cut from the average western larch log, 36 per cent is of C and Better grade.

A considerable portion of the stock of this grade is manufactured into flooring, ceiling, partition, siding, wainscoting, molding, and finish.

D SELECT

D Select grade includes all stock between C and Better and the common grades and will admit quite serious defects, if at the same time the piece retains a good appearance. (Pl. 7.) The D grade of western larch provides an excellent stock for paint finishes, but includes as well a fair percentage for interior uses where a natural finish is customary. In this grade one cut is allowed in pieces 12 feet or longer if the resultant waste does not exceed 4 inches, provided the piece is otherwise better than average. Fine season checks over the entire face or several larger season checks are admitted in the D Select grade, as well as numerous small knots, pitch pockets, raised and torn grain or other defects common to western larch and Douglas fir that do not give a course or common appearance to the piece.

The defects in the grade as marketed in 1928 are shown in Table 13.

TABLE 13.—*Character and occurrence of defects in western larch D Select grade* [1]

Kind of defect	Frequency of occurrence	General character
	Per cent	
Knots	68	Average diameter one-third inch. Average number to board, two. All but few encased or partly encased. About 1 in 60 loose. Knots over 1 inch in diameter found in 1 board in 30.
Checks	60	Over one-half end checks. One-third small. Large checks rare. None through.
Torn grain	23	Responsible for some boards being in grade.
Puncture	18	About same as C grade. Seldom influenced grade.
Splits	11	Three-fourths short, balance medium.
Pitch	10	Seven-eighths light. One board in 100 contained medium.
Pitch pockets	10	One-half small. Two-fifths very small. Medium or large in 1 board in 75.
Skip	7	Occasional. Responsible for some boards in grade.
Burn	9	
Wane	6	
Pitch streak	3	Rare. Relatively unimportant.
Shake	3	
Wormhole	2	
Stain	2	
Bark pocket	1	
Decay	1	

[1] Based on 481 specimens of western larch 1 by 8 inches in size studied by the Forest Products Laboratory.

Practically all defects occur more frequently and in worse form in the D Select grade than in the C and Better grade. Knots and checks are about twice as frequent and are larger in D Select than in the C and Better grade. In addition the D Select grade differs from the C grade in that it contains boards with a serious defect which requires cutting.

In cutting for C and Better western larch at the head saw, some D Select naturally develops. This stock may or may not be utilized in the select grades. Entirely too large a proportion of the D Select grade is now put into dimension, timbers, and ties. Mill-scale studies show that approximately 64 per cent of the select material produced from the average run of larch logs is of the D Select grade.

COMMON GRADES

The standard grading rules of the Western Pine Manufacturers' Association provide that western larch common grades shall carry the same appearance, grade for grade, in the general measurement of defects as western yellow (Pondosa) pine. The rules, therefore, include specifications for No. 1, No. 2, No. 3, No. 4, and No. 5 Common boards. The characteristics of western larch common grades as distinguished from the select grades are a general coarseness of appearance caused by various defects in a greater or less degree according to grade. The numerous defects and blemishes that common western larch lumber may contain preclude its use for finishing purposes. Common lumber of western larch is suitable for general utility and construction purposes.

The following grades of common western larch lumber are available on the market: Select Common, No. 1 and 2 Common, No. 3 and Better Common, No. 3 Common, No. 4 Common, and No. 5 Common.

Douglas fir ("Inland Empire" type) is permitted in all grades of western larch. The Douglas fir ("Inland Empire" type), which is generally of poorer quality than the western larch, produces considerably more stock of the grades of common lumber and dimension. Mill-scale studies (Table 8) show that Douglas fir produces 35 per cent of its lumber in the common grades, as compared with 26 per cent for western larch. Larch-fir common lumber, however, contains about the same amount of each species.

NO. 1 COMMON

Mill studies have shown (Table 8) that only one two-thousandths or one-twentieth of 1 per cent of the western larch cut falls into the grade of No. 1 Common. No. 1 Common western larch is usually combined with No. 2 Common and sold as No. 1 and 2 Common. This grade is suitable for shelving, cornice, fine barn board, and all uses where best quality and appearance of common lumber are required.

No. 1 Common western larch boards and strips include all sound, tight-knotted stock with the size of the knot the determining factor of the grade. Knots, light pitch, season checks, and small pitch pockets are admissible in No. 1 Common grade if they do not affect the general utility of the piece in which they occur. So small is the percentage of No. 1 Common produced in western larch that no study was made of the characteristic defects of the species in this grade.

NO. 2 COMMON

Eleven per cent of the cut of the average western larch log falls into the grade of No. 2 Common. This grade averages approximately 42 per cent of the total cut of common western larch lumber. In practice No. 2 Common western larch is sold in mixture with No. 1 Common and ordinarily makes up the bulk (99 per cent) of the grade. (Pl. 8.)

No. 2 Common western larch is subject to the same inspection as No. 1 Common except that coarser and larger knots not necessarily sound, or their equivalent, form the basis of inspection. Some of the most common types of knots admissible in this grade are large

knots, branch knots, checked knots and those not firmly set in the piece. Other defects permitted in the grade are season checks, heart shake, pitch, and pitch pockets. No serious combination of the above defects is admissible in any one piece.

No. 1 and No. 2 Common were combined in the study of the characteristic defects. The defects shown by these combined grades sold as No. 2 and Better are shown in Table 14.

TABLE 14.—*Character and occurrence of defects in No. 2 Common and Better western larch*[1]

Kind of defect	Frequency of occurrence	General character
	Per cent	
Knots	91	Average diameter one-half inch. Average number to board, 13. 93 per cent 1 inch or less in diameter. About one-third are intergrown. Loose knots occur in about 1 board in 6.
Checks	69	Four-fifths end checks, rest small and medium.
Splits	13	One-third short and two-thirds medium.
Pitch pockets	10	Four-fifths very small. Remainder small or medium. None large.
Torn grain	8	Unimportant in determining grade.
Burn	8	Do.
Shake	7	One-half small. 1 board in 70 contains through shake.
Skip	6	
Puncture	5	Small.
Wane	5	
Pitch streaks	4	Two-thirds small. One-third medium. None large.
Wormholes	4	Small and scattered.
Decay	1	Rare. Relatively unimportant.
Pitch	1	

[1] Based on 211 specimens of western larch 1 by 8 inches in size studied by the Forest Products Laboratory.

No. 2 Common grade differs from the select grades principally in size and number of natural defects. Natural defects, except wane and pitch defects, are larger and more numerous in No. 2 Common than in the select grades. Manufacturing defects are about as frequent in the No. 2 Common grade as in the select grades. Punctures are less frequent in No. 2 Common than in the select grades because the boards forming the grade come from nearer the pith of the tree. Seasoning defects are somewhat more frequent and injurious in No. 2 Common than in the D Select grade.

No. 2 Common and Better is of a character that fits it for doors, flooring, partition, molding, siding, sheathing, subflooring, and roofing.

NO. 3 COMMON

The grade of No. 3 Common western larch comprises much of the lower product of the log. Although the appearance of a part of the stock is coarse, it is a good general utility grade having a wide variety of uses. (Pl. 9.) No. 3 Common makes up approximately 47 per cent of all the common lumber cut from the average western larch log. Seventy per cent of the No. 3 Common western larch produced is sold separately under that grade name. The remainder is sold in combination with No. 1 and No. 2 Common as No. 3 and Better Common.

Some of the defects permitted in the No. 3 Common grade are large, loose, or unsound knots, large spike knots, occasional knot holes, season checks, skips and roller splits, some red rot, and con-

siderable heart shake. A serious combination of the above defects is not admissible in any one piece. The defects found in the grade as marketed are shown in Table 15.

TABLE 15.—*Character and occurrence of defects in No. 3 Common western larch*[1]

Kind of defect	Frequency of occurrence	General character
	Per cent	
Knots	98	Average diameter one-half inch. Average number to board, 17. Ninety per cent 1 inch or less in diameter. Few black. One loose knot in every two boards.
Checks	69	Two-thirds end, one-fourth small or medium. One board in 18 has through check.
Splits	30	About equally divided between short and medium. One board in 37 has long.
Torn grain	25	Unimportant in determining grade.
Wane	11	
Pitch pockets	9	About two-thirds are very small. One-third small. About 1 board in 300 contains large pitch pockets.
Pith	9	
Skip	9	
Shake	8	Over half through, one-third fine or small.
Burn	8	
Puncture	7	
Pitch	6	One-half light, one-third medium. About 1 board in 150 has heavy or massed pitch.
Seam	6	
Decay	4	Two-thirds incipient, one-third advanced.
Pitch streak	3	
Pitch seam	3	
Wormholes	2	Rare. Relatively unimportant.
Bark pockets	2	
Stain	1	

[1] Based on 408 specimens of western larch 1 by 8 inches in size studied by the Forest Products Laboratory.

All natural defects, except various pitch defects, are more frequent in the No. 3 Common than in No. 2 Common. The size of defects in No. 3 Common does not differ greatly from that of No. 2 and Better, but defects are generally of lower quality. Manufacturing defects, except torn grain, occur with about the same frequency in No. 3 Common as in No. 2 and Better. Of the seasoning defects, checking is about the same in No. 3 Common as in No. 2 and Better, but the splits are more than twice as common and are larger in the No. 3 Common.

No. 3 Common western larch is used extensively as siding, flooring, partition, sheathing, subflooring, roofing, concrete forms, scaffolding, plaster grounds, and boxes.

NO. 4 AND NO. 5 COMMON

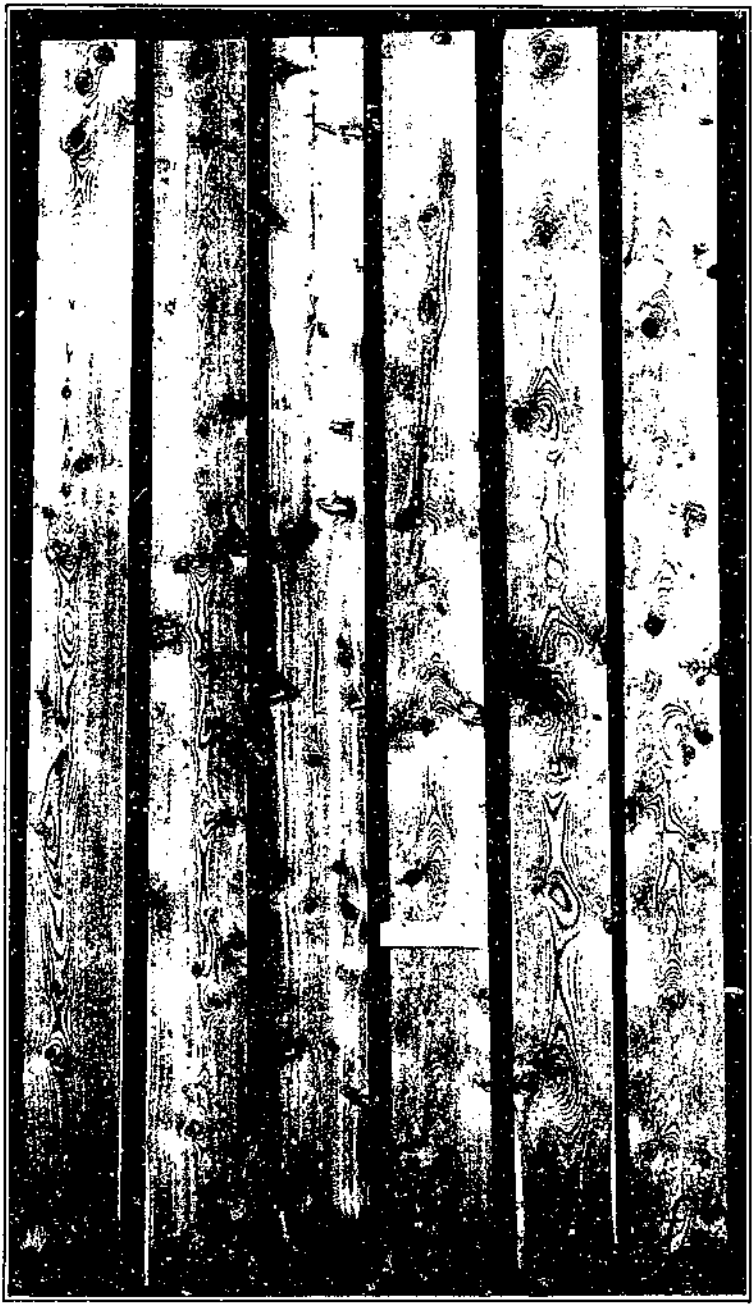
The defects common to No. 4 Common grade are much the same as those found in No. 3 Common, but exist in more serious combination or to a greater degree. (Pl. 10.) Approximately 10 per cent of the total cut of western larch common falls within the No. 4 Common grade.

No. 5 Common is the lowest recognized grade and admits all defects known in lumber, provided the piece is strong enough to hold together when carefully handled. Highly defective western larch or Douglas fir ("Inland Empire" type) trees are seldom cut in the woods; consequently not many greatly defective logs ever reach the mill. The cut of No. 5 Common larch-fir is less than 1 per cent

Typical D select western larch board surfaced on two sides. Board *a* has a combination of knots and raised grain; *b* has a knot, bark pocket, and checks; *c* has intergrown knots over one-half inch diameter and black incased knots under one-half inch; and *d* has six black incased knots under one-half inch and a mechine gouge. Boards *e* and *f* have loose knots which can be cut out and thus give two practically clear pieces.

M 21987 F

Typical No. 1 and 2 Common or No. 2 and Better Common western larch boards. The knots are all tight, but not necessarily sound. Boards *a* and *b* have numerous black incased knots, all tight and under 1 inch in diameter; *c* and *d* have numerous intergrown or partially intergrown knots under 2 inches in diameter and also a few small, tight, incased knots under 1 inch in diameter; *e* has only a few incased knots, but some are 1 inch or larger in diameter and though tight may loosen under adverse conditions; *f* has small intergrown knots under one-half inch in diameter and intergrown and partially intergrown spike knots. Board *f* is typical of the western larch boards obtained from near the pith of the log



M 12135 F

Typical No. 3 Common western larch boards surfaced on two sides. Planer checks, loose, broken, and black knots, and torn grain around knots are defects most commonly found in this grade. Occasionally boards contain a knot hole. The knots in boards *a*, *b*, and *c*, are all tight, but are over 2 inches in diameter and are either checked through or broken. Boards *d*, *e*, and *f* have fewer knots than boards *a*, *b*, and *c* but the knots are of poorer quality. In addition, *e* has knot holes and through checks, and *f* has a through puncture

M 27487 F

Typical No. 4 Common western larch boards surfaced on two sides. Boards *a* and *c* are in the grade because of serious seasoning or planer checking. The knots are small and tight. Boards *b*, *d*, and *e* are in grade because of holes or the size or quality of the knots. The knots are large, loose, decayed, or broken. Board *f* contains serious check combined with large knots. Boards containing decay are also found in this grade

of the total common lumber of these species produced. No study was made of the defects in No. 4 or No. 5 Common western larch, as the value of these grades and the type of uses to which they are put are such that a detailed study of their defects is not warranted.

DIMENSION AND TIMBER GRADES

The dimension and timber grades from a quantitative standpoint are the most important grades applicable to the larch-fir mixture. Sixty-one per cent of the cut of the average western larch log goes into dimension, timbers, and ties. Sawed railroad ties make up approximately 6 per cent of the total western larch cut for the dimension and timber grades. Western larch and Douglas fir are considered excellent material for construction and heavy-duty stock, and it is for this reason that such a high percentage of the cut goes into the dimension grades. The fact that No. 1 larch-fir dimension has a selling value almost equal to that of the very best grades of common lumber is another reason for its large production. At present a good percentage of the product of the log that should be in the D grade is put into dimension, timber, and ties.

Three grades of dimension and timber are recognized under the standard grading rules of the Western Pine Manufacturers' Association: namely, No. 1, No. 2, and No. 3 Dimension and No. 1 and No. 2 Timbers. Sales of ties and timbers and planks are often made separately.

The dimension and timber grades do not specifically limit defects injurious to the strength; consequently the strength of material in these grades depends almost entirely upon the judgment of the graders, which varies considerably. Timbers of the foregoing grades, therefore, show such a wide range of strength that it is impracticable to assign safe working stresses to the grades; however, the Western Pine Manufacturers' Association have recently prepared structural grades for Douglas fir and western larch that do limit the defects. These new grades conform to the basic requirements for structural material of the American lumber standards and, although not commonly carried in stock by mills, may be had on special order.

NO. 1 DIMENSION AND TIMBERS

A mill-scale study showed that 96 per cent of the larch-fir dimension and timbers produced is of the No. 1 grade. The specifications of the No. 1 grade are therefore the most important of dimension and timber grades.

The rules of the Western Pine Manufacturers' Association specify that No. 1 Dimension and Timbers must be of a good sound character but will admit of defects that do not impair the strength of the piece. On the basis of a 2 by 4 inch piece, wane on edge is admissable one-half inch deep for half of the length, or a proportionate amount for a shorter distance on both edges. In any case, one side and two edges should allow a good nailing surface. "Small dimension must be moderately straight, and larger dimension must be more so. A few wormholes are admissable."

The strength of material of the grade will vary widely, both because of mixture of species and because there are no specific limi-

tations of defects injurious to strength. It can be used to advantage where the user has widely varying strength requirements and can sort the material into strength classes. Such a sorting or regrading can be made with the aid of the basic provisions of the American lumber standards for structural material (*28*).

No. 1 Dimension can not be recommended for uses where uniformly high strength is essential because of uncertainty as to strength of the weaker pieces. The working stresses recommended for western larch on page 60 are only applicable when the material has been regraded to meet the American lumber standards basic provisions for select and common grades.

NO. 2 DIMENSION AND TIMBERS

Less than 4 per cent of the dimension and timbers produced from the average western larch log is of the No. 2 Dimension grade. Under the rules of the Western Pine Manufacturers' Association material of this grade will "admit of large, coarse knots, not necessarily sound, considerable wane, also shake, wormholes, dozy streaks, crooked pieces or other defects which weaken or impair the pieces to such an extent as to render it unfit for No. 1 grade. A serious combination of these defects is not admissible in any one piece."

The decay streaks and unsound knots admissible in the grade may reduce the strength to less than half that of clear wood. Timbers and dimensions of this grade are therefore not suitable for use where great strength is desired. They are used for temporary structures and where stiffness rather than bending strength is desired. Even in such structures the pieces containing decay should be sorted out and used where strength is relatively unimportant.

NO. 3 DIMENSION AND TIMBERS

Only about one-quarter of 1 per cent of the western larch dimension and timbers produced are of the No. 3 grade. The rules of the Western Pine Manufacturers' Association "admit a great deal of rot and all the imperfections allowed in No. 1 and No. 2, but in a much more pronounced form." The grade is suitable for use only where strength requirements are of practically no importance or where the material is cut to short lengths and the more injurious defects eliminated.

WORKING STRESSES FOR DIMENSION AND TIMBER

Working stresses are assigned strength values used to determine the safe load-carrying capacity of timbers or the size and number of timbers necessary to safely carry a given load. They are intended primarily for use in design of structures and are therefore a basic limitation imposed by building codes or other engineering specifications.

The working stresses shown in Table 16 were obtained by adjusting the strength of the clear wood to meet conditions which exist in service (*18*). Such adjustment is made to take care of the reduction in strength due to the knots and other defects permitted by the grade specifications, the occurrence of pieces below the average strength, the lower strength shown by wood subjected to long-time loads from that shown by test specimens which are loaded only a

few minutes, and the weakening effect of certain species characteristics. In addition the working stresses in Table 16 provide for a factor of safety (*37*) to take care of accidental overloads up to one and one-half times the design load. The adjustment for the injurious effect of defects of necessity limits the application of working stresses to a specific grade of a species except in the case of modulus of elasticity and compression perpendicular to the grain, which are not seriously affected by defects. Values for these two properties are therefore applicable to all grades.

A comparison of western larch with other species based on the working stresses will differ from a comparison based on the strength of clear wood. This is due primarily to the fact that the strength values for clear wood are an average obtained from tests, whereas working stresses are based on engineering judgment, which takes into consideration not only the strength of the clear wood but also species characteristics, characteristic defects, results of tests on structural sizes, and all other available data.

The working stresses for western larch are conservative; that is, they are lower than would appear necessary for the strength shown by the clear wood. The comparatively low values assigned to some of the properties for western larch in Table 16 are due to results obtained in tests of structural timbers (*9*, *11*).

The working stresses of Table 16 are applicable only to timbers graded in accordance with the basic requirements of American lumber standards for structural material (*28*). The dimension and timber grades of western larch previously discussed do not meet these requirements. It is possible, however, to use the working stresses recommended in Table 16 with timbers purchased on special orders provided the specifications embody the basic principles for structural material of American lumber standards (*28*). American lumber standards provide structural-grade examples which make it easy to prepare such specifications. The application of the working stresses to dimensions or to stock timber of the Western Pine Manufacturers' Association grades (*32*) requires regrading. Such a regrading is not difficult to accomplish with the aid of structural-grade examples (*28*) and will result in all but a small percentage of timber falling into one of two grades. Timbers falling outside these grades can be used where great strength is not essential.

The working stresses recommended for western larch can not be safely used in all cases with the larch-fir mixture. The stiffness of western larch and Douglas fir ("Inland Empire" type) is practically the same, and the modulus of elasticity values in the last column of Table 16 can be safely used with the larch-fir mixture. Likewise, the working stresses for western larch under the heading, Fiber Stress in Bending, can be used for the larch-fir mixture because of the conservative nature of fiber stress in bending values for western larch. Working stresses for western larch in horizontal shear and compression parallel and perpendicular to the grain are not applicable to the larch-fir mixture. The values recommended for Douglas fir (Rocky Mountain type) rather than those for western larch must be used with larch-fir. The difference in the values recommended for western larch and Douglas fir (Rocky Mountain type) in compression and shear is sufficiently large to justify a separation of the species in most cases.

TABLE 16.—*Working stresses, in pounds per square inch, for select and common grades of timber conforming to the American lumber standards basic provisions for structural material* [1]

(As recommended by the Forests Products Laboratory)

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] (not varied with conditions of exposure or with grade)
	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		
	All thicknesses		Material 4 inches and thinner		Material 5 inches and thicker		Material 4 inches and thinner		Material 5 inches and thicker													
	Select	Common	Select	Common	Select	Common	Select	Common	Select	Common	Select and common			Select	Common	Select	Common	Select	Common	Select	Common	
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	300	225	200	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	1,049	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	700	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	1,200,000
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	863	710	600	800	640	300	175	150	85	68	800	640	800	640	700	560	1,200,000
Poplar, yellow	1,000	800	800	630	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	550	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 in Simplified Practice Recommendation 16 (*28*); specifications for grades conforming to American lumber standards are published in the 1927 standards of the American Society for Testing Materials, and in American Railway Engineering Association Bulletin 284 (*2*).

[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 (*28*).

[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.

USES OF WESTERN LARCH

Western larch is an excellent general-utility wood. It is one of the strongest and hardest of our native softwoods; it has good decay-resistance and nail-holding power; the annual-growth rings are narrow and of uniform width; it glues well; it has a pronounced figure and can be given natural, polished, or paint finishes. On the other hand, certain of its properties, such as strength, nail-holding power, slow response to moisture changes, and its narrow and uniform width of annual-growth rings are sufficiently outstanding to warrant its consideration for special uses that require exceptional combinations of properties and characteristics. Primarily, western larch is a general-use wood, but a portion, possibly a selected portion, of the cut should be marketed as a specialty wood.

The suitability of western larch for any use must be determined largely from a comparison of its properties with the requirements of the use under consideration. Information on the properties of western larch is comprehensive and fairly complete. Information on use requirements, however, is in most cases based on observation and experience rather than on the results of laboratory or service tests. Complete information on use requirements will never be available because the uses are too numerous. Furthermore, the requirements of common and typical uses will vary enough with time and conditions to change the order of importance of the properties, if not to change entirely the actual properties required.

The discussions of uses of western larch in this bulletin are examples intended to illustrate how the data on the properties of western larch can be applied to determine the suitability of the wood for a use. The uses dealt with have been selected because of the amount of lumber consumed by them, the amount of western larch consumed by them, or because a study of properties and requirements indicates a possible market for western larch.

Table 17 is a list of some of the uses to which western larch and larch-fir commonly is put. The general grade or quality of material usually purchased for the various uses is also shown. The list is of interest principally as an indication of present practice, and it is not intended to imply that western larch is the best wood available for the various uses listed. In many cases several grades of material are shown to be employed in a single use. This apparent lack of definite grade requirements is due in part to different grades being required for different parts, but more generally to the range in the quality of the finished products and to differences in design influencing the grade requirements.

BUILDING MATERIAL

The properties of western larch adapt it for use in practically all the wood items used in buildings; consequently the bulk of western larch cut goes into building material. The properties that especially adapt western larch for building material are strength, decay resistance, and nail-holding power. Western larch is especially suited to those building material items for which it is impossible to predict the use requirements or conditions at the time of purchase. For example 8/4-inch dimension may be used for rafters, headers,

studding, or joists where bending strength, stiffness, and nail-holding power are desired but decay resistance is of little importance, or it may serve for sills or floor boards, which have some decay hazard. In adaptability to a wide range of building items western larch is similar to Douglas fir (all types) and southern yellow pine. The larch-fir mixture is not quite so adaptable for building items as western larch.

TABLE 17.—*Grade or form of western larch purchased for various uses*

Use	Grade		Form		Use	Grade		Form	
	Select	Common	Dimension, planks or timbers	Round, hewed, or split		Select	Common	Dimension, planks or timbers	Round, hewed, or split
Casings (window and door)	X				Poles and piling				X
Ceiling	X	X	X		Posts			X	X
Doors	X	X			Shelving		X		
Flooring	X	X			Snow fencing		X		
Frames (window and door)	X				Crossties			X	X
Partition	X	X			Well curbing		X	X	
Moldings and finish	X	X			Box crating		X	X	
Siding	X	X			Car construction	X	X	X	
Wainscoting	X				Caskets and coffin boxes	X	X		
Posts, girders, mud sills, stringers			X		Cooperage	X	X		
Planking, bracing			X		Electric machinery and appliances	X	X		
Bridge ties			X		Farm implements	X	X		
Joists, studding, rafters			X		Furniture and fixtures	X	X		
Sheathing, subflooring, roofing		X			Incubators and brooders	X	X		
Concrete forms, scaffolding		X	X		Refrigerators	X	X	X	
Plaster grounds lath		X			Screens (windows and doors)	X			
Corn cribbing			X		Signs		X	X	
Cross arms			X		Tanks and water troughs		X		
Culverts			X		Vehicles (wagon and automobile)	X	X		
Flumes and conduits			X		Wood-block paving			X	
Gates and fences		X	X		Woodenware	X	X		
Grain doors		X							
Mine timbers				X					

COMMON BOARDS AND SHIP-LAP

Common boards and ship-lap are not manufactured for a specific use. Not only are they used for a number of purposes in building, but they also go into a wide variety of other uses. Common boards and ship-lap are therefore general-utility items for which the strength, decay resistance, and nail-holding ability of western larch are especially adapted. Western larch boards can be used for concrete forms where strength is required, for roofing boards where strength and nail-holding power are required, and for drip boards, where some decay resistance is required.

About one-fourth of the cut of western larch and one-third of the cut of Douglas fir (Inland Empire type) go into common boards and ship-lap. Less than one-half of 1 per cent are of No. 1 Common grade. The bulk of the common boards and ship-lap is sold as No. 2 Common and No. 3 Common, or as No. 3 and Better. Some boards, about 1 per cent, are sold as No. 4 and No. 5 Common. Western larch common boards usually range from 4 to 10 inches in

width; a few boards, less than one-half of 1 per cent, are 12 inches or more in width.

Boards and ship-lap of the less decay resistant, lighter weight and weaker species have some advantage for certain uses over western larch. They are easier to cut, saw, nail, and handle, and hold paint better. When the final use can be anticipated before purchase these properties should be weighted against the greater strength, moderate decay resistance, hardness, and nail-holding power of western larch. The following discussion of individual uses of boards shows how the properties can be used in comparisons for specific rather than general uses.

SUBFLOORS

A number of species, including western larch, are successfully used for subfloors. This is due to the facts that under standard methods of construction there is little danger of floors failing mechanically and that the decay hazard is small. Western larch subfloors are very similar in ease of construction and serviceability to those of Douglas fir and southern yellow pine. Western larch subfloors are stronger and stiffer and hold nails better than those of the hemlocks, spruces, or true firs. On the other hand, western larch subfloors require more time to construct than hemlock, spruce, and true fir subfloors, which are softer and lighter species and consequently easier to work and handle. The lighter-weight species also stay in place better than western larch principally because of their smaller shrinkage. The moderate decay resistance of western larch, however, is some protection against decay hazards resulting from faulty plumbing, drip from ice-boxes, and other sources of moisture.

SHEATHING

Large amounts of western larch, especially of the No. 3 Common and Better grade, are used for sheathing. Where western larch is used for sheathing it is primarily because of the small size and tightness of the knots rather than because of the properties of the clear wood. The strength and moderate decay resistance of western larch are of little practical importance in sheathing, for the efficiency with which sheathing ties members into units depends upon nailing rather than the strength of the wood, and sheathing is so protected that it seldom decays. Capacity to stay in place is desirable to reduce to a minimum the passage of air and heat through cracks. Ease of working is desirable in that it speeds up and reduces the cost of construction. Tendency for cracks to open, however, is dependent more on the thoroughness of seasoning than on the capacity of species to stay to place. Ease of working influences cost but not service. Comparison of western larch with other species for sheathing should therefore be made largely on how well wood stays in place, tightness of knots, thoroughness of seasoning, and cost after adjusting for differences in ease of working.

ROOFING BOARDS

Western larch has a good combination of the properties desired for roofing boards. It will hold shingles or other roofing well, for it has a high nail-holding power and retains its nail-holding power

well with moisture changes. (Fig. 19.) Of the softwoods commonly used for roofing boards, only Douglas fir and southern yellow pine are stiffer than western larch. The moderate decay resistance of western larch, which is a desirable property should leaks develop, is about the same as that of Douglas fir. The tendency of western larch to split under roofing nails is slightly less than with Douglas fir. In ease of working, western larch is similar to Douglas fir and southern yellow pine but is harder to cut, saw, and nail than the hemlocks, true firs, and spruces.

Western larch roofing boards are obtained almost entirely from the No. 2 Common and No. 3 Common grades, which are always a larch-fir mixture. Roofing boards of larch-fir mixture are not equal to those of western larch alone. While they have the same stiffness they are slightly weaker in bending, contain more sapwood, and have a wider range in hardness. The difference in value, however, would probably not justify the cost of separating the species.

In so far as properties are concerned, there is little choice between larch-fir roofing boards and those of Douglas fir and southern yellow pine. As between larch-fir and the spruces, hemlocks, and true firs, the larch-fir roofing boards hold nails better, are stiffer, and more decay resistant, but are heavier and harder to cut, saw, and handle.

MISCELLANEOUS FARM USES

Western larch is a good general-utility wood; consequently the boards and ship-lap of the species have a wide range of usefulness on the farm. The hardness and strength of western larch boards adapt them to the heavy loads and rough usage to which the floors of many farm buildings are subjected, and their moderate decay resistance enables them to be used in pens, coops, troughs, and cribs that are subject to moderate decay hazards. The range of use of western larch boards is very similar to that of Douglas fir (coast type) and southern yellow pine; it is not so wide as that of southern cypress, but is wider than those of the true firs, hemlocks, and spruces. Because of paint-holding characteristics, ease of working, and light weight, the true firs, hemlocks, and spruces require less painting maintenance than western larch.

The larch-fir mixture does not have so wide a range of usefulness as western larch because of the higher percentage of nondurable sapwood in the Douglas fir ("Inland Empire" type). Boards with a high percentage of sapwood should not be used where there is a decay hazard. If the difference in the hardness of the two species in the larch-fir mixture is objectionable (p. 24), the Douglas fir can be separated from western larch.

DIMENSION

Dimension is used for many purposes in building construction. Joists, studding, stringers, planks, rafters, scaffolding, sills, and bracing are some of the more important uses of dimension. Each of these uses requires a different combination of properties. There are few softwoods that meet the requirements of all the uses of dimension as well as western larch. As a result over half the cut of western larch and Douglas fir ("Inland Empire" type) go into dimension.

Over 95 per cent of the larch-fir dimension is of the No. 1 Dimension and Timber grade. A small amount of No. 2 Dimension is manufactured, and practically no No. 3. The bulk of the larch-fir dimension is nominally 2 inches thick and from 4 to 12 inches wide. (Fig. 24.) Stock 3 and 4 inches thick and some stock wider than 12 inches, however, is available. Sixteen feet is the usual length; however, shorter lengths are available as a result of trimming. Long lengths of 20 feet and over are not readily available, although there is a demand for such lengths in some cities and they can be produced from western larch trees.

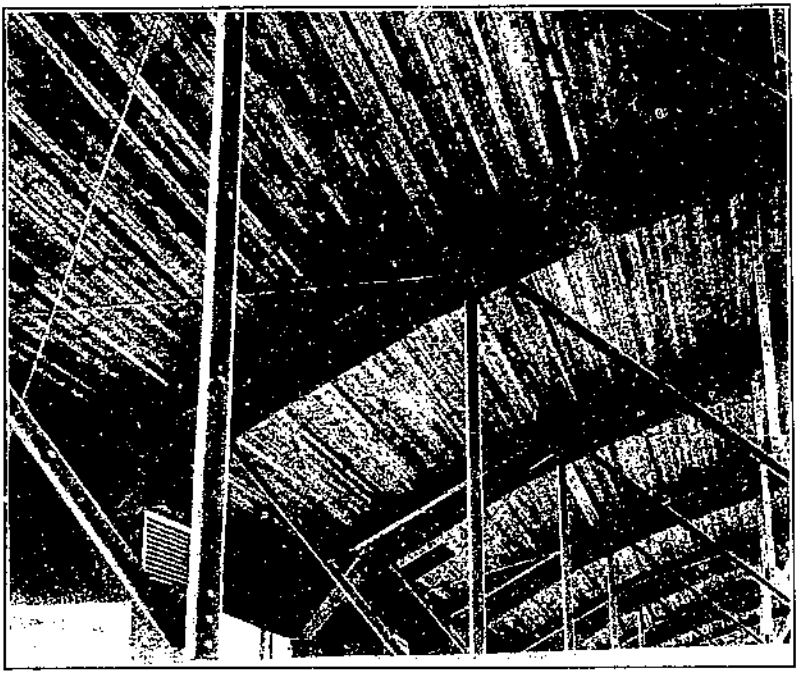


FIGURE 24.—Gymnasium roof made of western larch 2 by 4-inch dimension on edge. The strength and nail-holding power of western larch well adapt it to this type of use

High nail-holding power is a common requirement in practically all uses of dimension. It is desired to hold sheathing, flooring, or other covering to the framing. Light weight and ease of working, which facilitate fabrication, are also universally desirable properties in all uses of dimension. Stiffness is the most important strength property in many items of dimension, especially in 2-inch stock. In stock thicker than 2 inches bending strength usually replaces stiffness as the most important strength property. Comparison of western larch with other species in any of the foregoing properties, except ease of working, can be made from Table 4. Such a comparison justifies the previously made statement that few softwoods meet all of the use requirements of dimension as well as western larch.

The larch-fir mixture does not have so favorable a combination of properties for dimension as western larch. This is because the

Douglas fir ("Inland Empire" type) in the mixture has a lower nail holding power and a lower bending strength than the western larch. The stiffness of two species in the mixture is practically the same. The larch-fir dimension consists of about three parts of western larch to two parts of Douglas fir ("Inland Empire" type). (Table 8.)

JOISTS AND STUDS

From a utility standpoint stiffness and nail-holding power are the important properties in joists and studs. Stiffness is desired of joists and studs in house construction because the amount of deflection that can occur without damage to the plaster is small. Nail-holding power is desired to hold flooring, siding, sheathing, and lath in place. In stiffness and nail-holding power, western larch

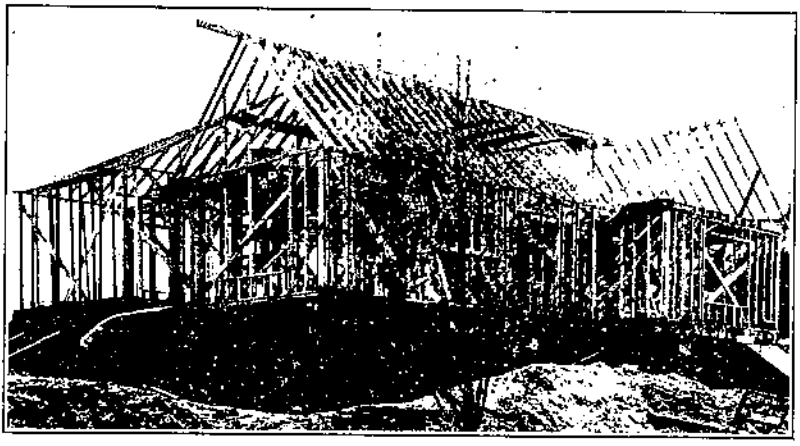


FIGURE 25.—Framing for dwellings is one of the principal uses for western larch. It is used for studding, joists, rafters, and sills

ranks high among the softwoods. Comparisons of the stiffness and nail-holding power of western larch with that of other species are made in Figures 15 and 19. Figure 25 shows western larch joists and studs in the framework of a dwelling.

In heavy joists over 2 inches in thickness, bending strength is usually of greater importance than stiffness, and decay resistance is often an added requirement. Heavy joists are used in the construction of warehouses, mills, and similar structures. They must carry heavy loads, there is no plaster to crack, and occasionally, as in textile mills, conditions are favorable for decay. The load-carrying capacity of heavy joists should be judged by the discussion under Structural Timbers (p. 71). Western larch meets the requirements of heavy construction even better than it does those of small houses or light construction. The bending strength of western larch (fig. 11) compares more favorably with that of other species than does its stiffness (fig. 15). The moderate decay resistance of western larch is also an asset.

Western larch joists and studs are heavy and hard, and consequently are not so easy to fabricate as those of the lighter and softer species shown in Figures 8 and 13. The importance of weight and

hardness in joists and studs lies in their influence on construction costs. Heavy joists and studs are harder and slower to handle and place than light ones. Hardness increases the difficulty in cutting, sawing, and nailing.

STRINGERS

Bending strength combined with decay resistance is the combination of properties desired in stringers. Bending strength is desired because stringers are primarily load-carrying members, and decay resistance is desired because they are often used under conditions favorable to decay. The requirements of stringers are, therefore, similar to those for heavy joists except that decay is more often an important requirement.

Stringers are structural timbers, although they may be and often are of dimension size, that is, under 5 inches thick. Like all structural members, the strength of stringers is dependent more on the size, number, and location of the defects than upon the strength of the clear wood. The safe working values in Table 16 should be used in preference to values for clear wood in comparing the strength of western larch stringers with those of other species. Such a comparison is based on comparable grades and consequently takes into consideration the influence of defects. A high percentage of western larch No. 1 Dimension and Timbers should class as select under basic requirements for structural material of the American lumber standards (*28*) because of the characteristically small size of the knots in western larch.

PLANKING

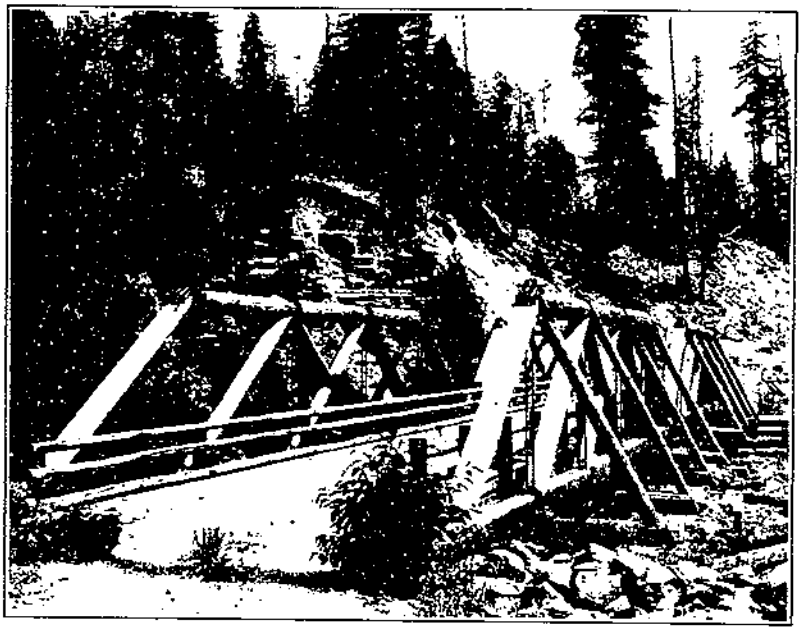
The value of western larch as planking lies largely in the combination of properties and characteristics which make it a good general utility wood. The use requirements of planking vary widely. (Fig. 26.) The most important requirement may be resistance to wear, resistance to decay, or load-carrying capacity. Some uses combine all three of these requirements. Western larch is especially adapted for use as planking, for it combines high hardness and bending strength with moderate decay resistance. In addition, the uniformly narrow annual rings in western larch result in a more even texture than is generally found in woods with alternate bands of hard and soft wood. A comparison of these properties and characteristics of western larch with those of other softwoods shows that while a few species rank higher in some one of the desired properties, none of the species rank higher in all.

The larch-fir mixture is not so desirable for use as planking as western larch. The difference in the hardness and texture between western larch and Douglas fir ("Inland Empire" type) when used in mixture may cause uneven wear, which is undesirable. In addition, higher working stresses are recommended for use with western larch than for the larch-fir mixture. Where the most important property desired is load-carrying capacity, the working stresses recommended in Table 16 for Douglas fir (Rocky Mountain type) should be used for the mixture. In computing load-carrying capacity the safe working values recommended in Table 16 are applicable to dimension used flatwise as well as on edge. Where planking is to be subjected to heavy wear western larch should be specified or

the Douglas fir should be sorted from the larch-fir mixture and used as a unit, preferably where wear and stresses are lightest. Such a separation of the larch-fir mixture will reduce the tendency of adjacent planks to wear unevenly. In addition the side from nearest the bark, that is, the sap side of flat-grained plank of both species, should be placed up to reduce the tendency to sliver.

RAFTERS

The primary requirements of rafters are bending strength and nail-holding power. Bending strength is required to carry loads imposed by roofing, snow, wind, and live loads; nail-holding power is required



PROTECTED 26 A highway bridge built of round western larch timbers. Western larch in round form has a high percentage of heartwood

to hold roofing boards in place. (Fig. 27.) Light-weight and ease of working are desired to facilitate construction.

The bending strength and nail-holding power of western larch, rather than its ease of working, commend it for use as rafters. The bending strength of western larch rafters is due more to the characteristically small size of its knots than to the high bending strength of clear wood. Western larch knots, though numerous, average smaller in size than those of any species commonly used for rafters. The nail-holding power of western larch combined with retention of nail-holding power under varying moisture conditions indicates that it will hold roofing in place as well as or better than any of the woods now in common use. In ease of working it is very similar to Douglas fir (coast type) and southern yellow pine, but it is harder to work and heavier to handle than the spruces, true firs, and hemlocks.

The larch-fir mixture does not differ greatly from pure larch in suitability for rafters. The load-carrying capacity of the Douglas fir ("Inland Empire" type) in the larch-fir combination will be slightly lower than that of western larch due to the lower bending strength of the clear wood and the slightly larger average size of the knots. The Douglas fir ("Inland Empire" type) rafters will probably not hold roofing boards quite so well, but will be easier to work and lighter to handle.

SILLS

Decay resistance or nail-holding power or both are usually primary requirements of sills. In small-house construction sills are usually protected from moisture. Their principal function is to hold in place members which are nailed to them. Sills, however, are often used in contact with the ground or under conditions favorable to decay. The

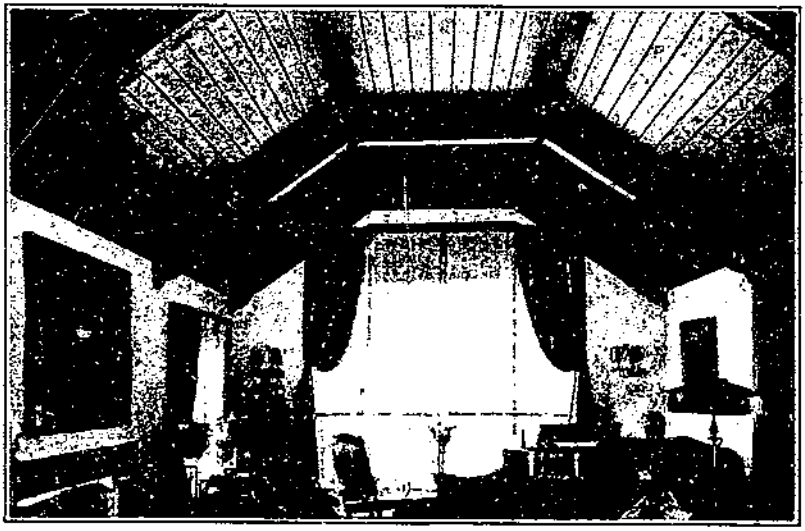


FIGURE 27.—Heavy rafters of western larch. The rafters are hand adzed

moderate decay resistance and nail-holding power of western larch are favorable to its use for sills. If the decay hazard is high, as when parts are in contact with the ground, the sills should be treated. A comparison of the properties of western larch with those of other species shows that none of the species commonly used for this purpose have a better combination of these properties.

SCAFFOLDING AND BRACING

The properties of western larch to be compared with those of other species in order to determine its value for scaffolding and bracing are stiffness, strength both in bending and compression, nail-holding power, and ease of working and handling. The strength, stiffness, and nail-holding power of western larch commend it for work where heavy loads are to be supported. The hardness and weight of western larch are a disadvantage in work where loads are light and speed of erection is important.

STRUCTURAL TIMBERS

The value of western larch for structural timbers depends primarily upon its strength in large sizes and upon its moderate decay resistance. The strength of structural timbers, however, depends more on the defects, such as knots, decay, shakes, and checks, that are present in the timbers than upon the inherent strength of the clear wood in them. Comparison of western larch structural timbers with those of other species must therefore be based on comparable grades. At present the commercial structural grades of other species are not comparable with the dimension and timber grades of western larch. The only comparable grades on which to base a comparison of the strength of western larch timbers with those of other woods are the American lumber standards (*28*) basic provisions for structural material. The working stresses recommended in Table 16 are for grades meeting these basic provisions and therefore can be used for comparing western larch structural timbers with those of other species. Such a comparison shows that the values recommended for fiber stress in bending and modulus of elasticity for western larch are lower than those recommended for a number of the softwoods. The values recommended for shear, compression parallel and perpendicular to the grain, however, do not differ greatly from those recommended for the heavier softwoods. The comparatively low values recommended for western larch for fiber stress in bending are due to the results of tests of the wood in structural sizes (*11*).

The determination of values from Table 16 on which to base design in a structure is a highly technical problem. It will vary in structures with the use requirements and conditions, and should be left to an engineer or an architect.

The character of the knots in western larch is favorable to the production of structural timbers. Their characteristically small size enables a high percentage of the timbers to meet the knot specifications of the higher strength grades. The predominance of encased over intergrown knots is an advantage, for encased knots are less injurious to the strength than intergrown knots of the same size because the grain distortion around them is less.

Many untreated structural timbers are used where conditions are more or less favorable to decay. The combination of moderate decay resistance and strength in western larch is such that the species can meet the requirements where untreated timbers are not essential. (Fig. 28.)

INTERIOR TRIM

The most desirable properties and characteristics of western larch for interior trim are its figure, color, hardness, and slow response to changing moisture conditions. Its alternate bands of hard and soft wood result in a pronounced figure that is especially adapted to natural finishes. Stains blend well with its natural reddish brown color, and hardness reduces the tendency to wear, mar, or dent.

Western larch interior trim is commonly used with natural or stained finishes rather than with paint finishes. (Fig. 22.) Natural and stain finishes bring out the figure. On the other hand, the tendency of the figure to show through and the tendency of the summerwood bands to rise slightly are objectionable in light-colored paint

and enamel finishes. Lighter-colored softwoods with less pronounced summer-wood bands are therefore generally preferred for enamel and highly decorative paint finishes.

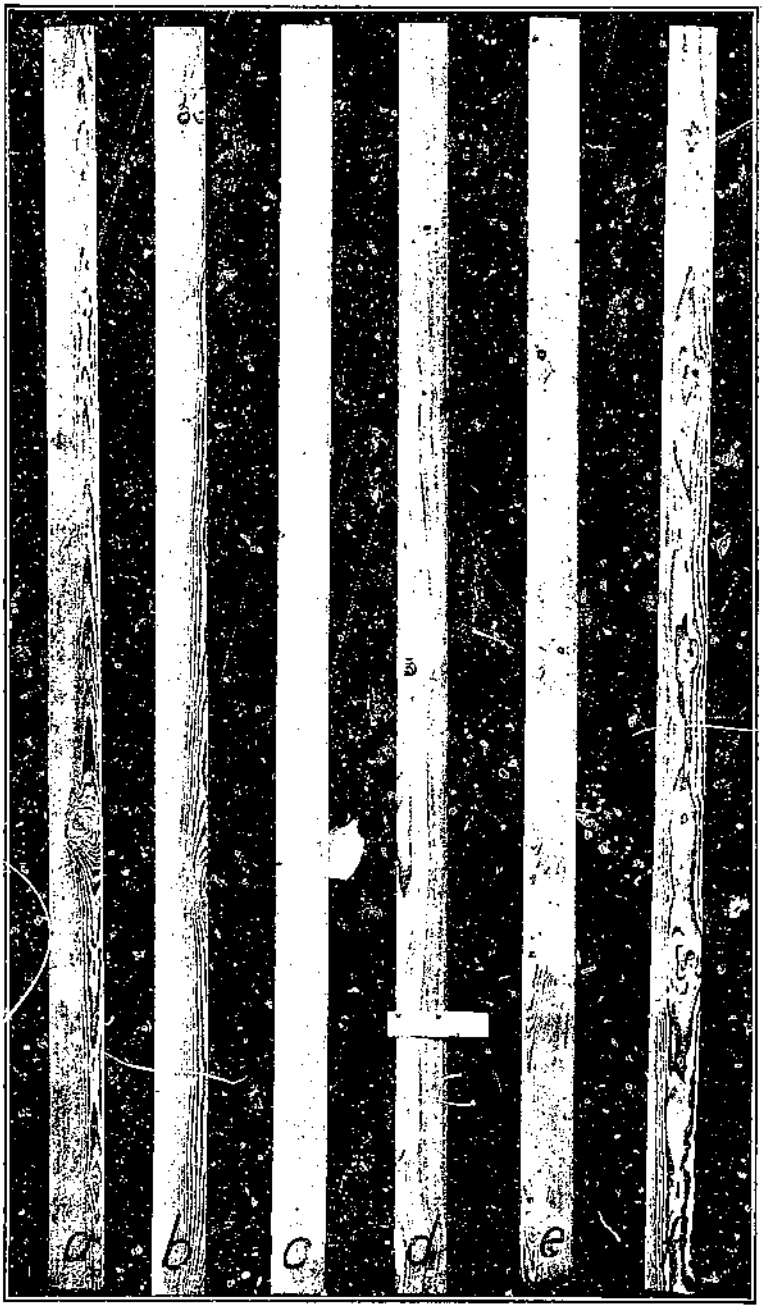
The principal items of western larch interior trim are ceiling, partition, and wainscoting, all of which are manufactured in a variety of patterns and go largely into such uses as porches, pavilions,

FIGURE 28.—A highway bridge of western larch. The strength and moderate decay resistance of western larch make it a desirable species for bridge timbers

and beach houses, where there is some exposure to the elements. In such uses the moderate decay resistance, adaptability to natural and stain finishes, and hardness of western larch form a desirable combination of properties and characteristics. Other items of western larch interior trim are molding, trim balusters, colonnades, newel posts, and stair treads. Figure is also desired for natural and stain finishes, and hardness for resistance to wear, denting, and marring. Decay resistance, except under exceptional conditions, is of no prac-

M 12405 F

Western larch finish of C grade has a high percentage of practically clear pieces, such as *a*, *b*, and *c*, and contains only small defects such as are shown in *d*, *e*, and *f*. The beauty of figure in flat grain *b* and the uniformity of figure in edge grain material *f* are shown



Western larch finish of D grade surfaced on two sides. The waste in converting the grade into clear material by cutting is small

M 21425 F

Center-matched, vertical-grained western larch flooring of C and better grade. The grade has a high percentage of practically clear boards, such as *a*, *b*, and *c*. Small black knots of about one-fourth inch in diameter, such as shown in *d* and *e*, are in about one-third of the boards. The narrow annual rings account for the uniform appearance and "wire-grain" figure that is typical of western larch vertical-grained flooring

M12141F

Center-matched, vertical-grained western larch flooring of the D grade. A practically clear floor can be obtained from this grade with small waste from cutting. About one-third of the pieces have a face free of knots, such as *a* and *b*. They are in the grade because of poor backs, cheeks, or torn grain. Other pieces, such as *c*, *d*, and *f* can be cut to give practically two clear pieces. Occasionally pieces will have small pitch pockets, such as shown in *e*

tical importance in interior trim. Figure 29 shows western larch beams, molding, casing, base, and doors used as an interior trim.

Western larch interior finish is manufactured principally in two grades, C and Better, and D. The general appearance of these two grades, both as to figure and defects, is shown in Plates 11 and 12. The C grade permits only small defects and has a high percentage of clear material. In fact, a single serious defect is sufficient to cause the rejection of a piece. The D grade is made up of pieces with one serious defect that may be cut out, thus leaving two practically clear pieces of boards having a C or Better face but a back that will not meet the requirements of the D grade, and of boards with a number of small minor defects.

FIGURE 29.—Western larch interior trim in beams, molding, casing, base, and doors. The adaptability of western larch to natural and stain finishes and its hardness are a desirable combination of properties for this use

Only about 3 per cent of the western larch finish is wider than 6 inches. Only about 1 per cent of the finish is thicker than 1 inch. Most of the finish is 16 feet long, although there is a demand in some sections and in the larger cities for 14-foot material because of the high proportion of porches which are 7 feet wide.

FLOORING

The combination of properties possessed by western larch makes it suitable for use in practically all types of flooring. The wood has hardness for resistance to denting, marring, and wear; uniform narrow ring growth for uniformity of appearance and wear; slow response to moisture changes for reduction of shrinking and swelling; high bending strength and stiffness for supporting heavy loads; a moderate resistance to fungous attack; and small, tight knots with correspondingly small effect on strength. Western larch shrinks

more than most softwoods used for flooring (fig. 17), but less than the hardwoods which furnish some of our finest flooring. Ease of working and painting characteristics of western larch also are not so good as those of a number of lighter, more uniform-textured softwoods.

Western larch is manufactured in a variety of types, grades, and sizes to meet demands of different types of flooring. The principal types are edge grain, flat grain, surfaced two sides, center matched, and jointed (square edge). The select grade is confined to narrow widths of 3, 4, and 6 inches and to thickness of 1 and 1¼ inches. Western larch select grades are largely edge grain. The common grades are largely 1-inch stock of mixed edge and flat grain, and are available in widths of 4 to 10 inches. The flat-grained stock predominates in the common grades.

Western larch is probably best adapted to the manufacture of high quality, narrow, end and side matched, edge-grained flooring of the type used in residences, offices, gymnasiums, and ballrooms. This type of softwood flooring is carefully selected for uniformity and narrowness of annual-ring growth. Narrow, uniform growth rings are the outstanding growth characteristic of western larch. A higher percentage of the cut of western larch meets the requirements for narrow ring growth than is the case with any of the other softwoods commonly used for flooring of this type. In addition, the narrow sapwood ring makes for a high percentage of all heartwood pieces. Sapwood is objectionable because it contrasts in color with the heartwood. Western larch has a high resistance to denting and marring because of its hardness. The edge-grained flooring of C and Better and D grades of western larch illustrated in Plates 13 and 14 show the "wire-grain" figure resulting from very narrow uniform annual rings.

The bending strength, stiffness, hardness, small tight knots, and uniform ring growth of western larch adapt it to heavy flooring for factories, mills, and grain elevators. Its bending strength enables it to support heavy loads, and the deflection under such loads is small because of the stiffness of the wood. Injury to strength from the characteristic small tight knots is small, and a good wearing surface is provided by the combination of hardness and uniform narrow annual rings, especially in edge-grained material. The wood is well adapted to bridge, platform, and similar types of heavy flooring, because it combines moderate decay resistance with the other properties that adapt it to heavy-service requirements.

One of the popular uses for western larch at present is for flooring in such structures as porches, pavilions, balconies, and beach houses. Jointed or square-edged flooring also goes into this type of use. Out-of-door flooring is subjected to some decay hazard, the wearing requirements are similar to those in houses or offices, and the wood may receive either a paint or natural finish. Edge-grained material is preferred and is superior to flat-grained material for out-of-door flooring. The larch-fir mixture is not so satisfactory for flooring as western larch, chiefly because of the higher percentage of sapwood, the wider and less uniform growth rings, and the lower degree of hardness of the Douglas fir ("Inland Empire" type).

The common grades of western larch make an excellent barn flooring. The knots, while more numerous, are smaller than in any of the softwoods used for this purpose. The average size of knot in the No. 3 Common grade of western larch is only one-half inch in diameter. In addition the knots in western larch are generally tight; only about 1 knot in 30 in No. 3 Common is loose or missing. Unsound and decayed knots are rare in the western larch grades higher than No. 4 Common, occurring in only about 1 board in 30. The small knots combined with the bending strength and the stiffness of the wood enable western larch flooring to carry the heavy loads it is sometimes called upon to support, the hardness provides resistance to wear, and the moderate decay resistance of the wood makes it desirable.

EXTERIOR TRIM

Western larch is best adapted to those items of exterior trim that are subjected to some decay hazard. While much exterior trim is used where conditions are unfavorable to decay action, some resistance to decay is necessary or desirable in such items as drip boards, garage doors, porch columns, and porch steps. Sometimes these items are so placed as to reduce or eliminate the decay hazard; however, knowledge that decay resistance will not be required is seldom available in advance of use. The more decay resistant a species is the better it is adapted to these items, other things being equal. On the other hand, items such as trim, moldings, and siding are seldom subjected to conditions favorable to decay. Where there is no decay hazard the better painting qualities and greater ease of working of the lighter-colored, more uniform-textured, lighter-weight, and softer woods will usually outweigh the greater strength and moderate decay resistance of western larch.

Western larch exterior trim should be painted as soon as practical after it is placed in service. The wood will start to weather check in a short time if exposed unpainted, especially if it is not thoroughly dried. Also, a good protective paint coating should be maintained on western larch, since the wood checks and the grain loosens or rises more quickly and more than on lighter, more uniform-textured woods.

Most items of western larch exterior trim are manufactured in both the select and common grades. The bulk of the production in all items, however, is of C and Better and D grades. A few items, such as casings, window and door frames, wainscoting, and screens, are produced only in the select grades. The finish shown in Plates 12 and 13 is as adaptable to exterior as to interior use.

SIDING

Western larch is produced in drop, bevel, and rustic siding. In addition, ship-lap and surfaced two sides and center-matched boards are also used for siding. The first three types are produced only in 4 and 6 inch widths of the select grades. The ship-lap and surfaced two sides and center-matched boards are obtainable in any grade and in widths up to 12 inches. The bulk of the production, however, is of common grades and in widths of from 4 to 8 inches.

Western larch siding is very similar to that of Douglas fir (coast type) in appearance, painting characteristics, decay resistance, and strength. Its painting characteristics are not so good as those of the more uniform-textured, softer, and lighter woods. This, however, can be compensated for to a large extent by confining the manufacture of western larch siding to edge-grained material. Edge-grained western larch siding will require repainting in approximately the same time as flat-grained siding of softer, lighter, and more uniform-textured species. Edge-grained material of such species, however, will not require repainting so soon as edge-grained western larch. The difference in time before repainting is required for the protection of the wood depends on the species. The properties and the characteristics of western larch that are desirable in siding are moderate decay resistance, the small, tight character of its knots, the small amount of sapwood, and the slow response to moisture changes. Sometimes one and sometimes a combination of the above properties and characteristics account for the use of the bulk of the western larch siding for barns, factories, grain elevators, houses, silos, and warehouses.

PORCH COLUMNS

The principal cause of failure of columns used for exterior decoration of houses is decay. The methods commonly used in construction permit the collection of moisture around the ends of the columns and thus establish a high decay hazard. Western larch porch columns, while moderately decay resistant, should be treated with a preservative. Columns must be kept well painted to prevent checking; the paint, however, also prevents any moisture that may be absorbed at the ends of the columns from drying out rapidly and therefore may make conditions favorable for decay. Columns constructed of nondurable woods or columns which contain sapwood rot out in a comparatively short time. The small percentage of sapwood in western larch makes it easy to select all heartwood pieces for columns. Care should be exercised to prevent, in so far as possible, the absorption of moisture through the ends of columns, even with a decay-resistant wood.

DOORS

The same properties and characteristics which have made the Douglas fir (coast type) doors so popular also make western larch a good wood for doors. Western larch has a pronounced figure with natural and stain finishes. It also has a high degree of hardness, which tends to reduce the denting and marking from knocks and blows. The high heartwood content of western larch makes it easy to obtain the desired uniformity of color. All heartwood is also important in some exterior and in many garage doors because of the low decay resistance of sapwood. High nail or screw holding power is also desirable in all doors for fastening hinges. It is especially necessary in garage doors because of their size and weight. The swelling and shrinking with changing atmospheric conditions, which are objectionable in all doors, are reduced by the slow response of western larch to moisture changes. This property, however, is largely offset by the high shrinkage of the wood. Western larch

doors that are exposed to the weather must be kept well painted or protected by a good natural finish if they are to prove satisfactory. In this respect they will require more maintenance than doors made from lighter, more uniform-textured woods. Generally, the properties of western larch adapt the species to doors subject to some decay hazard, doors with pronounced figured finishes, large heavy doors, and doors subject to hard usage from knocks and blows. While it is adaptable and can be used for light doors finished with paint or enamel, the lighter and more uniform-textured woods meet the requirements for such doors better, provided the decay hazard is low.

SASH AND FRAMES

Sash and frames for doors and windows are quite generally made from softer, more easily worked woods with more sapwood than western larch. So far practically no limitation has been put on the amount of sapwood admissible in sash and frames. Some demand, however, has arisen for more decay-resistant and stronger sash and frames. This demand has developed in factories, hotels, and greenhouses, and other buildings which have a decay hazard or which are using exceptionally large and heavy windows, where replacements are expensive. Western larch, because of its strength, hardness, and moderate decay resistance, meets these requirements about as Douglas fir (coast type) does. Edge-grained western larch is much better adapted to use in sash and frames than is flat-grained material.

STEPS

Resistance to decay and wear are two important requirements of stepping used out of doors. The hardness and moderate decay resistance of western larch adapt it for stepping. In addition, its narrow and uniform annual rings result in uniform wear, which is very desirable in stepping. Edge-grained western larch stepping is much superior to flat-grained stepping, because it takes and holds paint better, wears more uniformly, and reduces the chance of the grain loosening and creating a tripping hazard. Poor design, wood in contact with the soil, joints that collect and hold moisture, and lack of ventilation, rather than lack of decay resistance of wood, are responsible for much of the replacement necessary with stepping. Satisfactory results can not be expected from western larch stepping, even though it is decay resistant, if the design is poor.

The requirements of interior stepping differ considerably from those of exterior stepping. In interior use appearance is more important, wear is not so severe, protection against wear is better, and the decay hazard is practically negligible. Western larch stepping for interior use, therefore, does not have the advantages over stepping of soft, lightweight, nondurable woods that it possesses in exterior use. Stepping for interior use is selected in most cases to match other trim. Edge-grained western larch furnishes the popular "wire-grain" figure, and flat-grained material furnishes the pronounced figure. With natural finishes both edge-grained and flat-grained stepping result in a comparatively dark trim. The desirability of western larch stepping for interior use depends largely upon personal preference for color and figure.

INDUSTRIAL USES

It is impractical to discuss all of the industrial uses of western larch. They are too numerous and the requirements vary too widely, depending on the design and quality of the finished article it is desired to produce. (Fig. 30.) A few of the more important industrial uses are discussed to show how in the absence of experience or special tests the information on properties and characteristics can be used to determine the suitability of western larch. The consumer, with more complete knowledge of his requirements and local market prices can come to a more definite conclusion as to the suitability of western larch for his purpose than is possible in this bulletin. Here it is only possible to compare general requirements with properties and characteristics of western larch and show the adaptability of the wood to the use without deciding whether it or another wood should be used. Determining the most desirable species to use involves comparisons of price as well as of properties and characteristics.

MINE TIMBERS

Considerable western larch is used for mine timbers. A number of the mills, especially small ones, make a specialty of mine timbers and ties. Some of them run practically the entire cut to these products. The large mining operations in the "Inland Empire" furnish a ready market for western larch mine timbers. Because of its combination of strength, moderate decay resistance, high heartwood content, and small knots, western larch mine timbers are better than those of any other species grown in the "Inland Empire." As manufactured at present, sawed western larch mine timbers are probably equal to those of any softwoods commonly used for this purpose. Softwoods whose clear wood is stronger than that of western larch have larger and more injurious knots. When the quality of the clear wood and defects present in the various species are considered, therefore, western larch mine timbers will compare favorably with those of any of our other native softwoods.

Western larch in round form is especially adapted to the requirements of mine timbers because of its narrow sapwood. The high heartwood content results in a higher percentage of decay-resistant wood than is commonly found in any softwood species of equal or higher strength. An increase in the production of western larch mine timbers is not desirable from the standpoint of good utilization, because at present too much of the D product of the log is going into mine timbers. Good utilization requires that such high-quality material be marketed for uses with more exacting requirements.

CROSSTIES

About 10 per cent of the total western larch cut annually goes into crossties. It is estimated that about 4 per cent is in the form of hewed crossties and 6 per cent in the form of sawed crossties. Small circular mills, which produce only crossties and other rough products (fig. 31) increase the percentage of sawed crossties from the 1.1 per cent reported by association mills. (Table 9.)

The suitability of western larch for crossties is, so far as mechanical properties are concerned, shown by composite strength figures

FIGURE 30.—A logging chute constructed of larch-fir. The high degree of hardness and decay resistance of western larch adapt it to such outdoor uses where it is in contact with the ground and subject to exceptional loads and heavy wear

for softwoods (*14*) to be exceeded only by southern yellow pine, alligator juniper, and Pacific yew. The high rating of western larch is due to its bending strength which enables it to resist center bending, its nail-holding power which furnishes resistance to spike pulling, and its hardness which enables it to resist rail and plate wear.

The average life of untreated western larch ties in a mainline test track in Montana subjected to heavy traffic was seven and one-half years. Douglas fir ("Inland Empire" type) in the same test track had about the same average life. The life of ties, however, varies so widely with service conditions that the average life is indicative only and not necessarily a measure of the life that will be obtained in any specific tie. The high heartwood content and the moderate decay

FIGURE 31.—Manufacturing western larch crossties. Many circular mills, such as shown here, confine their output to crossties and mine timbers, to which uses western larch is well adapted

resistance of western larch are important assets when ties are to be used untreated. On the other hand, in ties that are to be treated with preservatives, the high heartwood content is not desirable, for sapwood is much easier to treat than heartwood.

Western larch is not an easy wood to treat with preservatives. However, with the aid of incision, a number of commercial plants now successfully treat the species.

TANKS

Decay resistance is usually the most important requirement of wood for tanks. Either tight-knotted material or clear wood is required, and the wood should not be easily penetrated by liquids. Water-soluble extractives are objectionable for some uses to which tanks are put.

The small amount of sapwood in western larch and the inherent decay resistance of the heartwood make western larch suitable for

tanks of moderate life requirements. Sapwood, when used in tanks, causes high maintenance charges and unsatisfactory service, for it is low in decay resistance. The sapwood is easily excluded from western larch tank material and involves less waste with western larch than with most woods used for tanks. The larch-fir mixture meets the requirements for tanks about as well as western larch except that a somewhat higher wastage occurs in eliminating the sapwood. Neither western larch nor Douglas fir ("Inland Empire" type) is easily penetrated by moisture, but the Douglas fir is more difficult to penetrate than western larch.

No. 1 and No. 2 Common are the grades of larch-fir commonly used for tanks. The tightness and small character of the knots in western larch and Douglas fir ("Inland Empire" type) enable such a low grade to be used with a small amount of cutting, the Douglas fir requiring more cutting than the western larch.

In western larch the galactan (p. 43), which is soluble in water, may prove objectionable for some tanks. Trouble from this source, however, can usually be prevented by thorough soaking before or after construction.

SILOS

Wood in silos is subjected to severe conditions. It is alternately wet and dry and therefore subjected to conditions favorable to decay and to swelling and shrinking. The pressure exerted by silage subjects the wood to some stress. Western larch has the desired strength for silos and can be used untreated, but will give better service if treated with a wood preservative.

Like all woods, western larch is a good thermal insulator, furnishing protection against the silage freezing and holding the heat in the silo during the fermentation stage. In this respect, western larch is better than the heavier woods, but not so good as the lighter woods. Generally, however, tightness of construction is more important in obtaining good thermal insulation than the kind of wood used.

Good silage can only be secured by having an air-tight wall. The wood in a silo must therefore stay in place well. Western larch is straight grained, and consequently has small tendency to warp and twist and thus permit leakage of air. On the other hand, its shrinkage is high, and in western larch silos therefore careful attention should be paid to hoop and anchor cables. The resistance of western larch to the penetration of liquids is an advantage when the wood is used in silos.

The small number of loose knots, knot holes, unsound and decayed knots in western larch favor its use in silos. Knot holes are objectionable in silos in that they may permit leakage of air, and boards or staves containing knot holes should therefore be cut or culled. While the black color of many of the knots in western larch is sometimes objectionable from an appearance point of view, they do not injure the serviceability of the silo when they are tight.

Silos constructed of western larch should be painted as soon after erection as possible to prevent weather checking. Western larch silos require somewhat more painting maintenance than lighter woods without pronounced summer-wood bands.

No sapwood should be permitted in untreated silo staves or siding because the sapwood of all species has low decay resistance. The narrow sapwood ring of western larch makes it easy for the species to meet the sapwood requirements for silos. One manufacturer reports changing from a more decay-resistant species to western larch because western larch has less sapwood. The change materially reduced maintenance charges resulting from his guarantee even though the larch required more painting. This manufacturer has used a special drop siding of western larch on thousands of silos.

The properties and characteristics of western larch are as a whole admirably adapted to the requirements of silos. To obtain full advantages of the properties of western larch, however, requires somewhat more care and attention than is necessary with the weaker and lighter woods with less pronounced summer-wood bands. Special grades for silo staves would aid in marketing western larch in this field. Such grades, if drawn to take advantage of the lack of sapwood and the small, tight-knotted characteristic of the species, would provide a high-quality silo material.

FREIGHT-CAR CONSTRUCTION

Decay is responsible for more replacements in freight cars than all other causes combined. A study of 265,666 individual freight-car parts showed that 82.3 per cent failed because of decay (4). In items, such as roofing, decking, grain strips, and running boards, replacements were due almost entirely to decay. The value of the decay resistance of western larch is obvious when the species is used in freight-car construction.

Strength and hardness are required in freight cars to withstand the shocks and to resist the hard usage that car material receives. Western larch ranks high in both strength and hardness. Only the strongest and hardest of the softwoods are equal to western larch in this respect. (Figs. 11 and 13.)

The use of western larch for car lining, siding, decking, and roofing has been handicapped by the fact that it has not been readily available in the desired sizes and quantities. Most of the western railroads use 1¾-inch stock for decking and 7/8-inch stock for siding, lining, and roofing. Western larch is not readily available in these thicknesses except to railroads owning their own mills. Railroads purchasing western larch have had to take 1⅝-inch stock for decking and 25/32-inch or ¾-inch stock for roofing and lining. Several car builders and repair shops report satisfactory service from No. 3 Common western larch for longitudinal roofing under a Douglas fir (coast type) finished lateral roof. Engineers report the successful use of western larch in refrigerator cars for lining, for strips to keep meat away from walls, and for temporary floor racks in fruit cars. The moderate decay resistance, hardness, and small, tight knots of the species are largely responsible for satisfactory results being obtained in spite of the fact that the material is thinner than that commonly used.

The combination of strength, decay resistance, nail-holding power, and retention of nail-holding power should enable western

larch to render good service as car framing. No. 1 and No. 2 Dimension are the grades commonly used for frames, sills, and posts. Moderate decay resistance, combined with high heartwood content, permits the use of western larch untreated timbers; the high bending strength combined with small knots provide for the required strength; the nail-holding power and the retention of nail-holding power enable timbers to hold siding, roofing, and lining under the varying atmospheric conditions that cars encounter in moving from one part of the country to another.

Generally the properties and characteristics of western larch are favorable to its use in freight cars, but the sizes in which it is most readily available are unfavorable to its use for certain items. If western larch is to be more extensively used for siding, lining, roofing, or decking, either the manufacturers must make provision to cut the special thicknesses that railroad-car builders believe to be necessary, or some conclusive data must be obtained to show that the sizes available in western larch are adequate to meet the requirements of some or all of these items.

CROSS ARMS

Very little western larch is used for cross arms. Douglas fir (coast type) and southern yellow pine furnish the bulk of wood for this purpose. One company alone used over a million cross arms of these two species. The heartwood of western larch, being very similar to that of Douglas fir of coast type in its strength properties and decay resistance, would be expected to meet cross-arm requirements about as that species does. The Douglas fir would have an advantage due to its greater stiffness, and western larch an advantage due to its greater hardness. Southern yellow pine would have an advantage in strength and stiffness but a smaller advantage in hardness. On the other hand, the growth and defect characteristics of western larch are better adapted to the rigid specifications of the large users of cross arms than are those of either Douglas fir or southern pine. The limitations on the size of knots in cross arms are rigid and definite. The average knot in western larch is smaller than that in Douglas fir and only about half the size of the average knot in southern pine. The percentage of the objectionable loose, missing, and unsound knots is also lower in western larch than in Douglas fir and southern yellow pine. Pitch pockets occur only about one-third as often in the western larch as in the other two species, and they average smaller in size. In addition, species having narrow annual rings are desired by cross-arm purchasers. In this respect western larch has no equal among the softwood species. Neither can any other decay-resistant softwood so readily meet the limitation imposed on sapwood. A slope of 1 in 12, which is the cross grain allowed in the specification on which the bulk of cross arms are purchased, is readily met by Douglas fir, southern yellow pine, and western larch. Only in the limitations on checks will western larch find more difficulty in meeting cross-arm specifications than Douglas fir and southern yellow pine. Checks are about three times as prevalent in larch as in those species.

REFRIGERATORS

Western larch is used both in the small household refrigerators and in large ones of the type used in meat markets. In the household type the species is used principally for frames, bottoms, insulation, and backing. Its strength, nail and screw holding power, and high heartwood content are the properties valued for frames. No. 1 Common western larch dimension is commonly used for this purpose. The brownish color and narrow uniform ring growth are largely responsible for the use of western larch for refrigerator backing and bottoms. Ceiling or dressed and matched western larch of the C and Better or D grade is used for these items. No. 3 Common 1 inch thick by 8 or 10 inches wide is sometimes resawed, and used for refrigerator insulation. As a thermal insulator, western larch has a higher heat conductivity than the lighter-weight woods, but the tightness and small size of knots and small amount of decay in the low grades of the species are advantages.

Western larch finish and ceiling are used principally for exterior trim in refrigerators for grocery stores and meat markets. It is used as an alternative for more expensive hardwoods as a front trim in the moderate-priced boxes. In more expensive boxes western larch ceiling is used for sides. In both the expensive and moderate-priced boxes the dark color of heartwood, combined with the "wire-grain" figure of edge-grained stock, is largely responsible for the use of the species for this purpose. The brown color of heartwood blends well with other trim, especially southern yellow pine. The dark color of western larch does not show dirt and hand marks on the sides of refrigerators so readily as would lighter-colored woods, and the hardness of the wood resists denting and marring. Western larch is only occasionally used for interior lining, since for this purpose the preference is for lighter colored and softer woods.

AUTOMOBILE BODIES

The use of softwoods in automobile bodies is increasing. In some of the smaller and lighter cars about 60 per cent of the wood used is softwood. In the heavier and larger cars softwoods are limited to those parts the property requirements of which are not exacting.

Southern yellow pine and Douglas fir are the principal softwoods used in automobile bodies. In the larger and heavier cars both species are used for floor boards, running boards, seat risers and frames, fillets, braces, and cleats. They carry no steel and are not subjected to heavy impact loads. Western larch lumber will serve as well as the species now used in such parts, but it is not so readily available. In some of the smaller cars, softwoods, particularly laminated Douglas fir (coast type), are used in more important structural parts, such as main sills, cross sills, and top or roof rails. Here nail-holding power, bending strength, and toughness are desired. Western larch has the same bending strength and toughness as Douglas fir (coast type) (figs. 11 and 14) and has a higher nail-holding power. In general, the properties of western larch indicate that it can be used for parts similar to those for which Douglas fir is successfully used. A comparison of the properties of western larch with those of red gum, a species widely used in the small type of cars, also

indicates the possibility of using western larch in automobile parts. Western larch has a higher nail-holding power and is stiffer and higher in compressive strength than red gum, but it is lower in bending strength and shock resistance and is not so uniform in texture.

The ease with which western larch can be glued is another property desired in a number of automobile-body parts. Sills are made of glued laminations, joints are glued, and other parts are built up. It is easy to glue western larch so as to obtain joints stronger than the wood.

Some of the growth characteristics of western larch are also favorable to its use in automobile bodies. The high heartwood content reduces trouble from decay, and the narrow uniform annual rings make for ease of working.

The use of western larch in automobile bodies is confined largely to running boards and floor boards. For running boards D Select 1 inch thick by 4 inches wide, dressed and matched boards are used. Floor boards are generally square-edged No. 1 and No. 2 Common.

The principal obstacle to the more extensive use of the species for automobile body parts is the comparatively small cut and stand. The stand of western larch, however, is sufficient to meet heavier demands than are now made on it and is larger than that of many of the hardwoods now used. Manufacturers of western larch must be prepared to meet a large demand over long periods of time if any appreciable amount of western larch is to be marketed for automobile parts.

BLEACHER AND STADIUM SEATS

Large quantities of lumber are used for seats and footboards in stadium and bleachers, but very little western larch has been used for this purpose. Douglas fir (coast type), southern cypress, redwood, southern yellow pine, and eastern spruce are the principal woods used.

There are two main types of stands: The stadium which has fixed seats on concrete, steel, or wood, and the bleacher, or temporary stand, which can be knocked down and moved from place to place. Stadium seats are usually exposed to weather the year round; temporary seats are usually exposed for only short periods or are used under cover. Bleacher seats are made largely of 1-inch stock, 6 to 12 inches wide; stadium seats are slats $1\frac{1}{2}$ or 2 inches thick and from 2 to 4 inches wide, or single planks 8 to 12 inches wide.

The two types of stands have a number of requirements in common. Both require strength in bending to carry live loads; hardness to resist denting, scuffing, and marring; and holding power for screws in order that the seat may not break loose. Twisting is objectionable because it causes slats to pull loose from fastenings, and also makes the seat uncomfortable for the occupant. Cupping is objectionable because cupped seats hold water after rain. Exudation of pitch or coloring matter is especially objectionable because they injure clothing, and loose or raised grain is objectionable because of danger from splinters.

The two types differ, however, in some of their requirements. Decay resistance and painting characteristics are more important in exposed permanent seats than in temporary, knock-down seats.

Strength in bending, stiffness, and toughness, on the the other hand, are more important in bleacher seats than in stadium seats because failure of seats or footboards in bleacher seats often has more serious results for the occupants. In addition, the bleacher seats are subjected to hard usage in knocking down and erection when they are moved from place to place.

The properties and characteristics of western larch adapt it to both types of seats. It has about the same bending and compressive strength, toughness, decay resistance, and painting characteristics as Douglas fir (coast type), which is the wood most commonly used for such seats. Douglas fir is stiffer and has a higher splitting resistance, but western larch is harder and has a higher nail-holding power. In addition, western larch is less resinous and less subject to pitch defects and will therefore give less trouble from resin exudation. Both species stay in place well and normally will give little trouble from warping or cupping.

The hardness, strength, nail-holding power, and decay resistance of western larch are the properties that commend the wood most strongly for bleacher seats. Western larch also has few pitch defects, and when common grades are used, the small, tight character of the knots is an advantage over the common grades of other softwood species. Western larch will require more painting maintenance than the other woods commonly used for seats, except Douglas fir and southern pine, which are very similar to larch in paint-holding qualities. Western larch is more subject to checking than any of the commonly used woods and must be kept well painted if checking is to be prevented. The coating of end surfaces is also advisable.

The general conclusion drawn from the properties is that western larch is an excellent wood for stadium and bleacher seats and stands. Service records to confirm this conclusion are lacking. Such records would be of value in opening this market to western larch, for actual performance in service is necessary as the final proof of the adaptability of a wood for any purpose.

The value of western larch for bleacher and stadium seats can be materially increased by the application of a few well-known principles. Edge-grained material will give more satisfactory service because it holds paint better, presents a more uniform wearing surface, shrinks and swells less, checks less, and is less subject to loose and raised grain than flat-grained stock, but it costs more. In permanent seats exposed to weather, all-heartwood stock should be specified or pieces containing sapwood should be culled because the sapwood of all species rots quickly. Checking at bolt holes near the end of the seat can be reduced by coating the end surfaces as soon after cutting as possible. Hardened gloss oil is an excellent coating for this purpose,[25] and will prevent most of the end checking, which is particularly objectionable at bolt fastenings. The heart side of flat-grained boards, that is, the side farthest from the bark, should be placed down. This arrangement will reduce trouble from splinters resulting from raised or loose grain. Most of the foregoing principles can be profitably applied to all of the woods now used, but are especially applicable to western larch.

[25] A formula for the preparation of hardened gloss oil can be obtained from the Forest Products Laboratory, Madison, Wis.

SHIPPING CONTAINERS

Western larch is used for all types of shipping containers. No. 1 and No. 2 Dimension are the grades commonly used for heavy and export crating. Wooden boxes are made from all of the common grades. Frames for veneer boxes are commonly made from 1 by 4 inch pieces of No. 3 Common ripped into three equal parts. One by four-inch square-edged boards of D Select grade are used for tight cooperage. The D Select grade, as well as No. 1 and No. 2 Common grades, is used in slack cooperage.

The properties of western larch adapt the wood better to crating, especially heavy and export crating, than to boxes. Crating for heavy and valuable merchandise requires a wood with high strength and nail-holding power. In these properties western larch ranks with the best of the softwoods. (Fig. 19.) The weight and dark color of western larch, while objectionable in boxes, are not objectionable in crating for heavy valuable commodities or in crating for shipment by water. The weight of the wood is given little consideration in crating valuable commodities, for the failure of only an occasional crate will usually more than offset the saving in transportation costs that could be made by using a lighter and weaker wood. Cost of transportation by water-borne shipments is based on volume; hence the weight of the container is not an important item. Color and appearance are less important in crates than in boxes because commodities are sold more often in or from boxes than in crates.

Boxes made of western larch are heavy, strong, and dark-colored. The average weight of the canned-food boxes of western larch used in tests (*3*) at the Forest Products Laboratory was 9.44 pounds. The same type of box of aspen averaged about two-thirds and of western yellow pine about three-fourths of the weight of western larch boxes. In resistance to rough handling the western larch boxes were between those of western yellow pine and aspen, which were higher, and those of western hemlock, which were lower. All of these woods are used extensively for boxes and are recognized by the box trade as excellent woods for that purpose. The western larch boxes had a relatively small percentage of failures from cross breaks, the outstanding cause of failure being splitting in sides, tops, and bottoms. This type of failure indicated that the efficiency of the western larch boxes could be improved by using thinner lumber and more and smaller nails than were used with softer and lighter woods. It is, however, hardly possible that western larch boxes could be made the equal on a weight basis of boxes of western yellow pine or aspen. The dark color of western larch boxes is shown in Figure 32 which also shows the size and type of box used in the tests.

Western larch is not primarily a box wood. The percentage of the cut of the species used for boxes will probably never be so high as that of the lighter weight, lighter colored, softer, and weaker woods.

Tight cooperage must be slow to absorb liquids and not easily penetrated by them. It must be easily bent to shape and must stay in place well. Western larch meets these requirements about like Douglas fir (coast type), which is used largely for tight cooperage. Western larch shrinks more than the Douglas fir (coast type) and is not so stiff. On the other hand, it is harder and less resinous. A high percentage of western larch has narrow rings of uniform

width; consequently a high percentage of the material from the tree is adapted to the manufacturing of tight cooperage. Western larch tight cooperage is used principally for pickle barrels.

The common as well as the select grades of western larch are used for slack cooperage. The small, tight knots of western larch are therefore an advantage over the same grades of stocks of other softwood species. On the other hand, the dark color of the wood is a disadvantage in tubs, pails, and buckets.

POLES

Western larch has been used locally in small quantities for poles. Poles in the past have been chosen principally for a combination of light weight, narrow sap ring, and high decay resistance. Western red cedar is one of the principal sources of poles of this type. Western larch poles are decay resistant, have a narrow sap ring, but

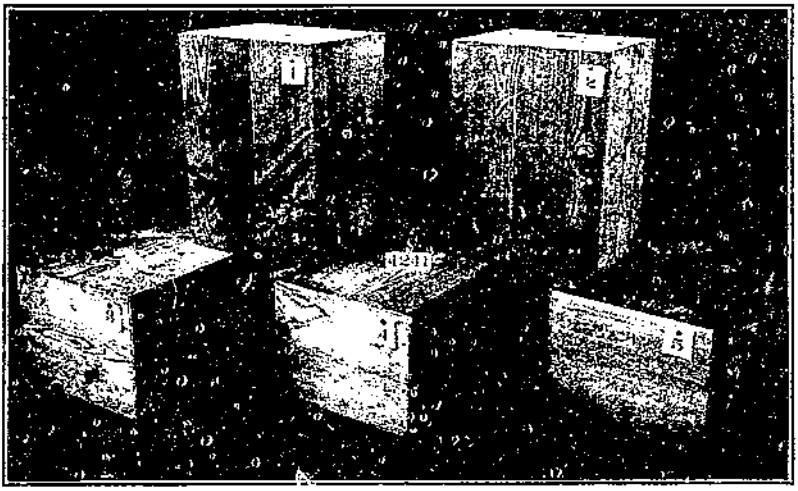


FIGURE 32.—Western larch style 5 standard canned-food boxes used in the tests at the Forest Products Laboratory. Western larch made a strong, heavy, dark-colored box

are comparatively heavy. They are, however, strong. Heavy, strong, decay-resistant woods are rapidly entering the pole market. Such poles are usually treated with a preservative, either because they have a wide sapwood ring or because they are less decay resistant than species previously used. Southern yellow pine is the principal source of these heavy, strong poles although some Douglas fir is also used. Western larch can furnish heavy, strong, moderately decay-resistant poles. The availability of light, more decay resistant woods, such as western red cedar, or strong, more easily treated woods, such as lodgepole pine, in the "Inland Empire" has prevented and will probably continue to prevent the marketing of much western larch for poles.

PILING

Western larch makes an excellent pile because of its strength and moderate decay resistance. The wood has the strength necessary to withstand driving, and has the hardness to resist mashing under the driving hammer. The heartwood is moderately decay resistant and

the sapwood band narrow; consequently it can be used untreated. Under conditions favorable to decay western larch piling should be treated with a preservative if long life is desired. Western larch, along with Douglas fir and southern pine, is classed among the softwood species best adapted to use as piling.

PULPWOOD AND PAPER

Western larch is not especially well adapted to use in the manufacture of pulp or paper. Although it can be pulped by the sulphite, sulphate, soda, and ground-wood processes (*31*), it is not so suitable for the production of pulp by any of these processes as are the spruces, true firs, or hemlocks. It is heavier than any of these woods, which fact tends to increase the yield per cord. Its fiber length, 2.6 millimeters, is the same as that of white spruce. Its hardness, dark color, and resin content, however, are not favorable to its use as a pulpwood.

Western larch is best adapted to pulping by the sulphate process. By this process the wood is readily pulped, yielding 1,290 pounds of pulp per 100 cubic feet of solid wood. The pulp is of good quality and strong. It is suitable for use unbleached in the manufacture of fiber boards and of good quality kraft wrapping paper.

Western larch is also adapted to pulping by the soda process. The yields obtained with this process, however, are lower than those obtained with sulphate processes, and the pulp is not quite so high in quality. There will therefore probably be little or no use of soda process with western larch.

Western larch is not well adapted to pulping by the sulphite process. It reduces unevenly and with difficulty. The unbleached pulp has poor strength and color. It is difficult to bleach, requiring 15 to 25 per cent of bleach. The yield is about 1,200 pounds of pulp per cord (100 cubic feet of solid wood). Western larch pulp produced by the sulphite process may be used for low-grade wrapping paper and boards.

Mechanical pulp is produced with difficulty from western larch. The hardness of the wood results in high power consumption. About two and one-half times as much power is required as is required for white spruce. The pulp is rather coarse, decidedly brown in color, and of fair strength. It is unsatisfactory for use as newsprint because of its dark color. It can be used as a filling material for boards or for any purpose where a medium quality of ground wood is desired and brown color is not objectionable.

The probability of using any large portion of the stand of western larch for the manufacture of pulp and paper is not great. Sulphate is the only pulping process which produces a satisfactory quality and yield of pulp from western larch. The amount of raw material suitable for use with this process is larger than for any other. It includes large amounts of woods and mill waste of better pulping species which are available in the "Inland Empire" and along the Pacific coast. It is reasonable to expect that the paper and pulp industry will utilize these species before attempting to use western larch. In addition, pulp mills along the Pacific coast will have an advantage over any mill established in the western larch region due to the lower cost of transportation by water.

APPENDIX

The names of lumber adopted as official by the Forest Service are not always identical with the names adopted by the trade as American lumber standards. Where the names are not identical some confusion may result. Table 18 has therefore been prepared to show the American lumber standards name (*28*) corresponding to the Forest Service name used in this bulletin. The common and botanical names of the trees from which the lumber is cut are also shown. Other trade names for lumber from the various species can be found in the Forest Service check list of the forest trees of the United States (*24*).

TABLE 19.—*Lumber names used by the Forest Service in this bulletin and corresponding American lumber standards names*

Name used in bulletin	American lumber standards name	Common name of tree	Botanical name of tree
Western red cedar	Western red cedar	Western red cedar	Thuja plicata.
Southern cypress	Red cypress (coast type)	Southern cypress	Taxodium distichum.
	Yellow cypress (inland type)	do	Do.
	White cypress (inland type)	do	Do.
Douglas fir (coast type)	Douglas fir (coast type)	Douglas fir	Pseudotsuga taxifolia.
Douglas fir ("Inland Empire" type).	Red fir (intermountain type).	do	Do.
Douglas fir (Rocky Mountain type).	Red fir (Rocky Mountain type).	do	Do.
Eastern hemlock	Eastern hemlock	Eastern hemlock	Tsuga canadensis.
Western hemlock	West coast hemlock	Western hemlock	Tsuga heterophylla.
Western larch	Western larch	Western larch	Larix occidentalis.
Southern yellow pine [1]	Southern pine [1]		Pinus.
Loblolly pine	Loblolly pine	Loblolly pine	Pinus taeda.
Shortleaf pine	Shortleaf pine	Shortleaf pine	Pinus echinata.
Longleaf pine	Longleaf pine	Longleaf pine	Pinus palustris.
Northern white pine	Northern white pine	Northern white pine	Pinus strobus.
Western white pine [4]	Idaho white pine	Western white pine	Pinus monticola.
Western yellow pine	California white pine	Western yellow pine [2]	Pinus ponderosa.[2]
	Pondosa pine	do	Do.
Redwood	Redwood	Redwood	Sequoia sempervirens.
Eastern spruce [3]	Eastern spruce [3]	Red spruce	Picea rubra.
		White spruce	Picea glauca.
		Black spruce [3]	Picea mariana.
Tamarack	Tamarack	Tamarack	Larix laricina.

[1] Forest Service includes five and American lumber standards four other species under the name southern yellow pine, but no data on these species are shown in this bulletin.
[2] Jeffrey pine (*Pinus Jeffreyi*) is marketed along with western yellow pine which it closely resembles
[3] Black spruce is not included in the averages shown in this bulletin.
[4] Changed to ponderosa pine after this bulletin went to press.

LITERATURE CITED

(1) ALLEN, T. E.
1923. FOREST FIGURES FOR PACIFIC COAST STATES. U. S. Senate Select Committee on Reforestation. [18] p.

(2) AMERICAN RAILWAY ENGINEERING ASSOCIATION.
1926. REPORT OF COMMITTEE VII—WOODEN BRIDGES AND TRESTLES. Bul. Amer. Ry. Engin. Assoc. 27 (284) : 829–912.

(3) AUSTIN, L. W., and EASTMAN, C. W.
1902. ON THE RELATION BETWEEN HEAT CONDUCTIVITY AND DENSITY IN SOME OF THE COMMON WOODS. Wis. Acad. Sci., Arts and Letters, Trans. 13 : [539]–542, illus.

(4) BOWE, E. E.
1929. LUMBER IN CAR CONSTRUCTION. South. Lumberman 135 (1757) : 76.

(5) BRADNER, M., and FULLAWAY, S. V., JR.
1927–28. SIZE OF TIMBER, AMOUNT OF DEFECT, IMPORTANT FACTORS IN LUMBERING. AN ANALYSIS OF THEIR EFFECT UPON PRODUCTION COSTS AND VALUES AND THEIR CONSEQUENT INFLUENCE ON PROFITABLE TREE AND LOG UTILIZATION IN THE "INLAND EMPIRE." Timberman 29 (2) : 38–40, 44, 46, 48; (3) : 40–42, 44, 46; (4) 62–63; (6) : 162–164, 166, 174.

(6) BROWNE, F. L.
1930. PROPERTIES OF WOOD THAT DETERMINE THE SERVICE GIVEN BY EXTERIOR PAINT COATINGS. Amer. Paint Jour. 14 : 22–78, illus.

(7) ———
1930. EFFECT OF PRIMING COAT REDUCTION AND SPECIAL PRIMERS ON THE SERVICE GIVEN BY PAINT COATINGS ON DIFFERENT WOODS. Indus. and Engin. Chem. 22 : 847–854, illus.

(8) CARLSON, T. A.
1929. SUITABILITY OF LITTLE-USED SPECIES OF WOOD FOR SHIPPING CONTAINERS. Barrel and Box 34 (1) : [15]–19, illus.

(9) CLINE, M., and HEIM, A. L.
1912. TESTS OF STRUCTURAL TIMBERS. U. S. Dept. Agr., Forest Serv. Bul. 108, 123 p., illus.

(10) CUNNINGHAM, R. N., FULLAWAY, S. V., JR., and WHITNEY, C. N.
1926. MONTANA FOREST AND TIMBER HANDBOOK. Mont. State Univ. Studies no. 1, 162 p., illus.

(11) GOSS, O. P. M.
1913. MECHANICAL PROPERTIES OF WESTERN LARCH. U. S. Dept. Agr., Forest Serv. Bul. 122, 45 p., illus.

(12) KOEHLER, A.
1917. GUIDEBOOK FOR THE IDENTIFICATION OF WOODS USED FOR TIES AND TIMBERS. U. S. Dept. Agr., Forest Serv. Misc. Pub. RL–1, 79 p., illus.

(13) MCELHANNEY, T. A., and PERRY, R. S.
1927. SOME COMMERCIAL SOFTWOODS OF BRITISH COLUMBIA; THEIR MECHANICAL AND PHYSICAL PROPERTIES. Canada Dept. Int., Forest Serv. Bul. 78, 44 p., illus.

(14) MARKWARDT, L. J.
1930. COMPARATIVE STRENGTH PROPERTIES OF 164 WOODS FOR CROSSTIES. Crosstie Bul. 11(9) : 6–14.

(15) ———
1930. COMPARATIVE STRENGTH PROPERTIES OF WOODS GROWN IN THE UNITED STATES. U. S. Dept. Agr. Tech. Bul. 158, 39 p., illus.

(16) ———
1931. THE DISTRIBUTION AND THE MECHANICAL PROPERTIES OF ALASKA WOODS. U. S. Dept. Agr. Tech. Bul. 226, 80 p., illus.

(17) ——— and GAHAGAN, J. M.
1929. NAIL HOLDING TESTS MADE. EXHAUSTIVE EXPERIMENTS COVERING WIDE VARIETY OF WOODS COMPLETED BY ENGINEERS OF FOREST PRODUCTS LABORATORY, MADISON, WISCONSIN. Timberman 30(10) : 142–143, illus.

(18) NEWLIN, J. A.
1927. UNIT STRESSES IN TIMBER. Amer. Soc. Civ. Engin. Trans. 91: 400–407, illus.

(19) PECK, E. C.
1928. SHRINKAGE OF BOARDS OF DOUGLAS FIR, WESTERN YELLOW AND THE SOUTHERN PINES. Amer. Lumberman no. 2774: 52–54, illus.

(20) ROWLEY, F. B.
1923. TRANSMISSION OF HEAT THROUGH BUILDING MATERIALS. Minn. Univ. Engin. Expt. Sta. Bul. 3, 74 p., illus.

(21) ———
1929. RESULTS OF THERMAL CONDUCTIVITY TESTS ON LUMBER. Minn. Univ. Rpt. 8 p.

(22) SNYDER, T. E.
1930. PREVENTING DAMAGE BY TERMITES OR WHITE ANTS. U. S. Dept. Agr. Farmers' Bul. 1472, 22 p., illus. (Revised ed.)

(23) STOKES, W. B.
1925. CANADIAN SOFTWOODS. Canada Dept. Int., Forestry Branch Circ. 19, 13 p., illus.

(24) SUDWORTH, G. B.
1927. CHECK LIST OF THE FOREST TREES OF THE UNITED STATES. THEIR NAMES AND RANGES. U. S. Dept. Agr. Misc. Circ. 92, 295 p.

(25) THELEN, R.
1929. KILN DRYING HANDBOOK. U. S. Dept. Agr. Bul. 1136, 96 p., illus. (Revised.)

(26) TRUAX, T. R.
1929. THE GLUING OF WOOD. U. S. Dept. Agr. Bul. 1500, 78 p., illus.

(27) UNITED STATES DEPARTMENT OF AGRICULTURE.
[n. d.] SIGNIFICANCE OF THE "FACTOR OF SAFETY" IN WORKING STRESSES FOR STRUCTURAL TIMBERS. U. S. Dept. Agr., Forest Prod. Lab. Tech. Note 222, 3 p.

(28) UNITED STATES DEPARTMENT OF COMMERCE, BUREAU OF STANDARDS.
1929. LUMBER. U. S. Dept. Com., Bur. Standards Rev. Simplified Pract. Recommendation R 16–29, 94 p., illus.

(29) ———
1926. RECOMMENDED BUILDING CODE REQUIREMENTS FOR WORKING STRESSES IN BUILDING MATERIAL. REPORT OF BUILDING CODE COMMITTEE, JUNE 1, 1926. U. S. Dept. Com., Bur. Standards Elimination of Waste Ser. BH9, 53 p., illus.

(30) VAN DUSEN, M. S.
1920. THE THERMAL CONDUCTIVITY OF HEAT INSULATORS. Refrig. Engin. 7: 202–231, illus. [Also published in Jour. Amer. Soc. Heating and Ventilating Engin. 26: 625–656, illus.]

(31) WELLS, S. D., and RUE, J. D.
1927. THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP. U. S. Dept. Agr. Bul. 1485, 102 p., illus.

(32) WESTERN PINE MANUFACTURERS' ASSOCIATION.
1929. STANDARD GRADING RULES FOR PONDOSA PINE, CALIFORNIA WHITE PINE, SUGAR PINE, IDAHO WHITE PINE, LARCH, DOUGLAS FIR, WHITE FIR, SPRUCE, AND CEDAR LUMBER. 69 p., illus. Portland, Oreg.

(33) WILSON, T. R. C.
1921. THE EFFECT OF SPIRAL GRAIN ON THE STRENGTH OF WOOD. Jour. Forestry 19: 740–747, illus.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE WHEN THIS PUBLICATION WAS LAST PRINTED

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	E. L. MARSHALL.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Engineering	S. H. MCCRORY, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration	LEE A. STRONG, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	JAMES T. JARDINE, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Forest Service	R. Y. STUART, *Chief.*
Branch of Research	EARLE H. CLAPP, *Assistant Forester in Charge.*
Forest Products Laboratory	CARLILE P. WINSLOW, *Director.*
Section of Industrial Investigations.	C. V. SWEET, *Principal Engineer in charge.*

U. S. GOVERNMENT PRINTING OFFICE 1932

For sale by the Superintendent of Documents, Washington, D. C. - - - - - - Price 35 cents

END