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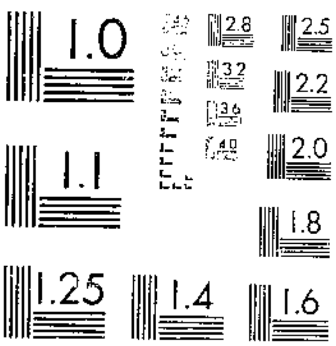

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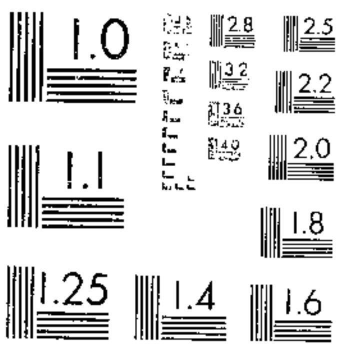

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By

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Engineer, Forest Products Laboratory

and

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Associate Forester, California Forest Experiment Station
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UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D.C.

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PROPERTIES OF WHITE FIR AND THEIR RELATION TO THE MANUFACTURE AND USES OF THE WOOD

By R. P. A. JOHNSON,[1] *engineer, Forest Products Laboratory*,[2] and M. R. BRUNDAGE, *associate forester, California Forest Experiment Station* [2] *Branch of Research, Forest Service*

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INTRODUCTION

White fir lumber, a relatively new wood from western United States, is now found quite generally in eastern and middle-western markets. Its introduction into these markets has been in the form of common

[1] Acknowledgment is made of assistance received from many members of the Forest Service, especially to E. M. Davis, Forest Products Laboratory, for the detailed information on characteristic defects of white fir, and to M. I. Bradner, Forest Region 1, for the information on white fir from Idaho. Further acknowledgment is made to the Mountain Pine Sales Association for contributed photographs.

[2] The Forest Products Laboratory is maintained by the U.S. Department of Agriculture at Madison, Wis., in cooperation with the University of Wisconsin; the California Forest Experiment Station at Berkeley, Calif., in cooperation with the University of California.

boards and dimension. A number of questions immediately arise with the entrance of a little-known wood into the lumber markets. The consumer quite naturally wants to know how the new wood compares with woods with which he is familiar. White fir is no exception to the rule, and there is a demand for information on the properties, the adaptability, and the suitability of the wood for various uses, especially small-house construction.

The purpose of this bulletin is to furnish detailed information on the properties and characteristics of the wood of white fir, for the assistance of consumers and manufacturers in determining the suitability of this wood for specific uses.

The name "white fir" is applied to lumber of several species of true firs.[3] About seven eighths of the lumber marketed as white fir, however, comes from two species, and all but a small percentage of the total is produced in California and Idaho. These two species are lowland white fir (*Abies grandis*), cut chiefly in the "Inland Empire"[4] and redwood region of California, and white fir (*A. concolor*) cut mainly in the Sierras of California. This bulletin deals primarily with the properies and uses of wood of these two species.

The confusion caused by the use of the name "white fir" for other true firs cannot be eliminated entirely, for it is not always possible to segregate by species combined data on the true firs. The following nomenclature is used in the text of this bulletin to eliminate insofar as possible the confusion of species names:

True firs: The tree or lumber of all *Abies* species collectively.

Western true firs: The tree or lumber of all *Abies* species growing in the western United States considered collectively.

Eastern true firs: The tree or lumber of all *Abies* species growing in the eastern United States; namely, balsam fir and southern balsam fir.

Commercial white fir: Collective name for the lumber of a group which may include any of the commercial species of western true firs.

White fir: The tree, timber, or lumber of white fir (*Abies concolor*) and lowland white fir (*A. grandis*) considered together.

White fir (*Abies concolor*): The tree or lumber of the species white fir (*A. concolor*) by itself.

Lowland white fir: The tree or lumber of the species lowland white fir (*A. grandis*) by itself.

The figures in this bulletin showing mechanical and other properties of wood are based on material carefully identified as to species and the names are those used by the Forest Service[5] for the trees from which material was cut.

SILVICULTURAL IMPORTANCE

LUMBER CUT

The Bureau of the Census (*27*) reports the 1929 lumber cut of western true firs as 307,000,000 board feet. This includes the cut of five species—white fir (*Abies concolor*), lowland white fir, silver fir, Cali-

[3] The true firs belong to the genus *Abies* as contrasted with Douglas fir, which is not a fir and belongs to the genus *Pseudotsuga*. The common names of the true firs are: Southern balsam fir, balsam fir, Alpine fir, corkbark fir, lowland white fir, white fir, silver fir, noble fir, California red fir, and bristlecone fir.

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

[5] The names employed by the Forest Service (*21*)[6] for lumber and for trees from which it is cut are used throughout this bulletin.

[6] Italic numbers in parentheses refer to Literature Cited, p. 75.

fornia red fir, and alpine fir, and is slightly more than 1 percent of the total softwood lumber cut. The annual lumber cut of the western true firs has remained approximately constant since 1922, averaging about 314,000,000 board feet (fig. 1). About two thirds of the lumber cut of the western true firs comes from California, about one fourth from Idaho, and the small remainder is principally from Washington, Oregon, and New Mexico (fig. 2, *A*).

Table 1 shows by States the total, average, and percentage cut of the western true firs for the years 1927, 1928, and 1929. These values differ from those in figure 2, which is based on a 5-year average. Figure 2 shows that the cut of the true firs by States is not in proportion to the stand, consequently it is to be expected that the States other than California and Idaho will eventually produce an increased percentage of true fir lumber and the percentage of cut and stand will be more nearly equalized.

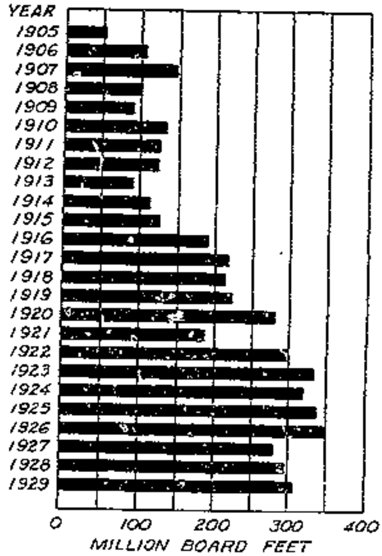


FIGURE 1.—The cut of western true firs by years. It includes some species not generally sold as white fir. No data by species are available but it is estimated that over 95 percent of the cut is from white fir (*Abies concolor*) and lowland white fir.

TABLE 1.—*Average and percentage cut by States of the western true firs, 1927–29*

State	Average cut, 1927–29	Percentage of total, 1927–29	State	Average cut, 1927–29	Percentage of total, 1927–29
	Board feet			*Board feet*	
Arizona	42,000	(1)	Oregon	15,813,000	5.4
California and Nevada	173,436,000	59.2	Utah	373,000	0.1
Colorado	1,407,000	0.5	Washington	22,809,000	7.8
Idaho	73,099,000	25.0	Wyoming	55,000	(1)
Montana	434,000	0.1			
New Mexico	5,403,000	1.9	Total	293,021,000	100.00

[1] Less than 0.1 percent.

About 90 percent of all the true fir lumber cut in California is white fir (*Abies concolor*). About 9 percent is lowland white fir and about 1 percent is California red fir. The lumber from Idaho sold as white fir is a mixture of several species, lowland white fir predominating. Occasionally a small amount of alpine fir is included.

WHITE FIR FORESTS

The stand of western true firs (p. 2) in 1931 is approximately as shown in table 2. The botanical ranges of white fir (*Abies concolor*) and lowland white fir are shown in figure 3. The limits of the ranges shown on the map in figure 3 represent the entire known spread of each species irrespective of whether or not it occurs in commercial size or commercial quantities. Probably less than half of the total stand is considered as commercial by lumbermen at the present time, the limiting factors being ease of accessibility and percentage of more valuable species in mixture with the western true firs. In the range of white fir (*A. concolor*), few stands have been exploited where the proportion of pines was less than 50 percent.

TABLE 2.—*Estimated virgin stand of western true firs by species*

[Revised estimates made by the Forest Service, 1931]

Common name	Botanical name	State	Approximate virgin stand—millions of feet, board measure
White fir	*Abies concolor*	California	28,600
		Oregon	5,500
		Washington	(1)
		Idaho	(1)
		Colorado	(2)
		Arizona, New Mexico	[3] 1,240
		All	35,340
Lowland white fir	*A. grandis*	California	2,200
		Oregon	4,500
		Washington	[4] 2,300
		Idaho, Montana	[4] 9,670
All			18,670
Red fir	*A. magnifica*	California	23,300
		Oregon	(5)
All			23,300
Silver fir and noble fir	*A. amabilis* and *Abies nobilis*	Oregon	[6] 10,920
		Washington	26,800
All			37,720
Alpine fir	*A. lasiocarpa*	Washington	(1)
		Oregon	(5)
		Idaho	2,990
		Montana, Wyoming, Utah	860
		Colorado	[4] 1,640
All			5,490
Total			120,520

[1] Included with lowland white fir.
[2] Included with alpine fir.
[3] Includes corkbark fir.
[4] Includes white fir (*Abies concolor*).
[5] Included with noble and silver fir.
[6] Includes alpine fir and red fir.

In parts of its wide range in California, white fir (*Abies concolor*) is associated in the forest with sugar pine, ponderosa pine, incense cedar, red fir, Douglas fir, and Jeffrey pine (fig. 4). Proportions of each species per acre and size of timber in a mixed stand of the sugar pine-white fir type are given in table 3. Occasionally in this type of stand white fir (*A. concolor*) trees measure 6 feet or more in diameter (fig. 4, *C*) and 200 feet in total height. In northeastern California and south-central Oregon, the forest is largely pure ponderosa pine and ponderosa pine-white fir. In this area, as a whole, the virgin timber stands of the types now considered merchantable will average about 20 percent white fir (*A. concolor*), 7 percent Douglas fir and incense cedar, and 73 percent ponderosa pine and sugar pine. The largest white fir (*A. concolor*) trees in northeastern California are rarely over 40 inches in diameter or greater than eight 16-foot logs in merchantable heights. The bulk of the timber now logged from this area

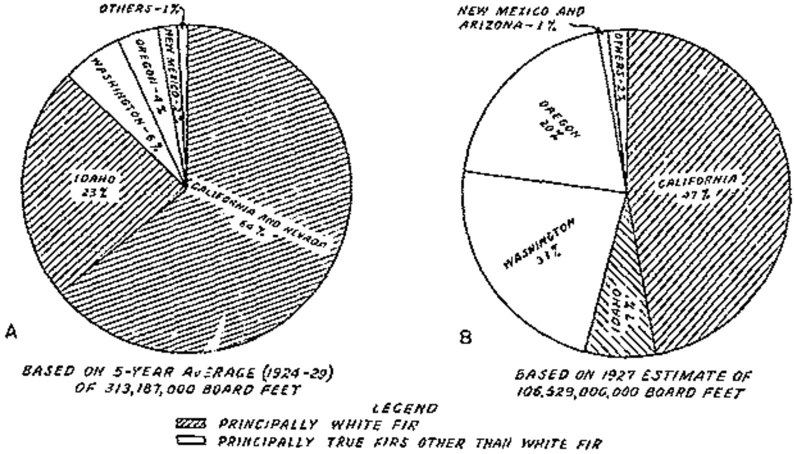


FIGURE 2. -The annual lumber cut and the saw-timber stand of western true firs: *A*, Cut of true western firs by States: *B*, stand of true western firs by States.

varies between 16 and 36 inches in diameter and averages about seven 16-foot logs to a thousand feet, net scale.

TABLE 3.—*Average number of trees of each species by size groups, volume per acre, and maximum size of trees in a stand of the sugar pine-white fir (Abies concolor) type on the western slope of the Sierra Nevada Range*

Species	Trees per acre at a diameter, breast height of—			Volume per acre		Maximum size of tree in stand	
	12 to 23 inches	24 to 41 inches	42 inches and over	12 inches and over diameter breast high	Percentage of total	Diameter breast high	16-foot logs per tree
	Number	*Number*	*Number*	*Board feet*	*Percent*	*Inches*	*Number*
Incense cedar	3.75	3.84	1.23	6,635	11.2	64	8.0
Sugar pine	3.58	2.51	2.54	20,374	34.4	80	11.0
Ponderosa pine	.69	1.45	1.30	11,690	19.7	74	11.5
White fir (*Abies concolor*)	13.08	6.33	1.60	20,585	34.7	65	[1] 10.0

[1] The average white fir (*Abies concolor*) log produced 344 board feet, net log scale, by the Scribner decimal C rule or 364 board feet, gross log scale. On the net scale the logs averaged 2.9 to each 1,000 board feet; gross log scale, 2.75 to each 1,000 board feet.

Being quite tolerant of shade, the branches of white fir persist on the lower part of the trunk until maturity, resulting in a much smaller percentage of select grades than is commonly obtained from the pines. In addition many of the logs that would qualify for this grade on the basis of size and clearness contain so much decay that they are left in the woods. In the pines, 2 and 3 grade 1 logs are fairly frequent in mature trees, but it is exceptional to find 2 clear logs in a white fir tree. In a typical stand in Tuolumne County, Calif., only 9 percent of all white fir (*Abies concolor*) logs brought to the mill could be classified as grade 1. Of the remainder, 52 percent were grade 2

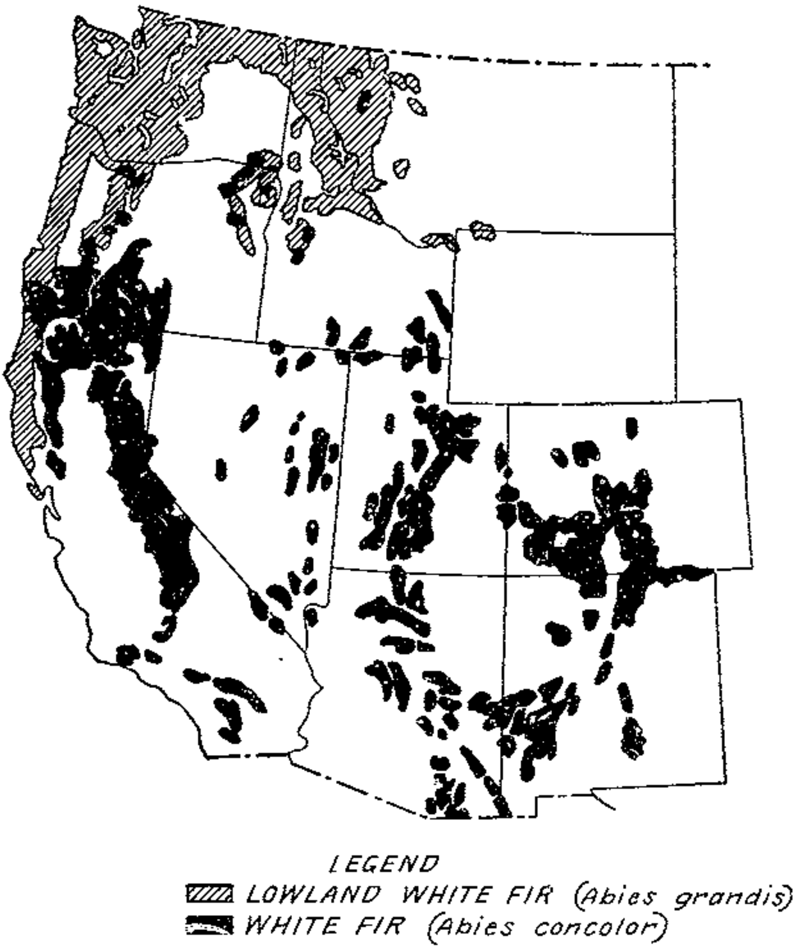


FIGURE 3.—Distribution of white fir (*Abies concolor*) and lowland white fir in the United States (*20*).

logs of the small-knotted common type and 39 percent were grade 3 of the large-knotted common type.

Lowland white fir (p. 2) is second of the western true firs in amount of lumber cut. About one twelfth of the stand and one fourth of the cut of the true firs are of this species. The botanical range includes southern British Columbia, western Montana, Idaho, Oregon, Washington, and northwestern California (*21*). The species seldom occurs in pure stands with the exception of small areas.

In the Inland Empire the lowland white fir tree on the best sites attains a diameter of 3 feet and a maximum height of about 140 feet.

FIGURE 4.—*A*, Mixed sugar pine, ponderosa pine, and white fir virgin forest on the Sierra Nevada Range. The darker, rough-barked tree near the man in the foreground is a white fir (*Abies concolor*). The lighter-colored tree with smooth bark is ponderosa pine. *B*, Mature and overmature white fir (*A. concolor*) left on logged area. *C*, A white fir (*A. concolor*) tree 68 inches in diameter.

The average mature trees to be found on any site are usually not over 18 inches in diameter and 80 feet in height (*15*). In California it is associated chiefly with redwood and Douglas fir. It forms only about 3 percent of the stand. Here on the better sites, it grows somewhat taller than white fir (*Abies concolor*), but seldom attains a diameter greater than 4 feet. It is less tolerant of shade, has more clear length, and is less defective than white fir (*A. concolor*) of California

EFFECT OF WHITE FIR ON FOREST MANAGEMENT

The lumber user, for whom this bulletin has been primarily prepared, is not particularly interested in the forest-management problems of the silviculturist and the lumberman. Furthermore, within the wide range of the western true firs (p. 2) the numerous variations in silvicultural and lumbering problems arising from the many local variations in climatic, stand, and topographic conditions and lumber-marketing considerations cannot adequately be covered in anything less than a separate bulletin. However, a brief discussion of some of the more important aspects of timberland management in the region where most of the white fir lumber is produced will give the consumer an enlightening perspective of the unsuspecting part he plays in the sphere of western forestry when he buys white fir boards or dimension from his local retail dealer.

At present, most of the private timberland operators in the West have not made any consistent attempts to operate on a sustained-yield basis. Their cutting systems are usually based exclusively on two factors, namely, comparative lumber values by species, and defect, that is, the cull material in the trees. The species showing the highest average values are cut heavily, usually to very small tree-diameter limits. Only badly defective trees are left standing. Species of low average value are cut lightly or not at all. A few operators have recently modified their cutting practices to some extent with the idea of leaving a better reserve of growing stock, but by and large, the current profit margin derived from deducting average woods-run costs from average mill-run species value determines the cutting and utilization rules to be followed by the woods crews.

When the average selling value of white fir lumber is below the average production cost, as it has been in the past, cutting principles based on lumber values and defect naturally lead to forest deterioration in stands containing a large proportion of white fir. With trees of the more valuable species above 12 to 18 inches in diameter practically all removed, the second cut must necessarily be confined to the less valuable white fir. If the white fir were inherently resistant to decay and tree-killing insects and were preponderantly sound and thrifty in the mature classes, the result would not be so serious, but unfortunately the situation is not so favorable, directly the reverse, in fact, in the pine-white fir (*Abies concolor*) types of the Sierra Nevada.

All things considered, the evidence is convincing that the older white fir trees not removed with the first cut from the virgin forest will be practically a total loss before the second cutting takes place. But this is by no means the really serious result of such practice. Decadent and diseased trees occupy root space and use soil moisture just as truly as sound trees, regardless of the fact that they are contributing nothing to the net increment of merchantable wood. Thus they continue to retard the growth of surrounding young trees and detract further from the potential yield of the site. Badly diseased trees are also an added menace as prolific centers of infection.

Another undesirable consequence following the removal of only the pines in a mixed pine-white fir stand is the effect on the composition of future yields. White fir is usually a more prolific seeder than its associated species, the seedlings are more tolerant of shade, and it is persistent. From these factors it follows that a preponderance of white fir left on a cut-over area now will most likely result in a preponderance of white fir in succeeding generations.

White fir lumber undoubtedly will bring greater returns in the future than it brings at present, but it is hardly conceivable that it will ever be as valuable to the commonwealth as pine lumber, considered from the standpoint of uses as we are able to visualize them at present. If the greatest value is to be realized from future forest crops, therefore, the plan of management should incorporate whatever measures appear to offer the greatest likelihood of increasing, or at least of holding even the present proportion of more valuable species in the virgin stand.

The question now arises—Why has the selling price of white fir lumber, in normal times, been below the cost of production? This is a fair question because white fir lumber is intrinsically worth enough more than the price usually received for it to wipe out the operating deficit and thus allow the species at least to pay its way.

A complex of factors leading to over production of competing species and consequent demoralization of selling prices, combined with considerable prejudice traceable to unsound manufacturing and merchandising practices have made the price of white fir lumber what it is, rather than any inherent inferiority of the wood itself. White fir is now giving and has given satisfactory service wherever it has been properly manufactured, thoroughly seasoned, and intelligently used. Trouble has followed when it has been nailed in place in a green or half-dried condition, when it has been used in situations favorable for the development of wood-rotting fungi, when the wrong grades, types, and sizes of material have been substituted for the classes of stock that should have been used and when careless workmanship has resulted in the failures inevitably following a disregard of sound fabricating and construction principles.

Just as white fir occupies an important place in the general scheme of forest management wherever it occurs in appreciable quantities, so likewise should it occupy a position of importance in fulfilling many requirements of wood users. It is hoped this bulletin will help prevent in the future many of the abuses to which white fir has been subjected by describing its qualifications for particular purposes, and by explaining its peculiarities and limitations so that the consumer may know when and how it should not be used as well as when and how it should be used.

From the standpoint of sound forest management in the true fir types, it is highly important that the evils lying at the root of the existing prejudice against white fir lumber in many quarters be speedily corrected.

MERCHANDISING PRACTICES

DISTRIBUTION OF LUMBER CUT

The Mississippi Valley States are the largest consumers of white fir lumber (p. 2) and take about one third of the annual cut. California consumes about one fourth of the total annual cut and about seven eighths of the cut consumed in California is home grown. The Inland Empire produced about one fourth of the total annual cut but uses less than any consuming region except the Pacific Northwest. Over one half of the white fir is shipped to distant markets (table 4).

TABLE 4.—*Distribution of the lumber cut of the western true firs* [1] *by regions*

Place of use	Shipped from—				Total	Consumption of the total production for the United States
	California	Inland Empire	Washington and Oregon	Rocky Mountain States		
	M board feet	*M board feet*	*M board feet*	*M board feet*	*M board feet*	*Percent*
California	69,374	735	11,605	----------	81,714	27.9
Other States west of Rocky Mountains	3,469	735	5,802	----------	10,006	3.4
Rocky Mountain States	5,203	736	3,868	7,370	17,177	5.9
Prairie States	13,875	7,353	5,802	----------	27,030	9.2
Mississippi Valley States	65,906	40,443	3,868	----------	110,217	37.6
Atlantic coast	15,609	23,531	7,737	----------	46,877	16.0
Total	----------	----------	----------	----------	293,021	100.0

[1] White fir, lowland white fir, silver fir, California red fir, and alpine fir, collectively reported by the Bureau of the Census under the name "white fir."

PERCENTAGE OF THE CUT GOING INTO VARIOUS LUMBER ITEMS

White fir has gained its greatest popularity as construction material for small buildings, particularly as framing. For this reason, over one half of the total white fir production in California is now made into small dimension, chiefly of the 2- by 4-inch and 2- by 6-inch sizes.

Most of the select grades in white fir are usually square-edged stock although various patterns, such as ceiling, siding, and baseboard are also made in the select grades. Heavy construction timbers are manufactured frequently to fill special orders. There has been little attempt made so far to supply the general market for large sizes as a regular mill practice. Ties are produced regularly for use in logging railroads.

Table 5 shows the approximate distribution in the various lumber items of white fir marketed from California in 1931. Ties, timbers, and other material used in the manufacturers' own operations are not included.

TABLE 5.—*Percentage of white fir from California going into various classes of sawmill products* [1]

Kind	Item and grade	Total sales
		Percent
Select	Square edged and patterns, such as baseboards, siding, ceiling, and flooring of D and better grade	3.0
Dimension [2]	No. 2 and better 1⁹⁄₁₆ and 1⅝ inches	43.0
	No. 2 and better 1¾ and 1⅞ inches	7.5
	No. 2 and better miscellaneous	4.0
	No. 3 dimension all thicknesses and all widths	4.5
	Total	59.0
Common	No. 3 and better common [3]	15.5
	No. 4 common	5.0
	No. 5 common	1.0
	Box lumber and box shook	12.5
	Total	34.0
Timbers	End dimensions of all sizes. Mostly less than 26 feet in length	4.0
Total		100.0

[1] Ties, timbers, and lumber used by operators are not included.
[2] Largest single item in small dimension is the nominal 2- by 4-inch size.
[3] Includes shiplap, tongue and groove, flooring, and roofing.

SIZES IN WHICH COMMONLY MARKETED

Most of the nominal 2-inch white fir dimension shipped to the Eastern States is surfaced to 1⁹⁄₁₆ inches in thickness. American lumber

FIGURE 5.—A medium-sized mill operating in mixed pine and white fir (*Abies concolor*) type in central California.

standards thickness of 1⅝ inches may be obtained at a somewhat higher price but the bulk of all shipments is of the substandard size. This practice originally became established in the manufacture of pine dimension for box lumber. For surfaced 1⅝-inch dry dimension, green planks must be cut 1¾ inches thick, which means greater waste if later made into box shooks or sold as 6/4 box lumber. At the time of sawing (fig. 5) it is difficult to foretell whether a box demand or a dimension demand will prevail later in the season, therefore the mill man cuts this stock so that it may serve a dual purpose.

An opposite departure from American lumber standards is the extra-standard white fir dimension marketed in the San Joaquin Valley of California by six nearby mills. This is surfaced to 1¾ inches and 1⅞ inches in thickness. This oversized stock, known locally as "Valley dimension", is produced specifically to compete with naturally stronger woods.

MOISTURE CONTENT OF LUMBER AS MARKETED

The marketing of white fir in a half-dried condition is responsible more than any other thing for the current prejudice against white fir. The lumber manufacturers can remove a large part of this prejudice through proper seasoning. If they sell only good and dry white fir lumber, there is no apparent reason why a larger demand will not be forthcoming.

It has been common practice at some mills to machine and ship white fir for local use at a moisture content of more than 25 percent of the weight of the dry wood. Much of such material is not green in the sense that all of the moisture is present that was in the log when the tree was cut, which may have been from 100 to 200 percent, but it is practically equivalent to green lumber from the shrinkage standpoint (p. 12), and will be unsatisfactory if built into construction without further seasoning. Much partially seasoned white fir lumber, that is, lumber having an average moisture content of about 18 percent, has also been marketed. As a rule, lumber for eastern shipment has been more thoroughly seasoned than lumber sold locally because railroad freight charges on lumber are based on weight and therefore the longer the haul the more profitable it is to season the lumber thoroughly before shipment. If the lumber is shipped directly after removal from the green chain, the entire cost of extra handling and seasoning is saved, which means an appreciable reduction in total operating expense, but since unseasoned white fir lumber, or any unseasoned lumber for that matter, is unsuited for most of the uses to which the species is best adapted, such practice results in dissatisfaction on the part of the consumer and ultimately loss to the manufacturer. On the other hand, well-seasoned white fir is obtainable from reliable mills and reliable lumber dealers when well-seasoned lumber is specified.

HOW TO DISTINGUISH WHITE FIR FROM OTHER WOODS

The exceptionally flat, white color of the spring wood makes it easy to distinguish white fir lumber (p. 2) from that of all but a few woods. Douglas fir, the pines, cedars, cypress, and redwood are all readily distinguished from white fir by color differences. The other true firs, hemlocks, and spruces, however, are light-colored woods which are not so easily distinguished from white fir. As a matter of fact, there is no known method of positively distinguishing the wood of white fir from that of the other true firs even with the aid of a microscope. The wood of white fir can be positively distinguished from the spruces by the resin ducts in the latter. Resin ducts are normally absent in white fir. The hemlocks are distinguished from white fir by their darker color. Individual isolated specimens, however, are difficult to identify on the basis of color alone, and positive identification can only be made by structural differences visible under the microscope.[7] Where white fir and western hemlock lumber are mixed, as they often are, it is comparatively easy to distinguish white fir by the flat, white color of spring wood which contrasts with the darker color and silky sheen of the western hemlock. In addition the summer wood imparts a bluish-purple tinge to white fir and occasional trees yield lumber of a decided grayish hue. Although such material is quite unlike the general run of white fir in appearance it is, so far as is known, in no way inferior for general use.

DESCRIPTIVE PROPERTIES OF WHITE FIR

STRUCTURE, COLOR, AND ODOR OF WOOD

The annual rings of white fir (p. 2) are distinct, consisting of wide bands of spring wood and narrow bands of summer wood (pl. 1). The spring wood merges gradually with the summer wood. The result is a distinct though not pronounced figure that is similar to the figure of the spruces and the hemlocks. The figure is enhanced with natural finishes. Its attractiveness as compared with other species is a matter of personal preference. The figure is not so pronounced as that of Douglas fir but is more pronounced than that of the white pines.

White fir is a straight-grained, fine-textured wood. While it is described as straight grained, it, like many other species, contains some cross-grained material. The cross grain may have developed in the trees or in manufacturing. The amount of cross grain in white fir will probably not differ greatly from that in the principal softwoods.

The wood cells of white fir are fairly uniform in size. The summer-wood cells are thicker walled than the spring wood but summer-wood cells are comparatively few in number. The wood is therefore described as fine textured.

The heartwood and sapwood contain less color than any other of our commercial softwoods, and are therefore not distinguishable. What color exists in the lumber of both white fir (*Abies concolor*) and lowland white fir is due to a slight reddish-brown tinge in the summer wood (*9*), the spring wood of both species being flat white. There is a decided preference for light-colored or white wood in a number of uses, especially containers. This preference makes the whiteness of white fir an asset.

The lumber of white fir has a slightly disagreeable odor when green. When seasoned the wood is without distinctive odor. The odor of green wood failed to return when the wood was soaked in trials made at the Forest Products Laboratory. These trials are substantiated by tests made by the University of California (*25*) and by the fact that white-fir boxes have been used with entire satisfaction for shipping butter.

HEARTWOOD CONTENT

The decay resistance of both the heartwood and sapwood of white fir is low; consequently the percentage of heartwood in white fir has no particular utility value.

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

ANNUAL GROWTH RINGS

White fir grows relatively fast. The annual growth rings in the lumber are therefore wider than those in most of the commercial softwoods. The rings average about 12 to the inch. The select grades average about 17 rings to the inch and common grades about 11. The width of the annual growth ring materially affects the figure of the wood but otherwise has no great practical signifinance in white fir lumber because of the fairly uniform texture within each annual ring.

WEIGHT OF THE WOOD

White fir is one of the lightweight softwoods. In a thoroughly air-dry condition of 12-percent moisture content white fir (*Abies concolor*) weighs 26 pounds and lowland white fir, 28 pounds per cubic foot. One thousand board feet of nominal 1-inch white fir (*A. concolor*) at 12-percent moisture content surfaced to twenty-five thirty-seconds inch will weigh about 1,550 pounds in 4-inch widths or 1,600 pounds in 10-inch widths; lowland white fir in corresponding widths will weigh about 100 pounds more per thousand board feet than white fir (*A. concolor*). The actual weight of white fir lumber as shipped will vary from the foregoing weights from about 4 percent lower to 10 percent higher, depending upon the degree of seasoning. Other items of white fir will vary in weight because of degree of seasoning and because the relation of actual to nominal dimension is different. Items of pattern stock will weigh less than square-edged stock because of the material that has been removed. A comparison of the weight of the wood of white fir (*A. concolor*) and lowland white fir with a number of the important commercial softwoods is made in figure 6. The comparison is made for air-dry wood of 12 percent moisture content.

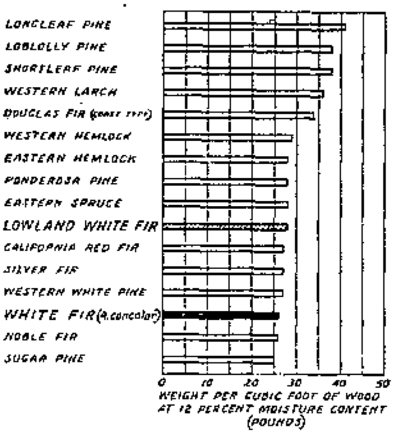


FIGURE 6.—The weight of air-dry white fir (*Abies concolor*) compared with the weight of other species.

There is little difference between the weight of white fir lumber and that of the other western true firs (p. 2). About the maximum difference to be expected in a thousand board feet of 1-inch dressed lumber at 12-percent moisture content of any of these species is 100 pounds. Douglas fir (coast type) lumber when thoroughly air-dried will weigh from 400 to 500 pounds more per 1,000 board feet than white-fir lumber. Sugar pine, on the other hand, will weigh from 50 to 200 pounds less.

The light weight of white fir is one of the properties largely accountable for the general use of the wood. It reduces cost of transporting the lumber to markets, reduces handling costs, and is a desired property in boxes and other containers.

SHRINKAGE

White fir shrinks less than most of the other important softwoods. The average shrinkage from a green to an oven-dry condition is about the same as that of ponderosa pine and eastern hemlock, lowland white fir having a larger and white fir (*Abies concolor*) having a slightly smaller shrinkage than these two species. The other western true firs, with the exception of alpine and corkbark fir, have a higher shrinkage than white fir as do the other species that are sold in mixture with white fir.

A comparison of the shrinkage of white fir (*A. concolor*) with the shrinkage of other softwoods is shown in figure 7. The comparison is based on the total shrinkage from a green to an oven-dry condition.

Small change in dimension from swelling and shrinking is a property desired in practically all uses, even in such uses as subfloors,

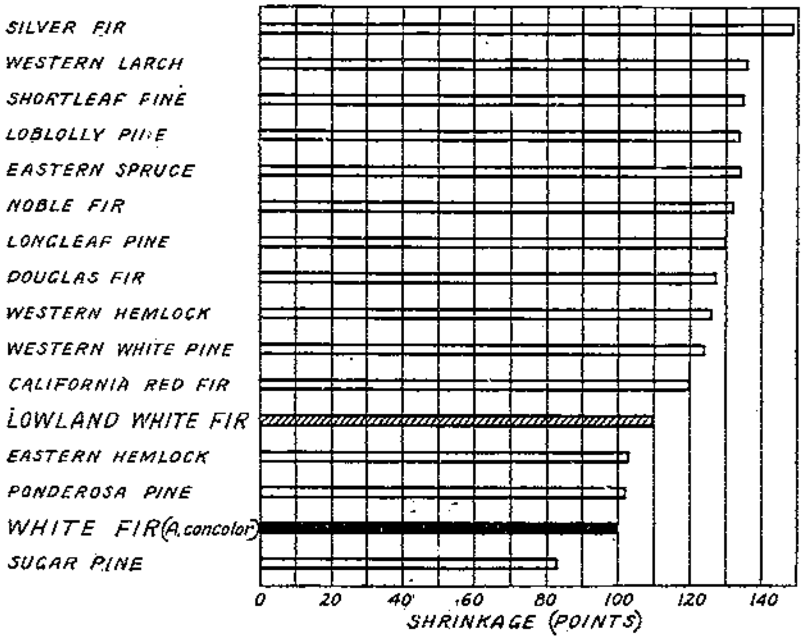


FIGURE 7.—The shrinkage of white fir (*Abies concolor*) compared with other species. White fir (*A. concolor*) is taken as 100 points.

sheathing, or concrete forms. In the more exacting uses, such as window sash, doors, and interior trim, small shrinkage is of prime importance. The comparison of the shrinkage of white fir (*Abies concolor*) and lowland white fir with that of other woods indicates that their shrinkage is small enough to meet the requirements of both rough and of many exacting uses.

The average shrinkage to be expected in white fir lumber between any given moisture conditions can be obtained from figure 8. For example, to determine the average change in dimension of 1 by 8 inch flat-grained white fir subflooring between 6 and 12 percent moisture, a horizontal line through 6-percent moisture meets the curve representing flat grain at 5.4 percent; a similar line through 12 percent meets the same curve at 3.7 percent. The difference between the two values is 1.7 percent. The difference multiplied by 7⅝, the actual width of nominal 8-inch boards, gives the amount each board will shrink, which is about one eighth of an inch. The curves of figure 8 are based on measurements made on short sections of boards selected from the commercial run of white fir lumber at a mill in the Inland Empire. A convenient rule-of-thumb for determining dimension change in percentage is to multiply the moisture change in percentage by one sixth for edge-grained and by one fourth for flat-grained lumber for the change in dimension of an 8-inch flat-grained board. This corresponding to a 6-percent change in moisture content would be 6×¼ or 1.5 percent of 8 inches, or about one eighth of

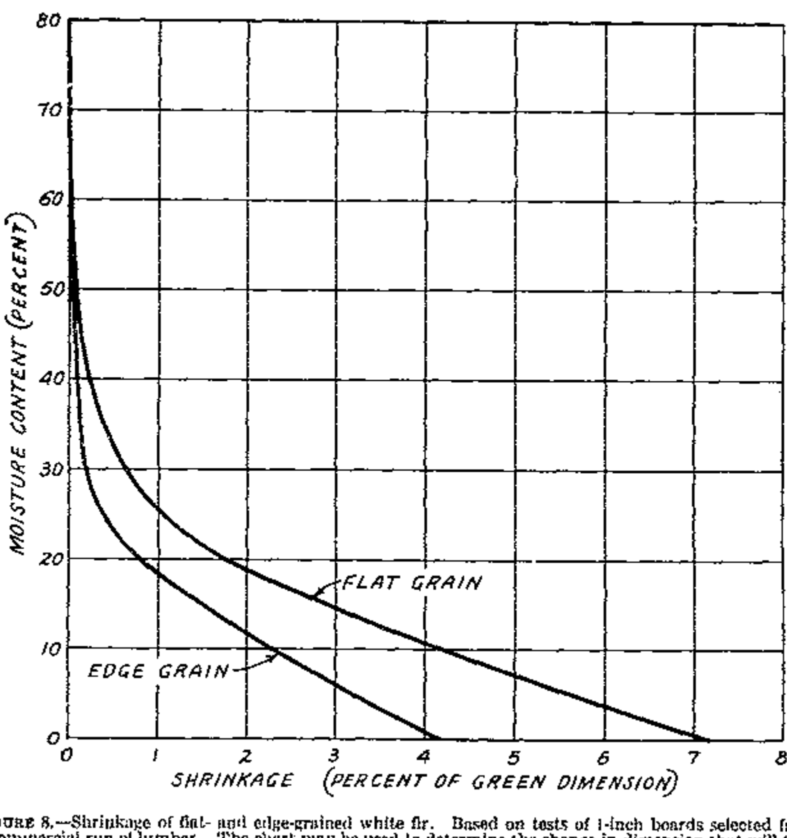
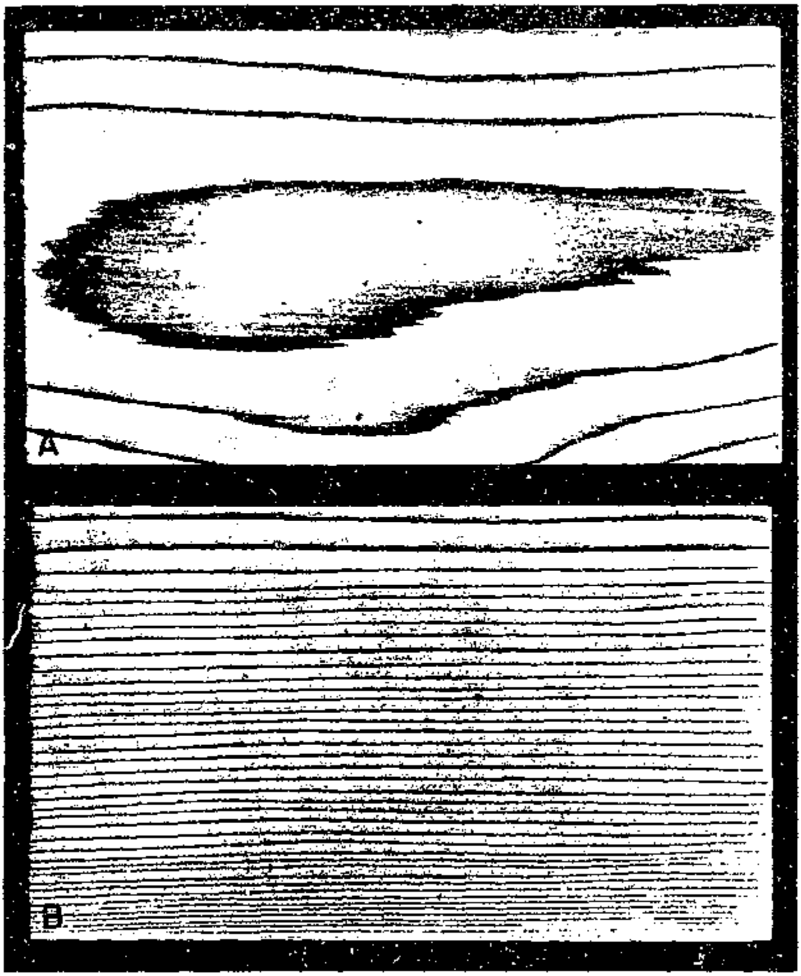


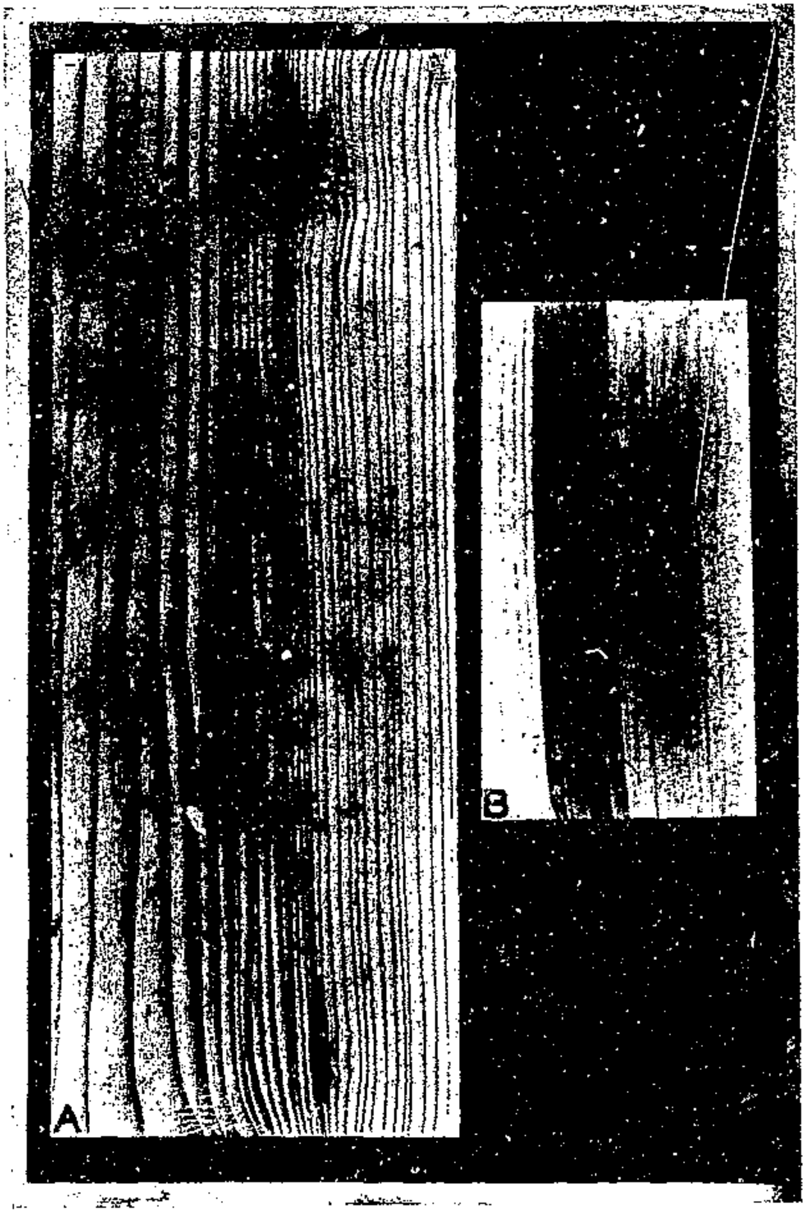
FIGURE 8.—Shrinkage of flat- and edge-grained white fir. Based on tests of 1-inch boards selected from commercial run of lumber. The chart may be used to determine the change in dimension that will take place with changes in moisture content of wood.

an inch. In an 8-inch, edge-grained board the change would be 6×⅙ or 1 percent, or about one twelfth of an inch.

When the marketing practices are considered, it is not difficult to understand why the moderately small shrinkage of the white fir has not created a more favorable impression. The marketing of wet or insufficiently dried wood has more than offset any advantages the species have as a result of their inherently small shrinkage. White fir lumber marketed at more than 25-percent moisture content, if used in the interior of buildings, will probably dry to 6 percent in moisture content when the buildings are heated. The shrinkage in an 8-inch flat-grained board under such conditions is shown by figure



TYPICAL FLAT-GRAINED AND EDGE-GRAINED WHITE FIR.
A, Flat grain. B, Edge grain.



A, Dark streak in white fir. B, Pronounced compression wood is shown by the darker colored band. Note the cross breaks resulting from the excessive longitudinal shrinkage of this abnormal wood.

8 to be about one third of an inch, which is too large a shrinkage for most uses. So long as any large proportion of white fir lumber is marketed before it is adequately seasoned the wood will not acquire the reputation for small or moderately small shrinkage to which it is entitled.

CHARACTERISTIC DEFECTS

The characteristic defects of a species not only affect the appearance but also determine the suitability of the lumber for specific uses. A detailed tally was made of all defects in 20,000 board feet of 1- by 8-inch white fir (p. 2) boards. One half of the material was studied at 2 mills in the Inland Empire and one half at 1 mill in California.

There was a marked difference in the character of the defects between the white fir lumber from the Inland Empire and that from California. Part of this difference was because the grades are not identical (p. 41) and part because of species differences. The defects found in the lumber of the two sections are therefore presented separately. Table 6 tabulates the occurrence of the principal defects found in the various grades in the two regions.

TABLE 6.—*Occurrence of defects in white fir lumber as shipped from California and the Inland Empire*

Defect	Occurrence of defects expressed as percentage of all boards studied					
	California [1]			Inland Empire [2]		
	C and Better	No. 2 and Better	No. 3 Common	D and Better	No. 3 and Better	No. 4 Common
Knots	41	92	98	92	100	100
Checks	13	16	28	20	38	59
Wormholes	8	7	9	1	2	6
Stain	5	4	3	5	5	14
Torn grain	6	(3)	(3)	12	(3)	(3)
Dark streaks	3	(3)	(3)	52	(3)	(3)
Splits	1	4	7	4	25	45
Shake	......	3	3	2	4	4
Wane	......	2	2	1	4	7
Decay	......	1	8	......	6	17
Pith	......	1	......	......	5	8
Holes	......	......	......	13	......	......
Skips		......		4	......	......
Burn		(3)	(3)	2	(3)	(3)

[1] Based on 10,400 board feet principally of white fir (*Abies concolor*).
[2] Based on 9,400 board feet principally of lowland white fir.
[3] This defect did not affect the grade and therefore was not recorded.

Defects are of three general types: natural, seasoning, and manufacturing. Natural defects develop in the growing tree. Seasoning and manufacturing defects develop during logging, milling, or storage. The natural defects are distinctly characteristic of species. Seasoning and manufacturing defects, on the other hand, are primarily indicative of methods used in manufacture but do show certain species tendencies. Thus the amount of checking found in the lumber is dependent largely upon the seasoning methods used but a species with a large difference between radial and tangential shrinkage will check more than one with more uniform shrinkage.

NATURAL DEFECTS

KNOTS

The knots of white fir as compared with those of other softwoods are in general intermediate in size and number. In the mill run of white fir, the knots averaged slightly over one half inch in diameter and there were about 1,200 to a thousand board feet. The knots averaged about the same size as those in western hemlock, were smaller than those in eastern hemlock, and larger than those in Douglas fir (coast type). A large proportion of the knots in white fir were black. They were exceptionally free from decay, but a higher percentage were loose, broken, or checked than in any of the other species studied.

The difference in the size and number of the knots in white fir from California and the Inland Empire is shown in detail in table 7. White fir lumber in the Inland Empire contained more than twice as many knots as the white fir lumber of California. The knots in the white fir of the Inland Empire were, however, much smaller.

TABLE 7.—*Size and number of knots in white fir lumber* [1]

Place of growth	Grade	Knots per thousand feet board measure	Average diameter	Percentage of all boards containing the defect
		Number	*Inch*	*Percent*
California	C and Better	89	0.41	41
	No. 2 and Better	849	.71	92
	No. 3 Common	1,059	.88	98
Inland Empire	D and Better	636	.30	92
	No. 3 and Better	2,103	.46	100
	No. 4 Common	2,300	.48	100

[1] Based on 20,000 board feet studied by the Forest Products Laboratory.

PITCH DEFECTS

White fir is nonresinous [5] and normally contains no pitch pockets, pitch streaks, or pitch in any form. The absence of these defects is a decided advantage where lumber is to be painted or where odor, taste, or exudations are objectionable.

SHAKE

About 1 board in every 33 of the white fir studied contained shake. Of the 14 commercial softwoods included in the study, 4 showed less and 9 showed more shake than white fir. Ponderosa pine had about one third as much shake and shortleaf pine about twice as much as white fir. Though the amount of shake in white fir was small, when it did occur it was of a severe type. There was no great difference between the shake found in white fir lumber from the Inland Empire and that from California.

DARK STREAKS

Dark streaks are peculiar to the western true firs (p. 2) and western hemlock. They consist of dark brown or black scars result-

[5] Occasionally as a result of injury to tree resin ducts and pitch pockets are formed. They are rare and insofar as the use of the wood is concerned, are of no practical importance.

ing from the attack of the fir bark beetle. In edge-grained boards the scars appear as thin streaks or seams ranging from a few inches to several feet in length. In flat-grained boards they appear as small, black bark pockets (pl. 2, *A*). The streaks are so narrow in edge-grained boards that they are not considered defects in any lumber grades. In the common lumber neither the streaks nor the bark pockets are considered defects. From one third to one half of the white fir lumber studied in the Inland Empire, depending on grade, had dark streaks. In white fir from California dark streaks occurred in only 3 to 10 percent of the lumber. The frequency of the occurrence of dark streaks is therefore a rough indication of the region from which the material was cut.

DECAY

In the study of the defects in 1-inch boards decay was found more frequently in white fir than in most woods. About 1 piece in 11 contained decay as compared with about 1 piece in 10 of western white pine and 1 piece in 24 of Douglas fir (coast type). No decay, however, was found in the select grades. Practically all of the decay found in the better common grades of white fir from both California and the Inland Empire was incipient. Advanced decay was present in from 4 to 5 percent of the lumber of the third grade in each region. Pieces having either advanced or incipient decay should not be used where strength is an important requirement.

WORMHOLES

The wormholes in white fir were principally pinholes. In the white fir from the Inland Empire 1 to 6 percent of the pieces studied had wormholes and in that from California 7 to 9 percent. Except in certain uses of C and better grade, the wormholes are of little importance. The effect of wormholes upon strength is negligible except in very small pieces.

PITH

Pith is a defect of minor importance and occurs only occasionally in lumber of any species. The select grades of white fir showed no pith and it was present in only from 1 to 8 percent of the lumber of the common grades.

CROSS GRAIN

The grading rules do not class cross grain as a defect in the yard lumber of any softwood species. No mention is made of it in the grading rules for white fir. Cross grain, however, is a serious defect because of its injurious effect upon the strength. It is also responsible for much of the warping of the twisting type.

COMPRESSION WOOD

Compression wood (*18*) is abnormal wood (pl. 2, *B*). It is generally somewhat darker than the normal wood and is characterized by a lack of strong contrast between summer wood and spring wood. It shrinks longitudinally much more than normal wood and therefore is objectionable in lumber because the longitudinal shrinkage causes lumber to warp and in extreme cases to rupture. In service, compression wood is often responsible for open joints.

A study of the occurrence of compression wood in white fir showed that about one fourth of the lumber contained varying amounts of compression wood. About three fourths of this compression wood was of such a type that it would not seriously injure the serviceability of the lumber. Although the lumber grader takes no account of compression wood, the twisting and cross breaks resulting from it cause the worst of it to be eliminated at the mill or the lumber containing it to be dropped into the lowest grades that go into less exacting uses.

Observations were also made on the compression wood in ponderosa pine, sugar pine, and western white pine. In two of these species compression wood occurred with about the same frequency as it did in white fir and in all three species the type of compression wood that causes cross breaks was more prevalent than it was in white fir. The problem of compression wood is, therefore, not peculiar to white fir, but is common to most of the commercial softwoods.

SEASONING DEFECTS

White fir has acquired a worse reputation for seasoning defects than it deserves. This reputation is based on behavior of partially seasoned lumber in service. The partially seasoned lumber exposed to the sun and wind in service dries too rapidly, and, only one side being exposed, dries unevenly. The checking and splitting that result are consequently much worse than would occur in the seasoning pile.

About one third of the thoroughly seasoned white fir lumber studied was checked, about one fifth contained splits, and about one sixteenth was stained. All but 3 of the 14 softwood species studied showed less checking and splitting than white fir. About one half of the species studied showed more staining.

The more general use of dry kilns and the improvement of seasoning practices and drying schedules will reduce the number and seriousness of the seasoning defects, especially in white fir.

CHECKS

White fir has a tendency to check. The tendency is partly because of the large difference between the radial (edge grain) and the tangential (flat grain) shrinkage. In both white fir (*Abies concolor*) and lowland white fir the tangential shrinkage is more than twice the radial shrinkage. Practically all the commercially important softwood species were studied and few had as many checks as white fir and in addition the checks in white fir were somewhat worse. The percentage of the pieces of white fir having checks and the types of checks are shown in table 8. The white fir from the Inland Empire had considerably more checks than that from California. The difference, however, was not important, for it was due principally to the greater number of end checks in the Inland Empire material. The lumber from the two regions did not differ greatly in the types of checks that seriously affect the serviceability.

TABLE 8.—*Percentage of pieces of white fir having checks* [1]

Place of growth	Grade	Small surface checks	Medium surface checks	Large surface checks	End checks	Through checks	All types
California	C and better	9			4		13
	No. 2 and better	8	1		5	3	16
	No. 3 Common	4	5		8	16	28
Inland Empire	D and better	8	3		16		20
	No. 3 and better	10	11	1	18	3	38
	No. 4 Common	10	15		35	13	59

[1] Based on 20,000 board feet studied by the Forest Products Laboratory.

SPLITS

White fir had more splits than most woods studied. The white fir from California had less and shorter splits than that from the Inland Empire. The percentage of splits found in the different grades of the white fir from the two regions is shown in table 9.

TABLE 9.—*Percentage of pieces having split in white fir* [1]

Place of growth	Grade	Short split	Medium split	Long split	All types
California	C and better	1			1
	No. 2 and better	2	3		5
	No. 3 Common	2	4	1	7
Inland Empire	D and better	2	2		4
	No. 3 and better	12	11	2	25
	No. 4 Common	17	18	10	45

[1] Based on 20,000 board feet studied by the Forest Products Laboratory.

STAIN

The sapwood of white fir lumber, although it can be readily stained under laboratory conditions, remains exceptionally free from stain discolorations in the seasoning pile and in use even where moisture conditions are highly favorable for the growth of staining fungi. The sapwood of green ponderosa pine and sugar pine lumber when piled for seasoning on pine stickers ordinarily discolors where stickers and boards are in contact, but when piled on white fir stickers, contact stains are greatly reduced. In parts of California, where staining conditions are quite severe during the fall and winter, white fir logs are frequently accumulated in storage by the operators during the summer in order that the other species may be sawed and piled before staining weather sets in. White fir lumber may be piled regardless of weather conditions with practically no danger of stain depreciation.

In studies of lumber defects less stain was found in white fir than in woods associated with it in the forest and at the mill. The amount of medium and heavy stain in white fir was negligible. Stain was found in 5 percent of the pieces in the select grades from both the Inland Empire and California; however, this stain was so light that it would not be objectionable in lumber to be painted. The stain found in the common grades of white fir would practically never be objectionable in uses to which this class of lumber is put.

TABLE 10.—*Average mechanical and physical properties of the clear wood of white fir compared with other species* [1]

Species of wood	Specific gravity based on weight when oven dry and volume when green	Weight per cubic foot		Composite or index values [2] (white fir taken as 100 points) for—								Strength at 12-percent moisture content	
		Green	At 12-per cent moisture content	Shrinkage	Bending strength	Compressive strength (endwise)	Stiffness	Hardness	Shock resistance	Splitting resistance	Nail holding power	Modulus of rupture	Compression parallel to grain
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
		Pounds	*Pounds*	*Points*	*Points*	*Points*	*Points*	*Points*	*Points*	*Points*	*Points*	*Pounds per square inch*	*Pounds per square inch*
Cedar, western red (*Thuja plicata*)	0.31	27	23	80	83	101	85	90	87	75	104	7,800	5,120
Cypress, southern (*Taxodium distichum*)	.42	50	32	109	110	126	107	124	127	105	146	10,600	6,390
Douglas fir (*Pseudotsuga taxifolia*) (coast type)	.45	38	34	127	125	147	143	141	135	99	149	12,300	7,650
Douglas fir (*Pseudotsuga taxifolia*) (Inland Empire type)	.41	37	31	118	111	123	125	138	120	125	----------	11,400	6,800
Douglas fir (*Pseudotsuga taxifolia*) (Rocky Mountain type)	.40	35	30	108	104	114	112	124	112	109	----------	9,600	6,140
Fir, alpine (*Abies lasiocarpa*)	.31	23	23	97	71	78	74	79	60	81	----------	6,800	4,100
Fir, balsam (*Abies balsamea*)	.34	45	26	108	82	92	93	74	83	69	----------	7,800	4,700
Fir, lowland white (*Abies grandis*)	.37	44	28	110	100	112	123	102	120	88	87	9,400	5,600
Fir, noble (*Abies nobilis*)	.35	30	26	133	103	104	118	93	113	85	----------	10,200	5,660
Fir, California red (*Abies magnifica*)	.37	48	27	120	108	101	105	124	118	118	----------	10,800	5,330
Fir, silver (*Abies amabilis*)	.35	36	27	149	97	104	116	88	117	94	107	9,600	5,650
Fir, white (*Abies concolor*)	.35	47	26	100	100	100	100	100	100	100	100	9,300	5,420
Hemlock, eastern (*Tsuga canadensis*)	.38	50	28	103	100	108	95	121	112	81	120	8,900	5,490
Hemlock, western (*Tsuga heterophylla*)	.38	41	29	126	103	115	113	119	122	100	143	10,000	6,200

Larch, western (*Larix occidentalis*)	.48	48	36	136	124	142	120	152	135	94	163	11,800	7,480
Pine, loblolly (*Pinus taeda*)	.50	54	38	134	129	142	131	148	155	114	159	13,000	8,200
Pine, longleaf (*Pinus palustris*)	.55	50	41	131	147	168	149	181	172	119	194	15,500	9,060
Pine, shortleaf (*Pinus echinata*)	.49	51	38	135	135	142	134	162	185	128	186	13,400	7,860
Pine, sugar (*Pinus lambertiana*)	.35	51	25	83	89	93	88	90	92	107	------	8,100	4,770
Pine, western white (*Pinus monticola*)	.36	35	27	124	96	103	108	83	108	95	132	9,600	5,720
Pine, ponderosa (*Pinus ponderosa*)	.38	45	28	102	90	95	88	98	97	115	120	9,300	5,340
Redwood (*Sequoia sempervirens*)	.39	52	28	71	115	141	108	129	108	------	------	10,100	6,200
Spruce, eastern (average of red and white)	.37	34	28	134	97	103	102	93	112	92	115	9,900	5,720
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 22.

[2] For derivation of composite values except splitting resistance and nail-holding power see Markwardt (*11*).

MANUFACTURING DEFECTS

Skips, holes, and wane were not exceptional in either occurrence or character in the white fir examined. They corresponded about to the average found in other softwoods. Broken knots were more frequent than in most species. Manufacturers complain of the degrade resulting from the breaking of knots in planing especially when planing wood that is thoroughly dry. All species of wood having a high percentage of black knots give trouble from knots breaking. Much can be done to decrease this breakage by regulating the speed of the feed, by careful setting of planer knives, and by keeping the knife edges sharp. Attempting to decrease knot breakage by dressing the lumber wet as is sometimes done results in poor surfaces.

Manufacturing defects in the lower grades of white fir, aside from broken knots, are relatively unimportant as compared to natural and seasoning defects. The frequency with which the important manufacturing defects occur under present manufacturing practice is shown in table 6.

MECHANICAL OR STRENGTH PROPERTIES OF THE WOOD

Wood users generally evaluate a species in terms of other species. The best basis for the comparison of species is the strength of the clear wood. The strength of clear wood is the inherent strength of the wood fibers of the species. Such factors as moisture, defects, size, and the like, have been eliminated, controlled, or adjusted. The following comparisons of the strength properties of the white fir (*Abies concolor*) with those of other species are made on the basis of the strength of the clear wood. White fir (*A. concolor*) is represented as 100 points in order that comparisons may be made with other species by a glance at table 10 or the figures. White fir (*A. concolor*) was chosen as the base in preference to lowland white fir because more lumber is cut from the former, and because some of its strength properties are somewhat lower than those of lowland white fir. When there is no way of knowing from which of the two species the white fir lumber was cut, it is safer and more conservative to use data on the weaker species.

White fir (*Abies concolor*) and lowland white fir are treated separately in tables, graphs, and the discussion of mechanical porperties. This is possible because data are based on material selected in the woods and carefully identified as to species. No attempt has been made to combine any species except that red and white spruce are combined as eastern spruce because lumber of these species is best known by that name.

The comparisons in table 10 are of averages. A knowledge of the probable departure of individual pieces from these averages is often of value. This information is shown in the bottom line of table 10. That is, in any shipment about one half of the material will vary from an average less than the percentage shown in the bottom line of the table, or in other words, there is a 50–50 chance that an individual sample selected at random will not vary from the average more than the percentage shown.

BENDING STRENGTH

White fir (*Abies concolor*) and lowland white fir have the same bending strength. The bending strength of these woods is the same as that of eastern hemlock. In this property they are somewhat higher than ponderosa pine or western white pine, but considerably lower than Douglas fir (coast type) or the southern yellow pines (fig. 9). Eastern spruce and eastern hemlock have for years been extensively used for framing, roofing, subfloors, crates, and other uses in which bending strength is required. White fir will meet requirements for bending strength equally well as these species.

Of the species sold in mixture with white fir, only alpine fir is weaker in bending strength. Western hemlock and California red fir have approx-

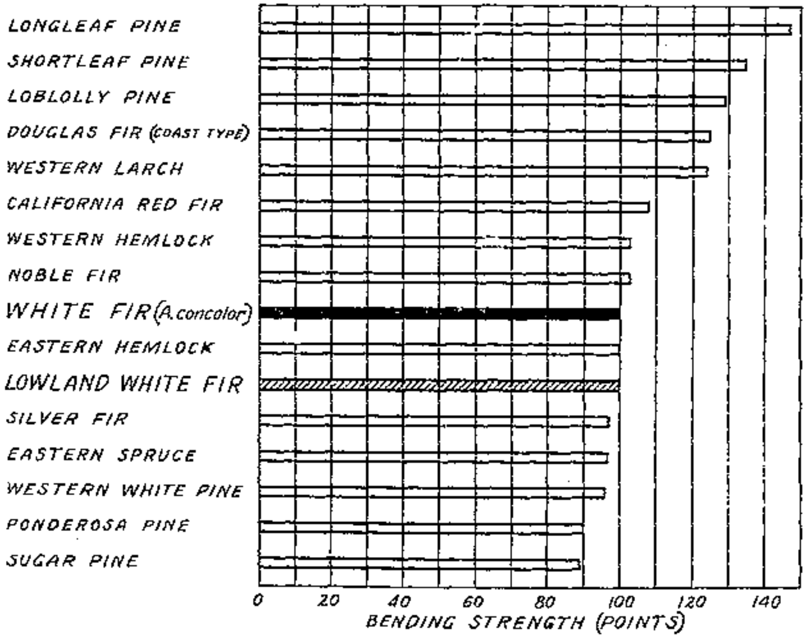


FIGURE 9.—Bending strength of white fir (*Abies concolor*) compared with that of other species of wood. The comparison shown here is for clear wood. The defects present, difference in dressed dimension, or moisture content may change the comparisons.

imately the same bending strength as white fir. The silver and noble firs likewise have about the same bending strength as white fir and can also be used interchangeably with it. Alpine fir should not be mixed with white fir lumber because the former has lower bending strength.

The bending strength of lumber is dependent more upon the defects present than upon the strength of the clear wood. The strength of joists, rafters, and structural timber is therefore largely a matter of grade. Comparison of the bending strength of structural material should be based on working stresses for fiber stress in bending shown on page 52.

The bending strength of white fir adapts it particularly to dwelling-house and other light construction. White fir can be used in structural sizes for bridges and mill-type construction, but such timbers of white fir must be larger than those of Douglas fir, western larch, and other heavier species in order to obtain the same bending strength.

COMPRESSIVE STRENGTH (ENDWISE)

White fir is in a group of softwoods that have about the same compressive strength (endwise). The group includes eastern hemlock, eastern spruce, and noble, silver, and California red firs (fig. 10). Lowland white fir is the strongest of the group and white fir (*Abies concolor*) the weakest. The difference between the two white firs is about 12 percent. The group is considerably lower in compressive strength

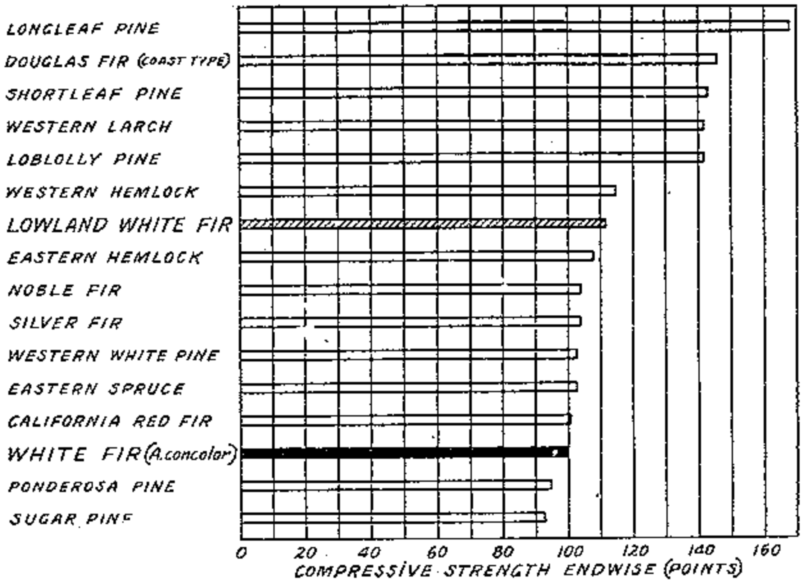


FIGURE 10.—Compressive strength of clear wood of white fir (*Abies concolor*) compared with that of other woods. The effect of defects, difference in dressed dimension, or moisture content may change the comparisons.

than the heavier woods, such as Douglas fir, southern yellow pine, and western larch, but is slightly higher than lightweight softwoods, such as western white pine, northern white pine, sugar pine, and ponderosa pine. All of the species in the group are interchangeable in uses where compressive strength (endwise) is an important requirement.

White fir posts and short columns in small houses and light construction need be no larger than those of woods with much higher compressive strength. The posts required to obtain the desired bearing area, stiffness, or stability for such uses are large enough to carry much greater loads than are ever placed upon them. Posts in small houses, therefore, do not fail from overloading. Post supports for bins and posts for similar heavy construction may be subjected to loads of sufficient size to cause failure. In such industrial uses white fir posts must be larger than posts of Doughlas fir (coast type), southern yellow pine, and other heavy or moderately heavy woods in order to have the same load-carrying capacity. The safe load-carrying capacity of structural timbers can be determined from working stresses given on page 52.

SHOCK RESISTANCE OR TOUGHNESS

Shock resistance or toughness is the capacity to withstand suddenly applied loads, a property desirable in some degree for practically all uses, but particularly essential for wood subjected to repeated shocks, jars, jolts, and blows. For uses such as tool handles, wheel spokes, and athletic equipment, where shock resistance is the principal requirement, only the heaviest hardwoods like hickory, ash, and elm can be used. On the other hand, where a degree of toughness is desired and it is equally or more important to have light weight, uniform texture, ease of working, or a combination of these or other properties as in ladder rails, boxes, and joists, the softwoods are preferred. White fir can meet requirements that permit the use of the lighter-weight softwoods but cannot be recommended where high toughness is a primary requirement.

It is not uncommon for white fir to be described as brittle or brash as compared with other woods commonly used in house construction.

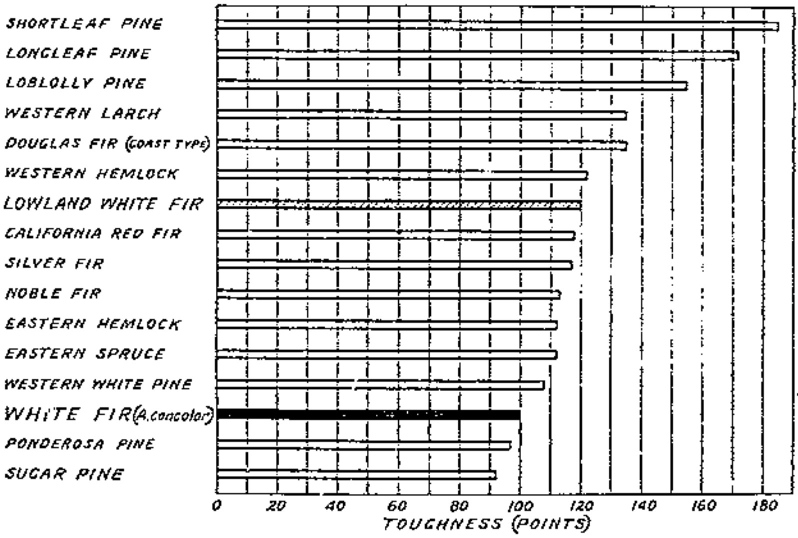


FIGURE 11.—Shock resistance or toughness of white fir (*Abies concolor*) compared with that of other woods. The comparison is for clear lumber. The loss in shock resistance resulting from such defects as knots and cross grain is especially high.

White fir is not so tough as the heavier softwoods, such as southern yellow pine, Douglas fir, or western larch. Such a description, however, is erroneous when the comparison is with the lighter softwoods (fig. 11). Lowland white fir is tougher and white fir (*Abies concolor*) not quite so tough as eastern hemlock and eastern spruce lumber. Of the species commonly sold in mixture with the white firs only alpine differs materially from the white firs in toughness. Alpine fir has less than two thirds the toughness of the white firs, and such a pronounced difference is bound to react unfavorably on the reputation of the white firs for toughness when alpine fir is sold in mixture with them.

The toughness of all lumber is greatly influenced by defects. A slope of grain of 1 inch in 10 inches will cause a loss of about one third in toughness. A large knot or a small amount of decay may readily reduce the toughness one half.

STIFFNESS

There is considerable difference in the stiffness of lowland white fir and white fir (*Abies concolor*). Lowland white fir is a stiff wood being almost as stiff as heavy softwoods like Douglas fir (coast type) and is stiffer than any of the lightweight softwoods (fig. 12). White fir is similar in stiffness to the lightweight softwoods. Its stiffness is about the same as that of eastern hemlock and eastern spruce, which are two species extensively used for joists and studs where stiffness is an important requirement.

Both the white fir (*Abies concolor*) and lowland white fir are stiff for their weight, but lowland white fir is outstanding. Of the principal species used for lumber only noble fir and silver fir can equal lowland white fir in this respect. The combination of stiffness and light weight of white fir is favorable to its use for joists, studding,

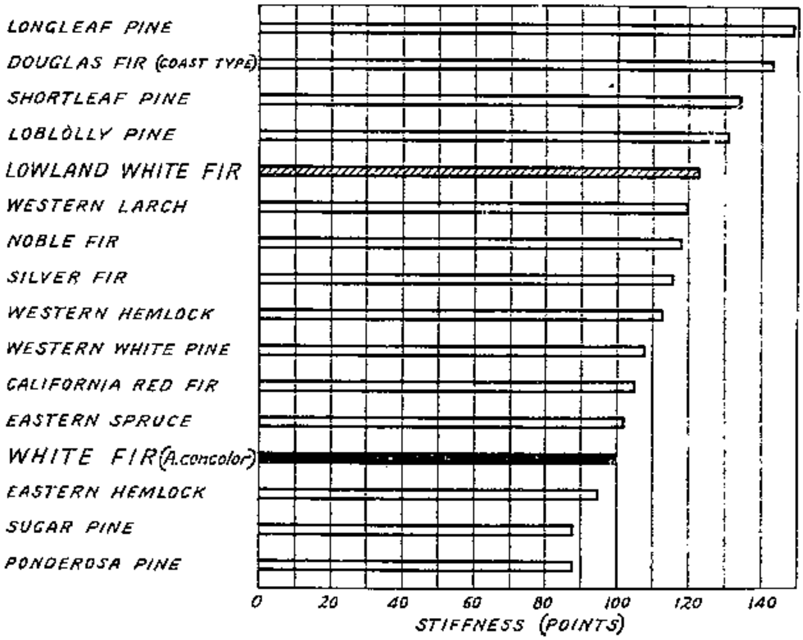


FIGURE 12.—Stiffness of white fir (*Abies concolor*) compared with that of other species. The comparison is for clear wood but applies also to any given grade of lumber almost as well, provided other things are equal.

and subfloors. All of the woods sold in mixture with white fir are more flexible than lowland white fir and all except alpine fir are stiffer than white fir (*A. concolor*).

Defects permitted in the sound commercial grades have little or no effect upon stiffness. The values in table 10 and figure 12 are therefore applicable to lumber almost as well as to the clear wood. An average value of stiffness for use in design is given in the table of working stresses under the heading Average Modulus of Elasticity (p. 52). The values for modulus of elasticity take into consideration species characteristics and peculiarities, and do not therefore check exactly with the stiffness values for the clear wood.

HARDNESS

White fir is used for its softness rather than for its hardness (fig. 13). The two species of white fir have about the same hardness, which is about the same as the hardness of ponderosa pine. They are softer than the hemlocks but harder than western white pine, northern white pine, or sugar pine. All of the other true firs, except California red fir, are softer than the white firs. Of the species that are at times sold in mixture with the white firs, California red fir, alpine fir, and western hemlock differ from them in hardness enough to have a practical significance. In uses where uniform hardness or softness is desired, such as in flooring, these three species may prove objectionable in mixture with the white firs—alpine fir because of its softness, and California red fir and western hemlock because of their hardness.

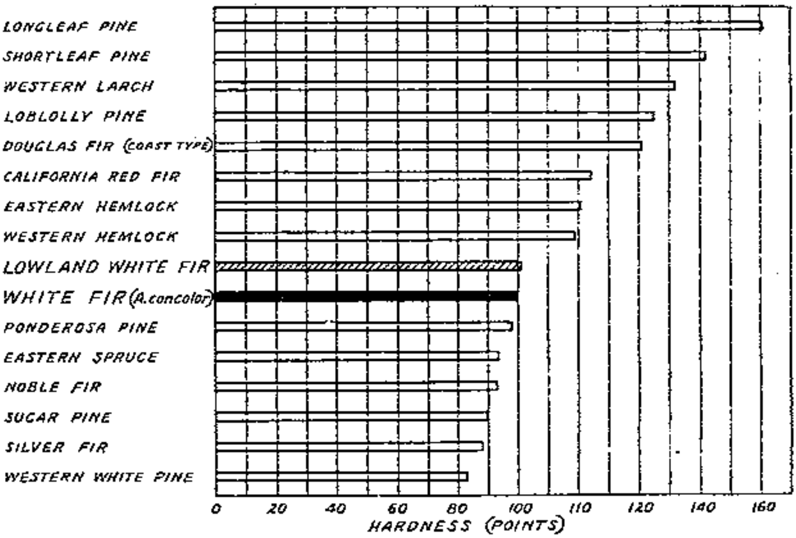


FIGURE 13.—Hardness of white fir (*Abies concolor*) compared with that of other woods. Comparison is applicable to all grades of lumber which contain only sound wood.

The softness of white-fir lumber is one of its greatest assets. It can be worked easily with hand tools. The carpenter and contractor like it because of the ease with which it is cut, sawed, and nailed enables them to put more of it in place in a day than they can of harder, less easily worked woods.

Softness is seldom a desirable property once the wood is in service or in place. Users are interested in the saving in cost of manufacture, fabrication, or construction because of the softness of white fir only insofar as these savings are passed on to them in reduced final costs. Softness is a requirement in a few uses of which drafting and bulletin boards are examples.

SPLITTING RESISTANCE

White fir is easy to split with an ax. The resistance of lowland white fir to the splitting action of axes or wedges is about the same as that of eastern spruce. White fir (*Abies concolor*) is more difficult to split than lowland white fir, being about the same in splitting resistance as western hemlock and Douglas fir (coast type). The comparison in figure 14 is based on the results of tests in which wood is pulled apart by forces acting at right angles to the grain. The comparison can be used to judge the ease with which the woods can be split into bolts or flitches and how well the wood will resist the splitting action of bolts or wedges. It is not a measure of the tendency to split in nailing, seasoning, or machining.

Splitting under the action of nails is influenced by hardness and uniformity of texture, as well as by splitting resistance. Lightweight, soft, uniform-textured woods usually split less in nailing than hard, heavy woods, with pronounced differences between summer wood and spring wood. White fir is soft, light, and fairly uniform in texture. In tests made at the Forest Products Laboratory Douglas fir (coast type), western larch, and western hemlock split more in nailing than white fir. Northern white pine splits less in nailing than white fir. White fir (*A. concolor*), because of its texture and splitting resistance, would be expected to split somewhat less when nailed than lowland white fir.

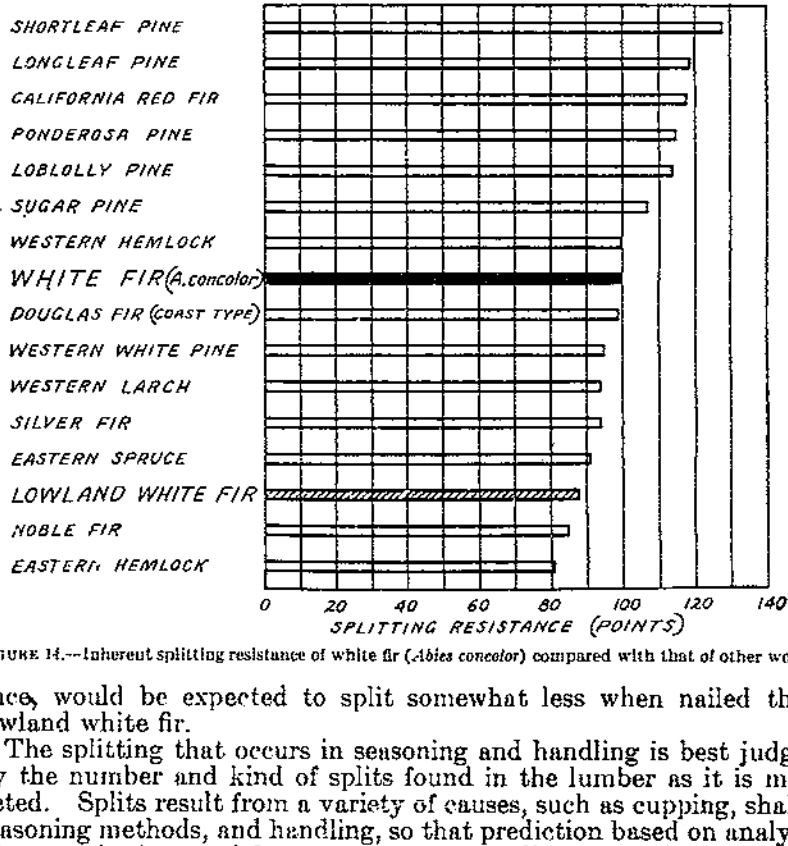


FIGURE 14.—Inherent splitting resistance of white fir (*Abies concolor*) compared with that of other woods.

The splitting that occurs in seasoning and handling is best judged by the number and kind of splits found in the lumber as it is marketed. Splits result from a variety of causes, such as cupping, shake, seasoning methods, and handling, so that prediction based on analysis of properties is unsatisfactory. An actual tally of the splits in representative samples of the lumber of 14 of the principal commercial species showed white fir to have about the same number of splits as eastern hemlock, western larch, and western white pine. The splits were larger and more numerous than in ponderosa pine, Douglas fir (coast type), southern cypress, or northern white pine.

NAIL-HOLDING POWER

The nail-holding power of white fir, though low, can meet ordinary-use requirements when nails are driven into the dry wood. The average holding power of a single 7-penny cement-coated nail driven 1¼ inches into the side grain of dry lowland white fir was 166 pounds. Driven into white fir (*Abies concolor*) it was 190 pounds (*13*). Nails driven into green white fir lost about one fourth of the original holding power when the wood dried. All woods lose holding power when they dry after nailing. It is, therefore, poor practice to nail into green or wet white fir or any species which will dry later. Most of the trouble from loose boards and pulled nails can be traced to the use of wet wood or inadequate nailing. It is seldom caused by the inherent weakness of the species in nail-holding power.

The nail-holding power of white fir is low as compared with that of other woods commonly used in building construction. It is about three fourths to five sixths that of eastern hemlock and ponderosa pine and about one half that of longleaf pine. More or larger nails

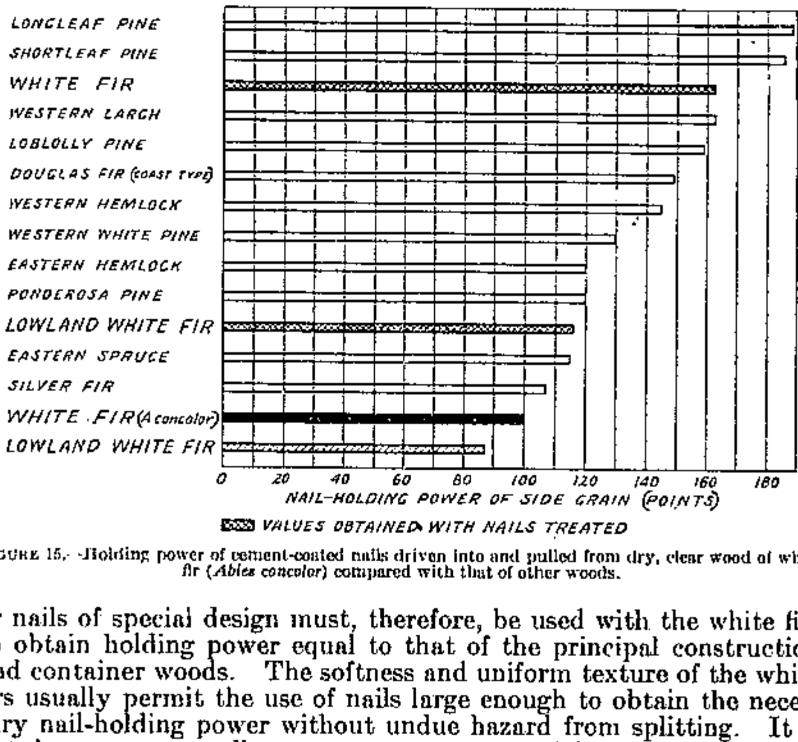


FIGURE 15.—Holding power of cement-coated nails driven into and pulled from dry, clear wood of white fir (*Abies concolor*) compared with that of other woods.

or nails of special design must, therefore, be used with the white firs to obtain holding power equal to that of the principal construction and container woods. The softness and uniform texture of the white firs usually permit the use of nails large enough to obtain the necessary nail-holding power without undue hazard from splitting. It is not, however, generally necessary to use a special type or to increase the size or number of the nails in subfloors, sheathing, and roofing boards fastened to white-fir framing in order to obtain satisfactory holding power.

The forest products laboratory has recently developed a simple chemical treatment[9] for nails that greatly improves their holding power (*14*). The chemically treated nails driven into white fir (*Abies concolor*) developed about two and one half times the holding power of smooth nails and about one and one third times the holding power of cement-coated nails (fig. 15). Such an increase makes whitefir-

[9] This treatment is covered by U. S. patent no. 1,011,421, which has been dedicated to the citizens of the United States and is available for use by any manufacturer without royalty charges.

nail-holding power with the treated nail about equal that of the best of the lightweight softwoods with the best of cement-coated nails, and probably equal to any of our native softwoods with plain nails. The treated nails have a corresponding increased holding power in other species.

SUSCEPTIBILITY TO ATTACK BY DESTRUCTIVE AGENTS AND TO TREATMENT

DECAY RESISTANCE

White fir (p. 2) is not suitable for use untreated where the decay hazard is high. Its resistance to decay is low. Based on service records and general experience the heartwood of white fir is classed with the heartwood of basswood, cottonwood, and other true firs in decay resistance.[10] Even where the decay hazard is moderate the average life is too short to justify the use of the species untreated. Where the decay hazard is low, such as in siding, subfloors, interior trim, studding, or joists, the wood will last indefinitely, for the fungi that cause decay cannot carry on their destructive work so long as the wood remains dry. Occasionally decay occurs in house framing, subflooring, or sheathing where there is no direct exposure to weather and the wood is apparently dry. The so-called dry rot is usually responsible for such occurrences. Dry-rot fungi can conduct water to dry wood from a distant source. Given a good preservative treatment the decay resistance of white fir is very satisfactory and the wood may then be used safely under conditions that favor decay.

TREATING CHARACTERISTICS

Both the heartwood and sapwood of the white firs are very resistant to the penetration of preservatives. In this respect they have been found to be similar to Engelmann spruce (*10*). The absorptions, however, were found to be somewhat heavier, the end penetrations were heavier, and the preservative more concentrated in treated portions in lowland white fir than in Engelmann spruce. Either creosote or a water-soluble salt, such as zinc chloride, may be used in treating white fir. Service records obtained from ties used in arid regions indicate that considerable checking is to be expected in white-fir ties in the course of 4 or 5 years unless petroleum or fuel oil is used in combination with the creosote or zinc chloride. The petroleum oil greatly retards the checking and splitting. Penetration of from five eighths to three fourths of an inch can be obtained in the heartwood of lowland white fir and 2 inches or more can be obtained in the sapwood by any of the standard processes, if properly applied (*10*). Experience indicates that white fir (*Abies concolor*) can also be treated successfully under the same conditions, although no special tests have been made.

WEATHERING

White fir, like all woods, weathers when exposed without paint or other protective coating. Unpainted white-fir (*Abies concolor*) panels exposed on a test fence at Madison, Wis., showed slight

[10] U. S. DEPARTMENT OF AGRICULTURE, FOREST SERVICE. COMPARATIVE DECAY RESISTANCE OF HEARTWOOD OF DIFFERENT NATIVE SPECIES WHEN USED UNDER CONDITIONS THAT FAVOR DECAY. U.S. Dept. Agr., Forest Serv. Forest Prod. Lab. Tech. Note 229, 2 pp. 1929. [Mimeographed.]

weather checking in about 3 weeks. At the end of a year the checking was marked. At the end of 4 years the weathering was more pronounced than in the cedars, southern cypress, and redwood, and about the same as in western white pine, northern white pine, sugar pine, and ponderosa pine, but not so marked as in eastern spruce or eastern hemlock. The change from smooth wood to weather-beaten wood takes place in about a year. The weathering is worse if the wood is exposed before it is thoroughly dried. Exposing partially seasoned white fir has in some localities caused the wood to acquire an unfavorable reputation for weathering. Weathering in white fir can be prevented by the application and maintenance of a good paint coating.

The white firs are unsuited for use as posts, piles, poles, ties, or in contact with the ground unless they are treated. Preservative treatment, however, adapts white fir to these and other uses for which they would otherwise be unsuited.

RESISTANCE TO ATTACK BY INSECTS, TERMITES, OR MARINE BORERS

White fir (p. 2) when used where it may be attacked by insects, termites, or marine borers should be treated with a preservative. In this respect it is similar to all of our commercial woods. While some of our native woods have a greater resistance to attack from such sources none is immune.

The high hazard created by the prevalence of termites and marine borers in parts of California presents an opportunity for the marketing of preservative-treated white fir. The cost of transporting white fir lumber from the mill to the region of high hazard is low because the haul is short. Little effort has been made to develop the market for white fir in these regions, probably because untreated white fir is unsuited for use in the region and because the mills cutting white fir do not have facilities for treating the lumber. The installation of treating plants either by white fir manufacturers or by others would open an additional market for the species.

CHARACTERISTICS DEPENDING ON A COMBINATION OF PROPERTIES

SEASONING CHARACTERISTICS

Several of the large operators regularly kiln dry their white fir of the select grades and a few kiln dry a portion of their common grades. By far the greater part of the white-fir production, however, is seasoned in the yards. Degrade due to defects developing from shrinkage, especially surface checking, end checking, loosening of knots, and splitting, is greater than in the pines cut by the same operators.

AIR DRYING WHITE FIR

Table 11 shows the percentages of various defects developed in air drying white fir in a California yard in which drying conditions were representative of the average for white-fir producing districts of the State. The data are for material in standard 16-foot piles erected in May, June, and July, and taken down in August, September, and October. The period of drying was from 1 month to 4 months. The moisture content at final inspection varied among the different piles and with different thicknesses of material.

TABLE 11.—*Defects developed in air drying white fir (Abies concolor) in central California during summer* [1]

Green grade	Thickness of material	Total [2] degrade	Types of defects found on degraded boards based on grade-volumes as piled [3]					
			Check [4]	Split [5]	Loose knots	Checked knots, broken knots, knot holes	Warp	Broken in handling
	Inches	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
C and Better	1	22.4	8.8	13.7	0.4	----	2.2	0.4
	1⅝	13.9	8.2	5.2	----	----	1.4	.4
	2	18.9	19.6	----	----	----	----	----
No. 1 Common	1	23.1	13.8	9.0	1.2	0.4	.3	----
	1⅝	16.9	5.8	4.9	3.0	1.2	4.2	.4
	2	20.5	16.5	1.7	4.6	----	2.3	----
No. 2 Common	1	30.4	14.6	7.7	14.1	12.8	3.5	.2
	1⅝	26.9	7.5	6.8	7.1	7.0	2.2	.7
	2	34.2	33.1	6.5	8.8	13.0	3.0	----
No. 3 Common	1	15.7	4.6	5.2	9.0	6.1	.2	.7
	1⅝	17.9	8.3	7.7	2.5	4.9	1.9	1.3
	2	22.3	23.1	12.5	1.9	4.1	.6	.4
No. 4 Common	1	5.1	1.7	4.2	.4	.7	----	----
	1⅝	14.3	5.0	10.6	.2	2.1	.9	1.4
	2	15.6	12.3	11.4	----	2.0	----	----

[1] Based on 123,000 board feet studied by the California Forest Experiment Station.
[2] The amount of degrade from all causes at time of taking down the piles. The final moisture content ranged from 6 percent in the material seasoned for 4 months to 30 percent in the material seasoned 1 month. Much of the loss indicated here is recovered by subsequent remanufacture.
[3] Percentages denote total occurrence of a given defect regardless of other defects in same piece and therefore do not jointly total with column 3.
[4] Includes end, spiral grain, and surface checks.
[5] Includes end, spiral grain, and surface splits.

Surface and end checking, the principal air-drying defects in white fir, are brought about by the rapid drying of the surfaces and ends and the slow drying of the interior of the piece. When a green board with, say, 150-percent moisture content is placed in a seasoning pile, evaporation will begin immediately and will proceed at a rate governed by the temperature, humidity, and circulation of air within the pile. At 150-percent moisture content, the board is far above the starting point of shrinkage but it does not take long to reduce this 150-percent to 30-percent moisture content or less on the ends of the board if they are exposed to direct sunshine, a strong wind, or both. Within 2 or 3 days end checking may take place, though a cross section cut from the board a foot or two back from the ends may still show a moisture content of approximately 125 percent. This rapid drying of the exposed surfaces of the board results in surface and end checks. In the interior of a lumber pile, the faces and sides of the boards dry slower than at the exposed ends; nevertheless, if they dry much faster than the interior the same force comes into play that takes place on the ends, that is, the external shell of the boards will reach the shrinkage point, the wet interior will remain expanded and will resist the shrinkage stresses in the shell so that the shell must split, or surface check, at irregular intervals until the stresses are equalized. Knot loosening may take place long before the interior of the board reaches 20-percent moisture content because the knots naturally dry out faster through their exposed ends than the surrounding wood. If the knot is firmly intergrown it will check or split in shrinking instead of loosening itself from the board. From the foregoing, it becomes evident that white fir at 20-percent moisture content exhibits practically as many of the principal drying defects as it does when dried to 10- or 12-percent moisture content.

Although there is little difference in pile degrade between 20-percent and 12-percent moisture content, nevertheless white fir depreciates badly in service if fabricated while green or only partially dry (20-percent moisture content). This is because each board is no longer a unit in itself free to complete its through-and-through shrinkage, but has become a rigidly nailed, glued, or doweled part of a larger, composite unit. Further, the board in the seasoning pile is held flat by the weight of the boards above it, and is therefore prevented from becoming severely warped or twisted, and in addition is enabled to complete its seasoning under much milder drying conditions than when exposed to unrestricted circulation and sunshine as part of the framework of a building under construction.

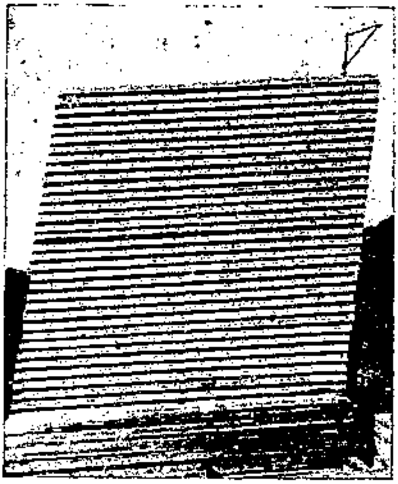


FIGURE 16.—White fir dimension 4 inches thick piled on stickers 1 inch thick to retard the drying rate so that checking will be reduced. This is ideal practice in hot, dry climates where too rapid evaporation will result in heavy degrade.

Present depreciation during the seasoning of white fir can be greatly reduced by more strict observance of sound seasoning practice. On established operations it is usually not feasible to relocate yards that are poorly situated, but much can be done to improve piling procedure and pile construction.

In the seasoning study from which the figures in table 11 were taken, 21.1 percent of the degraded C and better white fir had been fully exposed to the sun for 2 to 7 days while the pile was being erected. A truck load of white fir would be taken to the yard from the green chain and laid on stickers, 1 truck load being sufficient for about 7 courses. As C and Better of a particular thickness accumulated slowly at the sorting table, 4 or 5 days might elapse before another truck load would be ready for the yard. In the meantime, the top course last laid would check badly in the sun, the next course would check to a lesser extent, and even the third course would check slightly. The same procedure followed for every truck load, 6 or 7 in number, until the pile was built to a height of about 18 feet. The results are evident in table 11. An additional 15.6 percent of the degraded C and Better, white fir had been exposed either through lack of a pile roof during the entire drying period or because 2 or 3 days had elapsed between completion of the pile and the application of roof boards (figs. 16 and 17).

With proper piling and reasonable care in handling, there is ample evidence that white fir can be air dried to 10- or 12-percent moisture content with a depreciation in grade of 12 percent or less, equivalent to a depreciation in value of not more than 5 percent, mill run. The loss will be the same, at the time of unpiling, whether taken down at 18 to 20 percent or at 10-percent average moisture content. About one half of the loss in value can be recovered by simple trimming and ripping. In remanufacturing to dimension, the increase in value is often more than that lost through seasoning degrade. The dry stock, if stored, shipped, or used at once, will undergo practically no further degrade, but stock at 18-percent moisture content or higher

FIGURE 17.—White fir dimension planks piled for air seasoning with 1⅝-inch stickers. Drying is more rapid and degrade heavier than in figure 16. The piles illustrated are well constructed but lack roofs. When piles are left unroofed degrade is severe in the upper courses

will depreciate considerably more when stored, piled in a retail yard, or placed in use.

Some other factors (*6, 7*) contributing to an increase in degrade are poor placement of stickers, careless handling of lumber, and cross piling of occasional boards.

KILN DRYING OF WHITE FIR

A study of depreciation in commercially kiln-dried white fir (*Abies concolor*) was made in 1929 by the Forest Service at a California mill, the results of which are shown in table 12.

TABLE 12.—*Degrade in kiln drying 1⅝ by 8 inch white fir (Abies concolor)* [1]

Green grade	Percentage by volume falling to lower grades before remanufacture	Percentage by volume after remanufacture, rough dry				Loss (−) or gain (+) in final value.[2] Percent of original value
		Raised in grade	No change in grade	Below grade	Waste [3]	
C and Better	6.0	....	97.5	2.0	0.5	−1.5
No. 1 Common	10.0	5.0	85.5	8.0	1.5	−2.0
No. 2 Common	10.0	4.5	89.5	4.5	1.5	−1.2
No. 3 Common	3.0	15.5	79.5	1.5	3.5	+.1
No. 4 Common	5.0	25.5	65.5	3.0	6.0	−1.4
Weighted average all grades	6.15	11.4	82.4	3.4	2.8	−.9

[1] Based on 20,103 board feet of mixed No. 4 Common and Better studied by the California Forest Experiment Station.
[2] Extra cost of trimming and ripping included as a loss.
[3] Waste in percentage of original green volume from trimming and ripping.

The kiln was of the compartment type with forced circulation. The schedule used was designed for rapid output rather than minimum degrade, nevertheless fair results were secured. The average moisture content was about 18 percent for all runs combined. Enough material of low moisture content was tallied to indicate little or no increase in the development of defects between 20-percent and 10- to 12-percent moisture content.

In general, the temperatures and humidities were left fairly constant throughout the period of drying. The average dry-bulb temperature was about 150° F. and the relative humidity between 41 and 50 percent. Drying time was from 128 to 152 hours, a charge being removed when an end-coated sample reached about 18-percent moisture content.

Drying schedules vary greatly among different mills. Practically all call for temperature and humidity changes correlated with elapsed time periods. Each schedule is based on the experience of the individual mill with its own equipment, hence what will work at one mill may give poor results at another. The only schedule that can be universally recommended must necessarily make allowance for variations in type of equipment. For a complete discussion of kiln-drying procedure and outlines of schedules, kiln operators are referred to the Kiln Drying Handbook (*22*).

CAPACITY TO STAY IN PLACE

Capacity to stay in place is required in some degree by all uses of wood. It is one of the important requirements of interior trim, doors, window frames, and sash. It is also a requirement of rough uses, subfloors, sheathing, framing, and concrete forms, though not so important in these uses.

The properties that determine how well a wood stays in place are its shrinkage and tendency to warp. Shrinkage causes a change in dimension, warping a change in shape. Comparison of the shrinkage of white fir (*Abies concolor*) with that of a number of species is shown in figure 7. A numerical comparison of the tendency to warp cannot be made. Warping is caused by knots, cross grain, the difference in the shrinkage between radial and tangential directions, unequal shrinkage of heartwood and sapwood, and compression wood. No satisfactory method of evaluating the foregoing factors has yet been devised. An analysis of factors that influence the capacity of wood to stay in place indicates that white fir is satisfactory in this respect. Its shrinkage is low and it therefore swells and shrinks less than most commercial softwoods. The amount of compression wood in white fir is about the same as that in western white pine, which stays in place well. The frequency of occurrence of cross grain, which is responsible for most of the tendency to twist, and the proportion of heartwood and sapwood in white fir is not known. The difference in the shrinkage between the radial and tangential directions is large and is reflected in the tendency to check. White fir dimension is favorably known for its straightness, indicating that the capacity of the wood to stay in place is satisfactory for less exacting uses. The wood has also been used with satisfaction for more exacting purposes, such as interior trim. It is not suited for uses where the requirements are extremely exacting, such as in patterns.

The conflicting opinions among consumers regarding the tendency of white fir to stay in place are the result of differences in the degree of seasoning. To stay in place satisfactorily in any use the wood must be thoroughly seasoned. Most of the trouble experienced with white fir not staying in place can be traced to the use of green or partially dried lumber.

GLUING CHARACTERISTICS

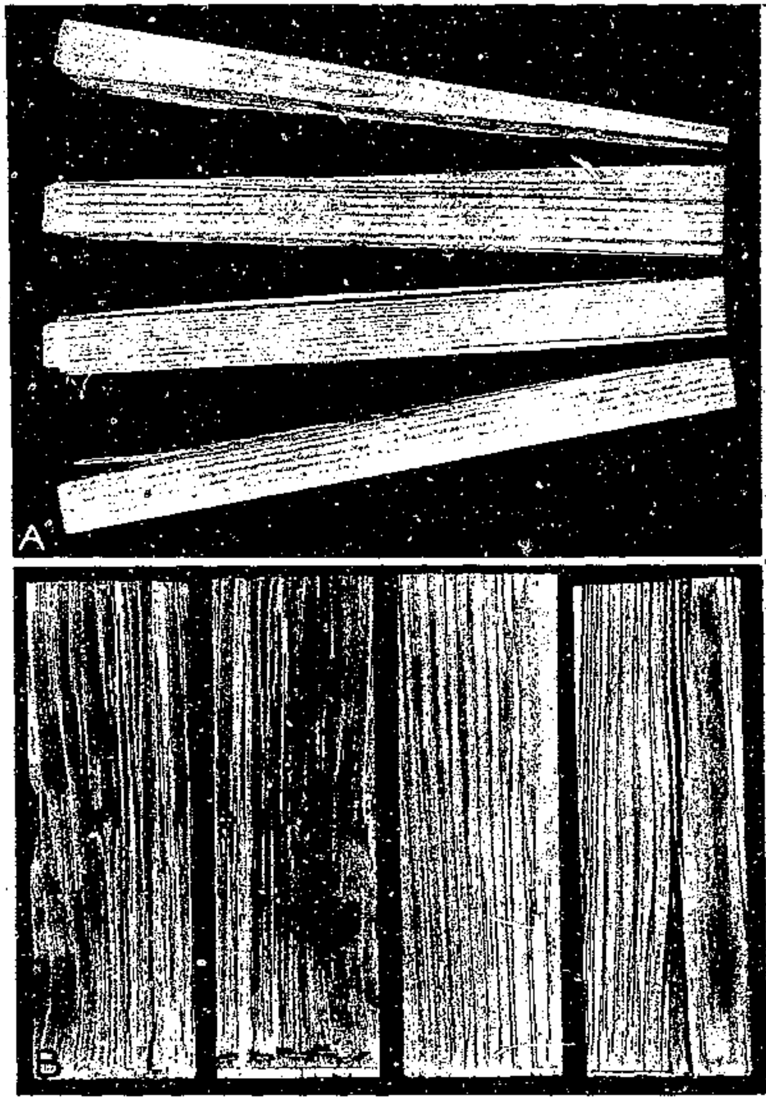
White fir (*Abies concolor*) is one of the easiest of our native species to glue (*23*). On joints made with animal, vegetable, or casein glue and then tested to failure, the failures occurred practically 100 percent in the wood (pl. 3). The joints developed on an average a shear strength of about 1,500 pounds to the square inch. The strength of the joints was about the same with all three glues and all the wood failures indicate that it was limited by the strength of the wood and not by that of the glue. Joints made with animal glue under poor conditions, which in many species result in starved joints, also failed in the wood so that their effective strength was as good as that of joints made under good gluing conditions. White fir (*A. concolor*) can therefore be glued satisfactorily under a wide range of conditions. The schedules developed at the Forest Products Laboratory and recommended for gluing white fir are shown in table 13. While all the tests were made on white fir (*A. concolor*) it is believed that equally good results can be obtained with lowland white fir, and the schedules of table 13 are recommended for use with it and the other true firs.

TABLE 13.—*Gluing schedules for white fir*

Kind of glue	Proportion of glue to water by weight [1]	Glue spread	Temperature of the wood	Pressure	Closed assembly time [2]
		Pounds per 1,000 square feet [3]	*°F.*	*Pounds per square inch*	*Minutes*
Animal [4]	1-2¼	60-65	70	100-150	0-1
	1-2¼	65-70	80	100-150	1-5
	1-2¼	70-75	90	100-150	3-20
	1-3	70-75	90	100-150	5-20
Casein [5]	1-2	60-70	70-90	100-150	0-15
	1-2⅛	70-80	70-90	100-150	3-20
Vegetable [5]	1-2⅛	60-70	70-90	100-150	0-20
	1-2¼	70-80	70-90	100-150	1-25

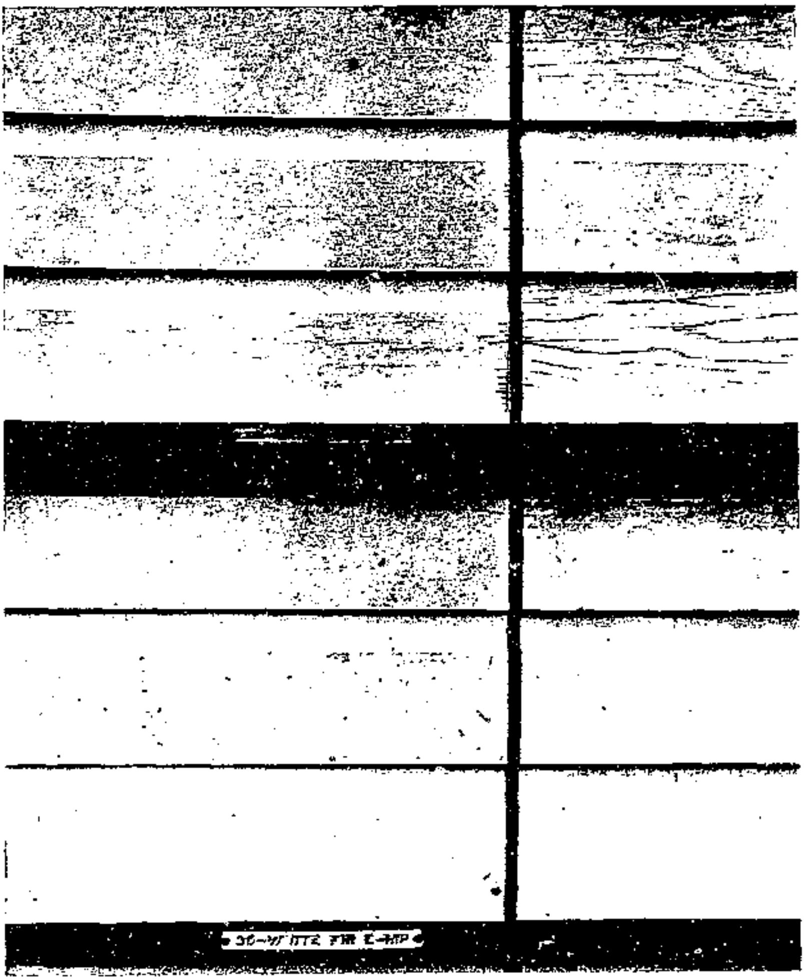
[1] The recommended proportions of glue and water are suitable for both lumber and veneer gluing, but ordinarily it is better to use a thicker glue mixture with lumber than veneer.
[2] Wood pieces laid together as soon as spread with glue.
[3] Weight of wet glue mixture.
[4] An animal glue equivalent to about No. 12 in the National Association of Glue Manufacturers grades. Other grades may be used if suitable adjustment in the proportions of glue and water are made.
[5] Some glues require more or less water than shown here in order to obtain the same consistency of mixture.

Little advantage has been taken of the excellent gluing characteristics of the white firs. The wood can be used for core stock, laminated construction, furniture, or other uses where good glue joints are an important requirement. Only comparatively small quantities, however, have been used for these purposes.



GLUED LAMINATIONS OF WHITE FIR SHOWING TYPE OF FAILURE RESULTING IN TEST.

A, Side view showing glue line, all four glue joints still intact. B, Surface view showing failure occurs in wood rather than glue.



WHITE FIR PAINTED PANELS AFTER 7 YEARS' EXPOSURE AT MADISON, WIS.

The panels received three coats of standard mixed paint when exposed in 1924. The portion to the left of the black line was repainted in 1927. The top panel is flat grain and the bottom edge grain. The panel shows that white fir holds paint well, especially on edge-grained surface.

PAINTING AND FINISHING CHARACTERISTICS

White fir (p. 2) holds paint well. In this respect it is classed with the hemlocks, spruces, and ponderosa pine. It holds paint better than the heavier, harder, and less uniform-textured woods, such as southern yellow pine and Douglas fir, but not so well as the lighter-weight cedars, redwood, and more uniform-textured white pines. White fir is nonresinous and therefore does not exude resin beads to spoil paint finishes; neither does the paint peel off the knots or become discolored as it does with resinous woods.

The Forest Products Laboratory is studying the painting characteristics of white fir and 17 other native softwoods. The study (*3*) has been in progress about 8 years and is conducted on panels exposed on test fences at widely scattered points throughout the United States. Plate 4 shows the results of 7 years' exposure of the white, fir panels on a test fence at Madison Wis. White fir when fully exposed to the weather ordinarily will require repainting in about 3 years. The time, however, varies greatly with exposure, climatic conditions, with edge-grained or flat-grained material, and with quality of paint. If the surfaces facing south are shaded by buildings or trees, repainting may not be needed oftener than once every 5 or 6 years in a climate like that in New England and the Lake States. In a climate where there is little rain, long periods of low humidity, and much sunshine, as in parts of California and the Southwest, unprotected southern exposures may require repainting every year or two.

White fir should be closely watched for weather checking. At the first sign of fine checks or breaks in the paint coat it is time to repaint even though the general appearance is still good. White fir has a decided tendency to weather-check when unprotected and directly exposed. The checks quickly become long and wide and may extend through the board. Maintenance of a good paint coat will prevent checking, and since white fir holds paint well it is not difficult to maintain the desired smooth, even appearance of painted surfaces. Edge-grained white fir holds paint much better than flat-grained material (pl. 4). Paint will prevent the weathering and checking of edge-grained white fir from one and one half times to more than twice as long as it will on flat-grained white fir, depending on climate. Very little edge-grained white fir is cut and it sells at a higher price than flat-grained material; edge-grained siding and other exterior trim will more than repay the difference in initial cost through lower painting maintenance.

The durability of paint on white fir can be increased a year or more by applying a priming coat of aluminum paint (*4*). A 3-coat job consisting of 1 coat of aluminum primer and 2 coats of light-colored paint costs little more than a standard 3-coat job but lasts longer. An aluminum primer coat on white fir makes it easier to keep the wood protected and thus decreases the checking and splitting hazard. Permanent protection from checking and splitting, however, can only be obtained by good maintenance.

No painting study directly applicable to interior conditions has been made on white fir. The suitability of the wood for enamel and natural finishes must therefore be judged by the results obtained in exterior tests, the figure and texture of wood, and the lack of resins and other extractives in the wood. The figure of the wood, especially in flat-grained material, is sufficiently pronounced to adapt white fir to natural or stained finishes. Finish of the types required for interior trim of houses is readily obtained and easily maintained. White fir should give good service with high-class paint and enamel finishes. It has no resin to stain or discolor the paints, the grain is not sufficiently pronounced to make it difficult to cover, nor is it likely to rise under the conditions to which interior trim is subjected. Grain raising occurs principally on the pith side of flat-grained boards. Enamel and high-class paint finishes should therefore be applied to the face nearest the bark. Manufacturers can do much to prevent the occurrence of raised grain by not finishing pattern stock on the pith face. Repainting will ordinarily be required because of soiling rather than because of inferior paint-holding by the wood. The paint-holding characteristics of white fir are adequate to meet the requirements of interior trim.

No wet wood will hold paint satisfactorily. Surfacing while wood is still green or dressing with dull planer knivers causes the grain to rise, which is especially objectionable in interior trim that is either to be enameled or given a natural or stain finish. Most painting and finishing troubles with white fir can be traced to one of these causes, or to applying paint to the pith side of flat-grained boards. The trouble is not inherent in the species and white fir should not be condemned for it, for properly manufactured and seasoned white fir can be satisfactorily painted or finished.

EASE OF WORKING

The effort required to cut, saw, and shape wood depends on the combination of softness, straightness of grain, and uniformity of texture. White fir has a favorable combination of these properties; it is soft, straight-grained, and fairly uniform in texture. The wood is therefore easy to cut, saw, and shape. In this respect it is easier to work than Douglas fir but not so easy as the soft pines. The ease with which it is cut, sawed, and nailed, combined with light weight, tends to speed construction and is responsible for much of the popularity of the white firs with the builders of small houses.

Hard, uniform-textured wood can be dressed and sanded to a smoother surface than soft nonuniform-textured wood. The texture and hardness of white fir are such that it can be dressed to a surface smooth enough for ordinary paint work. It can be sanded to a surface satisfactory for natural finishes. Such surfaces, however, are more difficult to obtain than with harder woods or wood with more uniform texture. The wood cannot be dressed satisfactorily when green, for it then tends to fuzz.

CHEMICAL PROPERTIES

The basic chemical properties of white-fir wood differ little from those of other softwoods. Because of the lack of extractives white fir has no special chemical possibilities.

Little is known of the acid resistance of white fir. No recommendation can therefore be made for its use for purposes requiring this property.

FIRE RESISTANCE

Differences in the fire resistance of species are commonly over emphasized (*24*). Differences within species resulting from oil, density, and resin are as significant as differences between species.

When high fire resistance is desired and untreated wood must be used, the wood should be selected for low resin and oil content and high density. In such a selection the absence of oil and resins in white fir entitle the species to consideration.

GRADES AND THEIR CHARACTERISTICS

White fir (p. 2) from California and the Inland Empire is graded under the rules of the Western Pine Association (*30*). These grades

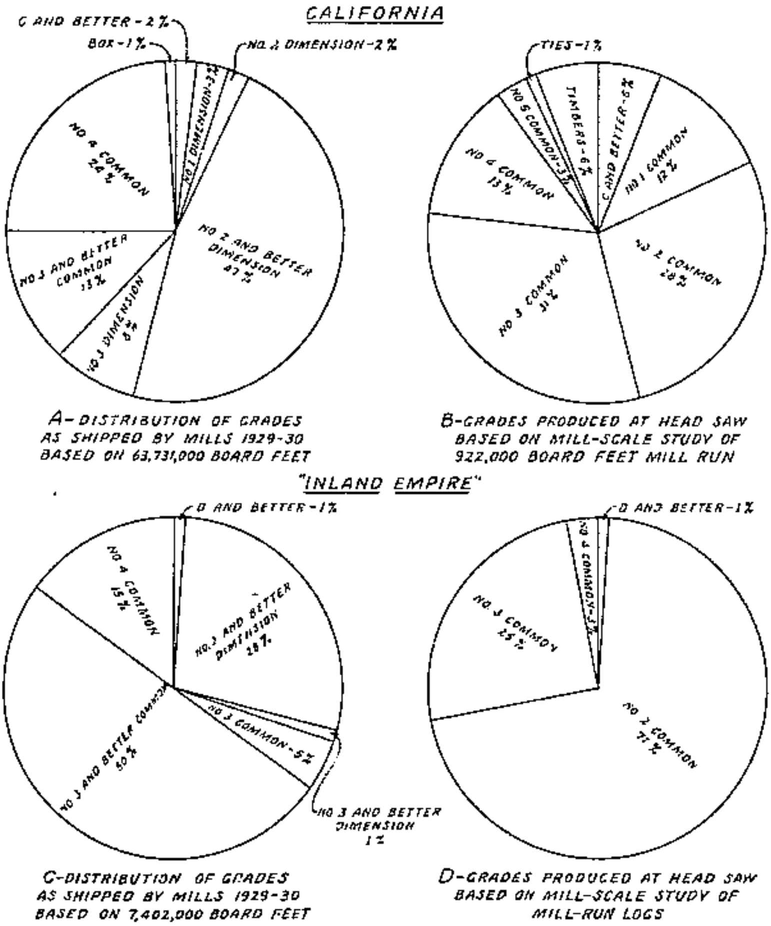


FIGURE 18.—Comparison of distribution of grades of white fir as shipped from mills and as cut at the head saw: *A*, The bulk of the California cut of white fir is sold as Dimension. Much of the select material is marketed with the Commons. *B*, The grades obtained from the mill run of white fir logs in California. Direct comparison cannot be made with grades shown in *A*, for Common grades are largely remanufactured into Dimension grades after seasoning. *C*, The bulk of Inland Empire cut of white fir is sold as 1-inch Common lumber in contrast with the California cut (*A*), which is sold as Dimension. *D*, Grades of white fir obtained from mill-run logs in the Inland Empire. A comparison with *B* shows the larger yield of higher grades from the larger and clearer California white fir (*Abies concolor*). Comparison with *C* shows that shipments do not reflect what the average log will produce with good cutting practice.

are theoretically the same as the pine grades of this association, but because white fir yields too small a proportion of some grades to justify their segregation certain grades are combined that are not combined in the pines. The standard grading rules (*30*), however, do not describe the combined grades in which white fir is marketed.

The practice of combining grades differs considerably in California and the Inland Empire (fig. 18), because of the characteristic differences in white fir trees in the two regions. The larger trees of the central-California pine region produce a greater percentage of select grades than the smaller trees found in the northern part of the region and in the Inland Empire. A grade of C and Better is commonly marketed by the California mills and D and Better by the other white fir producers. D select is also obtainable from the California mills, though material of this grade is usually made into pattern or No. 1 Dimension. Some California mills combine the first two common grades as No. 2 and Better Common instead of the first three common grades as No. 3 and Better Common. Practice in the two regions also differs in that white fir from California is marketed largely as dimension; that from the Inland Empire as 1-inch Common boards (fig. 18). The difference in the grades from the two regions is sufficient to warrant a separate discussion.

The grading rules (*30*) describe the grades by listing a number of typical examples under definitions that give the general characteristics of the grade. Such limitations cannot cover all the possible types and variations to be found in lumber of any grade. The typical examples are not repeated here. Instead, the grades are described by quoting the definitions from the grading rules and presenting a detailed record of the defects found in a study of the grades as marketed in 1928 and 1929.

Tables 14 and 15 show the practice of combining grades in the two producing regions and also the range of thicknesses most commonly sold in each grade. Periodic or annual summaries of white fir sales by widths in the Dimension grades or by patterns in any grade, such as baseboards, ceiling, and shiplap, are not kept by California mills, and cannot therefore be reported on a quantitative basis.

TABLE 14.—*Distribution by grades and sizes of white fir shipped by several California mills in 1929–30* [1]

Grade	Thickness [2]	Widths	Percentage of total	Grade	Thickness [2]	Widths	Percentage of total
	Inches	*Inches*			*Inches*	*Inches*	
C and Better	All	All	1.50	No. 3 and Better Common.	13/16	All	0.07
No. 1 Dimension	1 9/16	do	1.50		13/16	4 and 6	.08
	1 5/8	do	.08		13/16	8 and 10	.27
	1 3/4	do	.10		13/16	12	.54
	1 7/8+	do	1.40		1	All	.75
No. 2 Dimension	1 9/16	do	2.45		1	4 and 6	2.04
	1 5/8	do	.01		1	8 and 10	2.35
	1 3/4+	do	.02		1	12	1.10
No. 2 and Better Dimension	1 9/16	do	40.00		1 1/4+	All	4.50
	1 5/8	do	2.03	No. 4 Common	13/16	do	.37
	1 3/4	do	3.13		3/4	do	.35
	1 7/8+	do	2.45		1	do	14.32
No. 3 Dimension	All	do	7.85		1 1/4+	do	8.53
				Box	All	do	1.04

[1] Based on 63,731,000 board feet.
[2] The Dimension thicknesses are actual, the Common nominal.

TABLE 15.—*Distribution by grades and sizes of white fir shipped by Western Pine Manufacturers' Association from Inland Empire in 1929–30* [1]

Grade	Thickness [2]	Widths	Percentage of total	Grade	Thickness [2]	Widths	Percentage of total
	Inches	*Inches*			*Inches*	*Inches*	
D and Better	1	All	1.01	No. 3 and Better Common	$1\frac{1}{4}$, $1\frac{1}{2}$, 2	All	3.03
No. 1 and No. 2 Common	1	6	.08		$1\frac{5}{8}$	do	1.24
	1	8	.05	No. 1 Dimension	$1\frac{5}{8}$	do	.13
	1	10	.02	No. 2 and Better Dimension.	$1\frac{5}{8}$	do	27.74
	1	12	.11	No. 3 and Better Dimension.	$1\frac{5}{8}$	do	1.01
No. 3 Common	1	4	.23	No. 4 Common	All	do	14.69
	1	6	.81				
	1	8	2.07				
	1	10	1.05				
	1	12	1.05				
No. 3 and Better Common	1	4	3.20				
	1	6	10.37				
	1	8	13.68				
	1	10	10.37				
	1	12	8.06				

[1] Based on 7,402,000 board feet.
[2] The Dimension thicknesses shown are actual, the Common nominal.

SELECT GRADES

C SELECT AND BETTER

C Select and Better consists of the C Select grade and all the better products of the log. The grading rules (*30*) for C Select pine state: "This grade is primarily based on the idea of furnishing a high-class paint finish." The examples cited in the rule book show that a few pin knots, a few small knots firmly set, minor pitch pockets, and occasionally rough millwork on the back are admitted provided these defects are not in serious combination in the same piece, also various degrees of stain. Stain is found so seldom in white fir, however, that there is no need of describing the kinds and amounts of discoloration admitted in C Select or C and Better grade.

On the whole, C and Better white fir as now shipped is of high quality (pl. 5, *A*). Sample lots inspected in California frequently contained 50 percent or more of pieces that would grade B and Better under the pine rules (also known as 1 and 2 Clear).

The defects found in a study of 1,500 board feet of 1- by 8-inch C and better white fir are shown in table 16.

TABLE 16.—*Defect found in C and Better white fir from California* [1]

Defect	Percentage of boards having defect	General character of defect in C and Better
Knots	41	Average size 0.41 inch, 80 to a thousand board feet. About three fourths of the knots were ½ inch or smaller. Largely intergrown and encased and a few loose.
Checks	13	Mostly small surface checks, none through.
Wormholes	8	All pinholes.
Stain	5	All light.
Torn grain	6	All slight.
Dark streaks	3	Small and medium.
Splits	1	All short.

[1] Based on study of 1,500 board feet of 1- by 8-inch boards by the Forest Products Laboratory.

Defects averaged one to every 7 board feet; knots comprised nearly two thirds of the total. Seasoning defects, checks, stain, and splits were all present, but torn grain was the only manufacturing defect. Only knots and checks occurred in more than 10 percent of the pieces. Wormholes and dark streaks were the only special features of this grade as distinguished from most softwoods. Clear faces were found in 40 percent of the pieces.

D SELECT AND BETTER

D Select and Better grade is produced principally by the mills in the Inland Empire. The mill run of white fir logs in the Inland Empire produces such a small percentage of lumber higher than D Select grade that it does not pay to segregate it.

Practice varies in California in respect to the D Select grade. Some mills make no effort to segregate anything between No. 1 Common and C and better, others carry D Select with all the better products of the log under the name D and Better, and still others include D Select with No. 3 Common and Better and segregate the stock later if orders for D Select are received. If there is no special demand for D Select it may be made into pattern, No. 1 Common, or No. 1 Dimension.

The grade consists of D Select and all the better products of the log (pl. 5, *B*). Mill-scale studies, however, indicate that the grade contains little lumber better than the D Select grade. The description of D Select grade in the grading rules (*30*) is:

> This grade of lumber belongs between the higher finishing lumber and the common grades, and partakes somewhat of the nature of both. Many pieces have a finish appearance on one side only, the backs showing numerous or very serious defects. A type often placed in this grade is a high line of piece requiring a cut to eliminate a knot hole or other defect too serious to go into finish work.

A study of 1,500 board feet of D and Better at two mills in the Inland Empire showed it to have one defect to every board foot; slightly over two thirds of the defects were knots. Checks were next commonest with 26 percent occurrence while the other seasoning defects, stain and splits, were of little consequence. Holes and torn grain followed check in frequency of occurrence. The defects were all in minor degrees, except for some loose and broken knots. Only the first five defects listed in table 17 occurred in more than 5 percent of the pieces. Clear faces were found in 2 percent of the pieces.

TABLE 17.—*Defects found in D and Better white fir from the Inland Empire* [1]

Defect	Percentage of pieces having defect	General character of defect in D and Better
Knots	92	Average size 0.30 inch, 636 to a thousand board feet. About 10 percent larger than ½ inch, a few broken and loose.
Dark streaks	52	Small and medium.
Checks	26	Mostly end checks and small checks.
Holes (not through)	19	Caused by picaroons or dogs.
Torn grain	12	Chiefly slight and medium.
Stain	5	All light.
Splits	4	All short and medium.
Skips	4	All slight.
Burn	2	Small.
Shake	2	Slight.
Wane	1	All slight.
Wormholes	1	All pinholes.

[1] Based on a study of 1,500 board feet of 1- by 8-inch boards by the Forest Products Laboratory.

COMMON GRADES

The grading rules (*30*) contain specifications for five common grades of lumber. White fir logs from both California and the Inland Empire yield some lumber of all five grades (tables 14 and 15). Neither region, however, makes a practice of marketing five grades of white fir commons.

Nearly all the mills ship Nos. 1, 2, and 3 Common white fir invoiced as No. 3 and Better Common. No definite specifications are set up as to the approximate proportion of each grade in the mixture. This will vary among different mills depending on the run of logs cut. In the California pine region, No. 3 and Better Common consisted, roughly, of about 50 percent No. 3 Common, 35 percent No. 2 Common, and 15 percent No. 1 Common. In the Inland Empire it consisted of about 50 percent No. 2 and 50 percent No. 3 Common. Some mills ship a grade of No. 1 and No. 2 Common mixed, and occasionally orders are filled for No. 3 and No. 4 Common mixed.

Any individual common grade of white fir is obtainable at mills that cut a high percentage of white fir, and as time goes on it will undoubtedly become more common practice to market each grade separately at the sawmill. No information is at hand to indicate the trend of the demand for separate common white fir grades. There follows a description of the five common grades.

NO. 1 COMMON

The amount of No. 1 Common produced from white fir is small. In the Inland Empire the yield of this grade is not sufficient to justify its segregation. A California mill scale study indicates that between 11 and 12 percent of the mill run was graded as No. 1 Common. The mill at which the study was conducted, however, was not separating D Select from the common grades. Later inspection after seasoning indicated that about one half of the No. 1 Common would qualify as D Select. Table 16 indicates that whatever the production no appreciable amount of No. 1 Common white fir is sold as such by California mills. The grade of No. 1 Common white fir is, therefore, of little importance.

The grading rules (*30*) define No. 1 Common as:

> No. 1 Common includes all sound, tight-knotted stock with the size of the knot the determining factor of the grade.
>
> Light pitch, very small pitch pockets or season checks, or equivalent small defects and blemishes, are admissible.
>
> Light stain covering the entire face is admissible in otherwise high line pieces.
>
> This grade is of a character that fits it for shelving, cornice, and all uses where best quality and appearance of common lumber is required.

The general appearance of the grade is shown in plate 6, *A*.

NO. 2 COMMON

Very little white fir is sold as No. 2 Common. The white fir logs produce a high percentage of No. 2 Common in both California and Inland Empire, but it is sold as No. 2 and Better, or No. 3 and Better Common, or is remanufactured into dimension.

The grading rules (*30*) define No. 2 Common as:

> Subject to the same general inspection as No. 1 Common, except that coarser and larger knots, not necessarily sound, or their equivalents, 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 common to this grade are season checks, heart shake, heart pith, pitch, pitch pockets, slight traces of firm rot, and occasional wormholes. No serious combination of the above defects is admissible in any one piece.

The pitch defects permitted by the grading rules do not normally occur in white fir. Much of the lumber contains dark streaks, especially that from the Inland Empire. Dark streaks are not a defect in common grades. The general appearance of the grade is shown in plate 6, *B*.

A detailed study of the defects found in No. 2 and Better Common was made at a California mill. The defects found in the grade are shown in table 18. The grade was sound, but not tight. There were on the average 10 defects to every 10 board feet.

TABLE 18.—*Principal defects found in No. 2 and Better Common white fir from California* [1]

Defect	Percentage of pieces having defect	General character of defect in No. 2 and Better Common
Knots	92	Average size 0.71 inch, 849 to a thousand board feet, very few larger than 1½ inches. Loose knots in 30 percent and knot holes in 3 percent of pieces.
Checks	16	Mostly small surface checks and end checks, some through.
Wormholes	7	All pinholes.
Splits	4	Mostly medium, rest short.
Stain	4	Mainly light, rest medium.
Shake	3	All types.
Wane	2	All slight.
Decay	1	All incipient.
Pith	1	Small amounts.

[1] Based on a study of 1,300 board feet of 1- by 8-inch boards by the Forest Products Laboratory.

NO. 3 COMMON

No. 3 Common is marketed principally in the mixture of No. 3 and Better Common. Over one half of the white fir cut in the Inland Empire is sold in these grades. The yield of No. 3 Common white fir in California is larger than the yield of any other grade, but much of it is remanufactured into dimension.

The following description is quoted from the grading rules (*30*):

The grade of No. 3 Common takes in much of the lower product of the log and although the appearance of a part of the stock is coarse it is a good general utility grade having a wide variety of uses.

Some of the defects common to this grade are: Large, loose or unsound knots, large branch knots, occasional knot holes, large wormholes, season checks, pitch and pitch pockets, skips and roller splits, some red rot, considerable heart shake, and any amount of stain.

Very little stain is found in white fir.

"A serious combination of the above defects is not admissible in any one piece."

A detailed study of the defects characteristic of No. 3 Common was made in California and the Inland Empire on No. 3 and Better Common (tables 19 and 20). In California the defects numbered 12 to every 10 board feet; in the Inland Empire 24 to every 10 board feet. In general the lumber from both regions is low grade, having numerous defects, some of which are serious in themselves and others serious in combinations. The general appearance of the No. 3 Common grade white fir as produced in California is shown in plate 6, *C*.

TABLE 19.—*Principal defects found in No. 3 Common white fir from California* [1]

Defect	Percentage of pieces having defect	General character of defect in No. 3 Common
Knots	98	Average size 0.88 inch, 1,050 to a thousand board feet. About 3 percent are larger than 1½ inches, holes and loose knots common.
Checks	28	Half-through checks.
Wormholes	9	Mainly pinholes, rest chiefly medium.
Decay	8	Half advanced.
Splits	7	Mostly medium, rest short.
Stain	3	All light.
Shake	3	All types.
Wane	2	Chiefly slight.

[1] Based on a study of 7,000 board feet of 1- by 8-inch boards by the Forest Products Laboratory.

TABLE 20.—*Principal defects found in No. 3 and Better Common white fir from the Inland Empire* [1]

Defect	Percentage of pieces having defect	General character of defect in No. 3 and Better
Knots	100	Average size 0.48 inch, 2,163 to a thousand board feet. Less than 1 percent are larger than 3 inches, loose knots and holes common.
Checks	38	Chiefly minor degrees, a few through.
Splits	25	Mostly short and medium, very few long.
Decay	6	Mostly incipient.
Stain	5	All light.
Pith	5	Mostly small amounts.
Shake	4	All types.
Wane	4	Slight and medium.
Wormholes	2	All pinholes.

[1] Based on a study of 5,800 board feet of 1- by 8-inch boards by the Forest Products Laboratory.

NO. 4 COMMON

No. 4 Common is an important grade of white fir. It is produced and sold both in the Inland Empire and in California. Although it is occasionally combined with No. 3 Common it is usually sold alone.

The following description of the grade is quoted from the grading rules (*30*):

> The defects common to this grade are much the same as those found in No. 3 Common but exist in more serious combination or to a greater degree.
>
> Knot holes, red rot, massed pitch, excessive heart shake, and heavy skips in dressing are some of the serious defects admissible in this grade. Other types are extremely coarse-knotted, waney, badly split, or badly checked pieces.

The general appearance of the grade is shown in plate 6, *D*.

A detailed study of the defects in the grade made at 2 mills in the Inland Empire showed that the grade had, on the average, 28 defects to every 10 board feet, many of them serious in themselves or serious when in combinations (table 21). Bad knots, through checks, long splits, and advanced decay were usually the determining defects.

TABLE 21.—*Principal defects found in No. 4 Common white fir from the Inland Empire* [1]

Defect	Percentage of pieces having defect	General character of defect in No. 4 Common
Knots	100	Average size 0.48 inch, 2,300 to a thousand board feet, a few over 3 inches, loose knots and holes very common.
Checks	59	Nearly one fifth through checks.
Splits	41	About one fourth long.
Decay	17	Nearly one fourth advanced.
Stain	14	All light.
Pith	8	Mostly small amounts.
Wane	7	Slight and medium.
Wormholes	6	Chiefly pinholes.
Shake	4	All types.

[1] Based on a study of 2,100 board feet of 1- by 8-inch boards by the Forest Products Laboratory.

NO. 5 COMMON

The No. 5 Common grade is of small importance in white fir. Its value is too low to permit its being transported to markets at any great distance from the mill. Some mills use the grade in the manufacture of boxes, boards for grain cars, and similar articles, others sell the grade locally for rough and temporary uses, and still others send it to the slasher.

The grading rules (*30*) state:

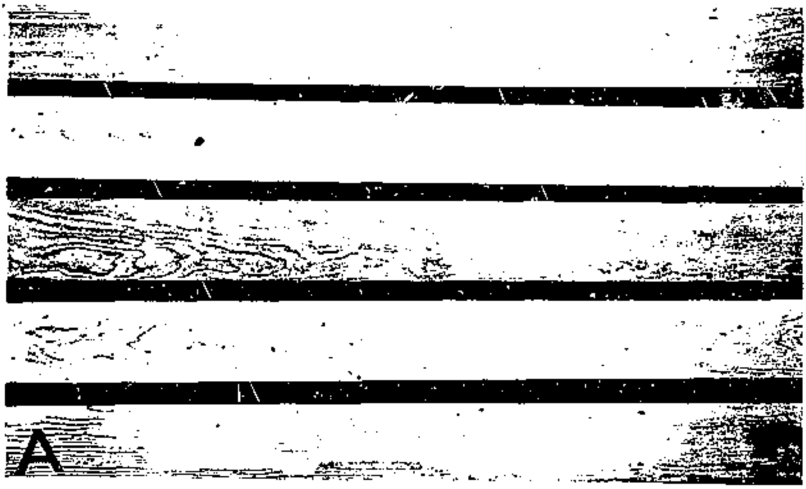
> No. 5 Common is the lowest recognized grade and admits all defects known in lumber, provided the piece is strong enough to hold together when carefully handled.

DIMENSION AND TIMBER GRADES

The grading rules (*30*) describe three dimension and timber grades; namely, No. 1, No. 2, and No. 3 Dimension and Timbers. Slightly less than three fourths of the cut of white fir in California and slightly more than one fourth of the cut of white fir in the Inland Empire go into these grades.

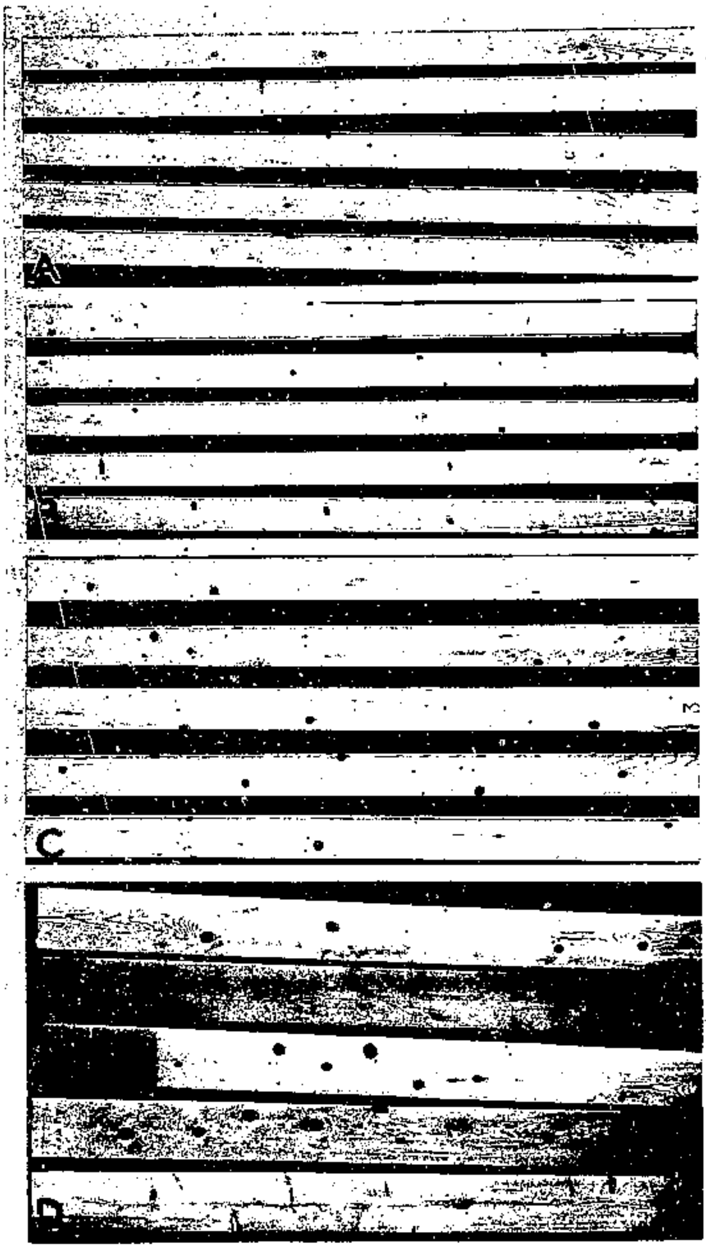
The grading rules do not specifically limit defects injurious to the strength. The only specified sizes of defects are those for wane and crook in No. 1 Dimension. The strength of the material in these grades is therefore dependent almost entirely on the grader's judgment of the influence of defects. The material therefore shows a wide range of strength for the judgment of graders will vary considerably. Working stresses cannot be assigned to such grades with any assurance because it is impracticable to determine the strength of the weakest pieces the grade may contain.

The defects found in the dimension grades in a study made at a California mill are shown in figure 19. The figure shows the percentage of pieces in which each defect occurred irrespective of other defects in the same piece. Of the defects listed, only knots, cross grain, breaks, shake, and checks materially influence strength. The other defects listed have little or no affect on strength, although, as is evident from figure 19, they are a factor in the grade determination. The amount of injury is dependent primarily on size and position of defect, while quality or character has little to do with the strength, although it may adversely affect the appearance. Thus, the injury resulting from a knot depends upon its size and location. Whether it is checked, broken, loose, or even missing, the effect is the same.



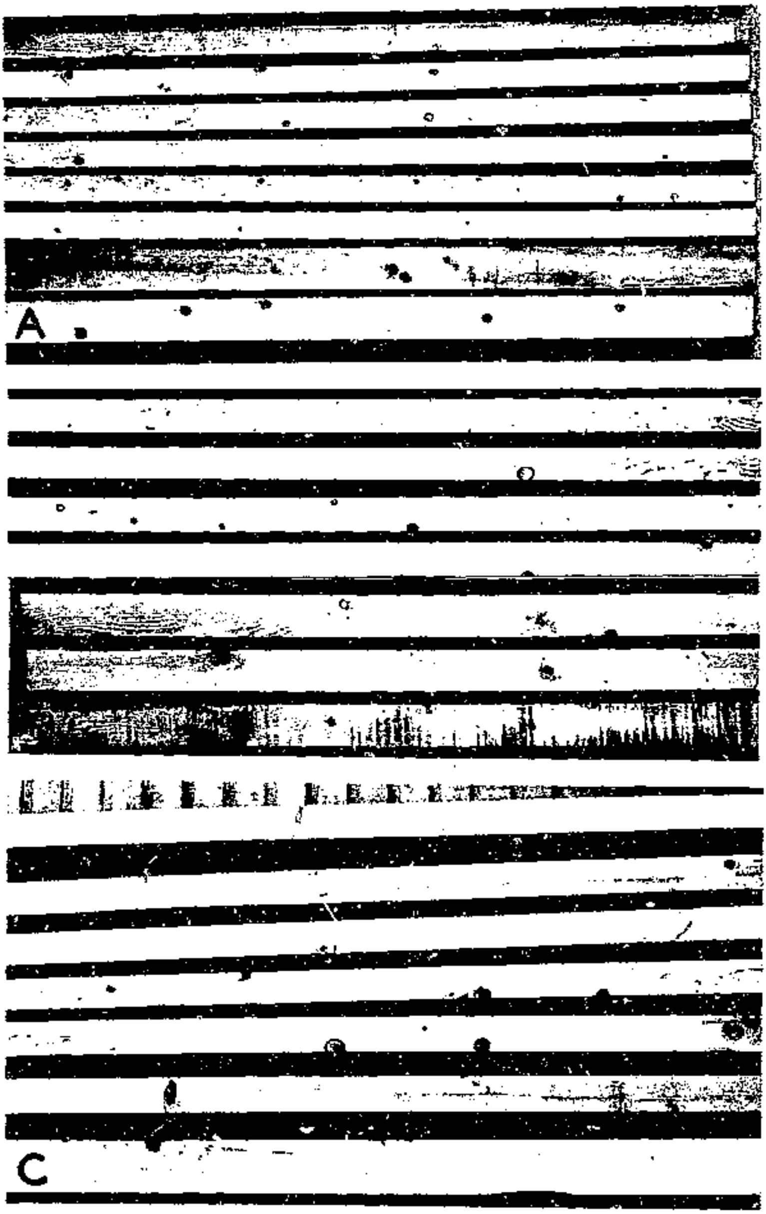
SELECT GRADES OF WHITE FIR.

A, C and Better white fir is of high quality containing many boards that would grade B or Better. This 1- by 8-inch finish shows the range in quality in the grade from the clear board on the top to the board on the bottom containing three small knots. B, D Select in white fir is intermediate between the Common and the Select grades having some characteristics of both. The range in quality is shown by the 1- by 6-inch and the 1- by 8-inch finish



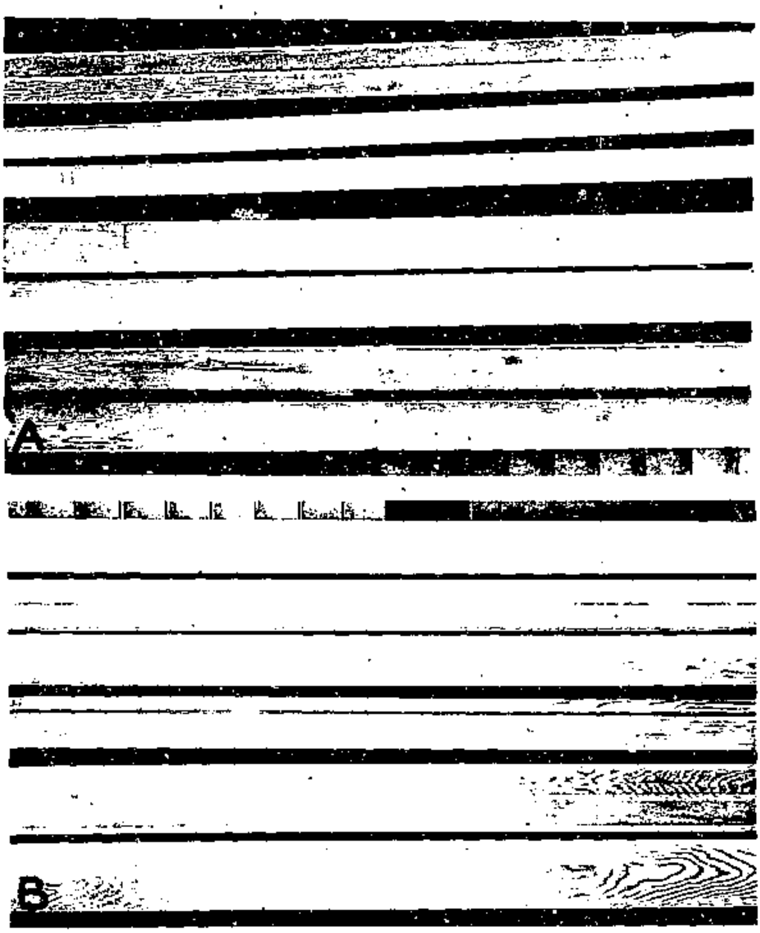
COMMON GRADES IN WHITE FIR.

A, No. 1 Common. White fir produces only a small amount of No. 1 Common. The range in quality of grade is shown by the specimens of 1- by 6-inch shiplap. B, No. 2 Common in white fir is usually sold combined with other grades. It may be sold as No. 2 and Better or No. 3 and Better Common. The range in quality of the No. 2 Common grade is shown by the 1- by 6-inch shiplap. C, No. 3 Common in white fir is sometimes marketed as such but principally as No. 3 Common and Better. The general run of the No. 3 Common grade is shown by the 1- by 6-inch shiplap. D, No. 4 Common 1- by 12-inch white fir boards showing range in quality in the grade.



DIMENSION GRADES IN WHITE FIR.

A, Representative 2- by 4-inch and 2- by 6-inch No. 1 Dimension in white fir. The many small encased knots are typical of the general run of the grade. B, Typical 2- by 4-inch and 2- by 6-inch No. 2 Dimension in white fir. C, Typical 2- by 4-inch and 2- by 6-inch No. 3 Dimenson in white fir. The grade permits defects that reduce strength but do not materially affect stiffness.



WHITE FIR PLANING MILL PRODUCTS.

A, *From top to bottom,* 1 *piece of novelty siding,* 2 *pieces round-edge novelty siding,* 2 *pieces of tongued* and grooved flooring; and 2 pieces of log cabin siding. B, From top to bottom, rustic siding, edge-grain center V ceiling; *flat-grain center V ceiling, pulley stile, and back view and face view, respectively, of* hollow-back baseboard.

Warping and compression wood are undesirable from a fabrication and use standpoint. Even the checks and splits are ordinarily of small importance to strength because of more serious injury resulting from knots and cross grain.

EQUIVALENT COMMON-DIMENSION GRADES

Dimension grades are commonly spoken of as being approximately similar to the next lower common grades; that is, No. 1 Dimension is

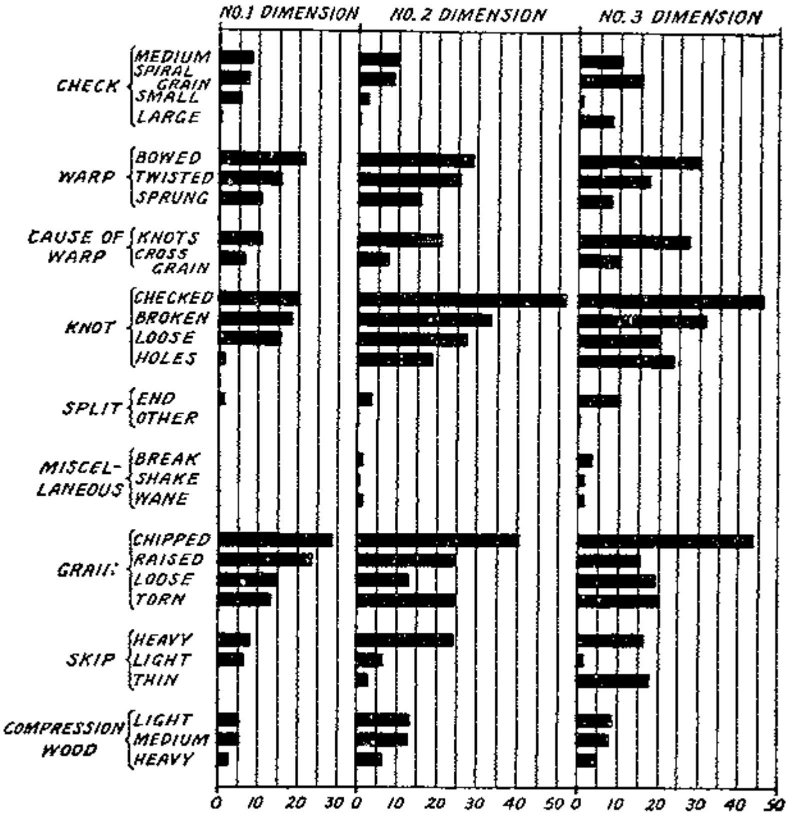


FIGURE 19.—Defects found in 1 9/16- by 4- by 8-inch surfaced and seasoned white fir. Bars show percentage of occurrence of each defect irrespective of other defects in combination in same piece.

similar to No. 2 Common, No. 2 Dimension to No. 3 Common, and No. 3 Dimension to No. 4 Common. As a rough approximation, this is fairly close to the truth, for the major portion of the pieces in any large sample of a given dimension grade will usually fall in the next lower common grade if graded by the common rules. White fir No. 1 Dimension, however, will ordinarily include a substantial proportion of No. 1 Common. In the nominal 2 by 4 inch size there may be as high as 15 to 20 percent of the pieces of No. 1 Dimension that would qualify as D Select or C Select and Better.

The ties produced for the logging railroads are generally of low quality, equivalent to a mixture of about one third each of No. 3, No. 4, and No. 5 Common if sawed into lumber. Ties occasionally produced for main-line railroads on special order are equivalent to No. 2 Common or Better.

Timbers are of good quality. If sawed into lumber, most of the product would be No. 3 and Better Common, probably equivalent to No. 2 Common in average value.

NO. 1 DIMENSION

Very little No. 1 Dimension of white fir is shipped. In both California and the Inland Empire it is common practice to combine it with No. 2 Dimension and ship it as No. 2 and Better Dimension (fig. 18). Under more favorable market conditions there will be an increasing tendency to separate No. 1 Dimension. The grade will eventually be considerably more important than is indicated by figure 18.

The grading rules (*30*) define No. 1 Dimension grade thus:

> 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 basis of 2 by 4, wane on edge is admissible ½-inch deep, for half 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, it being understood, however, that the wane in no case extends over more than one half the side of the piece.
>
> A piece may have a crook of 1 inch (provided it does not occur near an end) in 2 by 4 inches by 16 feet; and ⅛ inch less in each additional 2 inches of width. Pieces longer or shorter than 16 feet may have crook in proportion.
>
> A few wormholes are admissible.

The strength of individual pieces in the grade will vary widely. No. 1 Dimension (pl. 7, *A*), can be used to advantage where the user has wide varying strength requirements and can sort the material in strength classes, or where stiffness rather than bending strength is the controlling factor in design, such as in studding and joists for small-house construction.

Where uniformly high bending strength is required as in timber for mill construction and other structural purposes No. 1 Dimension should be regraded to meet American lumber standards basic provisions for structural material (*28*).

NO. 2 DIMENSION

Practically all of No. 2 Dimension is sold combined with No. 1 Dimension as No. 2 and Better Dimension. Under the grading rules (*30*) No. 2 Dimension grade—

> will admit of large coarse knots, not necessarily sound, considerable wane, also shake, wormholes, dozey streaks, crooked pieces, or other defects which weaken or impair the pieces to such an extent as to render it unfit for No. 1 Dimension grade. A serious combination of these defects is not admissible in any one piece.

The defects found in the grade are shown in figure 19. The general appearance of the grade is shown in plate 7, *B*. Not only are the defects more numerous than in No. 1 Dimension, as shown by figure 19, but they are larger and more injurious to strength. Dimension of this grade is best adapted to uses where stiffness rather than breaking strength control, such as joists. The decay streaks and unsound knots admissible under the grading rules may reduce bending strength to less than one half that of clear wood but have little influence on stiffness. No. 2 Dimension is not suitable for use in heavy mill construction or for parts of permanent structure where high strength is desired unless weaker pieces are sorted out by regrading.

NO. 3 DIMENSION

A relatively small amount of white fir is sold as No. 3 Dimension. The grading rules (*30*)—

will admit a great deal of rot and all the imperfections allowed in No. 1 and No. 2 Dimension but in a much more pronounced form.

This is the lowest recognized grade of Dimension and is not recommended for use in permanent structures. It is suitable for temporary construction or crating when rot or other defects which seriously injure the strength are cut out of pieces containing them. The general appearance of the grade is shown in plate 7, *C*. The presence of defects that do not show in the picture is indicated in figure 19.

WORKING STRESSES

Working stresses are used to determine the safe load-carrying capacity of timbers or the size and number of timbers required to safely carry a given load. They are intended primarily for use in design of structures, but can be used for comparison of structural material of species when grades are comparable. The grades are only comparable when they limit the size, location, and number of defects. Building codes or other engineering specifications generally place a limit on the permissible working stresses.

Safe working stresses cannot be assigned with any degree of assurance to the Dimension and Timber grades described in grading rules (*30*). The absence of specific defect limitation in the Dimension and Timber grades leaves their selection to the judgment of the graders and makes it impossible to determine the strength of a timber acceptable in the grade. It is possible and even probable that some graders may accept timbers in any of the dimension and timber grades that will have less than one half the strength of the clear wood. Working stresses established so that such timbers would safely carry the design load would be so low that they would practically prohibit the use of the grade.

Specifications of the American Society for Testing Materials (*1*) and American Railway Engineering Association (*8*) for grading structural timbers conform to the basic provisions of American lumber standards (*28*). They provide for two grades, Select and Common. Timbers of the Select grade will develop at least 75 percent of the strength of the clear wood, and of the Common grade, 60 percent.

Dimension and timbers graded in accordance with the foregoing specifications will safely take the stresses recommended in table 22 for white fir. The working stresses recommended in the table were obtained by adjusting the strength of the clear wood to meet conditions that exist in service (*17*). 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 as compared to that shown by test specimens which are loaded only a few minutes, and the weakening effect of certain species characteristics.

TABLE 22.—*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 largetooth 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	1,560	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	1,040	948	756	1,067	800	[6] 347	[6] 240	[6] 213	90	72	1,173	880	1,067	800	907	680	1,600,000
Douglas fir (dense) [5]	1,750	1,400	1,349	1,147	1,517	1,213	1,037	882	1,167	933	379	262	233	105	84	1,283	1,027	1,167	933	992	793	1,600,000
Douglas fir (Rocky Mountain type)	1,100	880	800	680	900	720	620	530	700	560	275	225	200	85	68	800	640	800	640	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	1,300,000
Elm, slippery and American	1,100	880	800	680	900	720	710	600	800	640	250	175	125	100	80	800	640	750	600	650	520	1,200,000
Fir, balsam	900	720	670	570	750	600	530	450	600	480	150	125	100	70	56	700	560	600	480	500	400	1,000,000
Fir, commercial white	1,100	880	800	680	900	720	710	600	800	640	300	225	200	70	56	700	560	700	560	600	480	1,100,000
Gum, red, black, and tupelo	1,100	880	800	680	900	720	710	600	800	640	300	200	150	100	80	800	640	750	600	650	520	1,200,000
Hemlock, eastern	1,100	880	800	680	900	720	710	600	800	640	300	225	200	70	56	700	560	700	560	600	480	1,100,000

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

[1] American lumber standards: Basic provisions for American lumber standards grades are published in U.S. Department of Commerce Simplified Practice Recommendation R16-29 (*28*); specifications for grades conforming to American lumber standards are published in the 1927 standards of the American Society for Testing Materials (*1*), and in American Railway Engineering Association Bulletin (*8*).

[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 percent greater than the horizontal shear values for the select grade.

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

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

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

In addition the working stresses of table 22 provide a factor of safety[11] to take care of small accidental overloads. In a structure designed from the stresses recommended in table 22 occasional timbers may be expected to fail in bending immediately upon being subjected to twice their design loads and about one timber in a hundred will fail at one and one half times the design load if the load remains on the structure for several years.

The adjustment for the injurious effect of defects of necessity limits the application of working stresses to specific grades, except that the recommended working stress for end compression perpendicular to the grain and the average values of modulus of elasticity are applicable to all grades, since these two properties are not seriously affected by defects.

The application of working stresses to dimension or timbers graded under 1929 grading rules (*30*) requires regrading. Such a regrading is not difficult to accomplish with the aid of structural grade examples (*1*, *8*, *28*).

USES OF WHITE FIR

White fir (p. 2) goes into a comparatively small number of uses. About three fourths of the cut is used for construction purposes. Of the remaining one fourth all but a fraction of 1 percent goes into boxes and crates, planing-mill products, sash, doors, blinds, and general millwork. Less than 0.5 percent goes into industrial uses.

The principal uses of western true firs[12] are shown in figure 20. The figure compares the use of western true firs with the average of 14 of the principal commercial softwoods based on the percentage of the cut going into the various uses. The use classifications are very broad, and each includes a number of more specific individual uses. Thus, under planing-mill products are grouped 20 or more specific uses, such as flooring, ceiling, partition, and the like. Generally the comparison shows that a higher percentage of the cut of the western true firs is used for building and containers and a smaller percentage for planing-mill products, general millwork, and industrial uses than of the cut of the average softwood. The small percentage of material of the select grades cut from white fir is partly the cause for the use distribution shown. Figure 20 does not show how successful the white firs are in meeting the requirements of the various uses. Service records over a long period are the best criterion of the suitability of a wood for a use. In the absence of such records the suitability can best be determined by comparing the properties of wood with the requirements of the use. Use requirements, however, are not always known and even when known are subject to change with time and conditions. Determination of the suitability of a wood for a use from analysis of properties should be checked against the experience of users if possible. In the following discussion of the uses of white fir, therefore, there is presented a comparison of the properties of the wood and use requirements insofar as they are known. Price is not considered, for it varies too widely with time and place. The discussion of uses of white fir can, therefore, be

[11] United States Department of Agriculture, Forest Service. significance of the "factor of safety" in working stresses for structural timber. U.S.Dept.Agr., Forest Serv. Forest Prod. Lab. Tech. Note 222, 3 p. [n.d.] [Mimeographed.]

[12] United States Department of Agriculture, Forest Service. lumber used in manufacture, preliminary statistics, forest survey of the united states. U.S.Dept.Agr., Forest Serv. 55 p. 1928. [Mimeographed.]

considered only as an aid to the consumer in determining if white fir is the most economical wood for his purpose. He must evaluate difference in properties or service and weigh them against difference in price of competitive species.

WHITE FIR BOXES AND CRATES

Boxes and crates are from a quantitative standpoint the most important of the industrial uses of white fir. About one sixth of the annual lumber cut of western true firs or about 46,000,000 board feet, go into this use. The western true firs rank seventh among the softwoods in amount of lumber used for containers. They owe their popularity as container woods to their clean bright appearance and white color, their light weight, freedom from stain and pitch defects, lack of odor when dry, ease of working, availability, and low cost. Their bending strength, stiffness, and shock-resisting ability are about the same as those of the soft pines, which are our principal

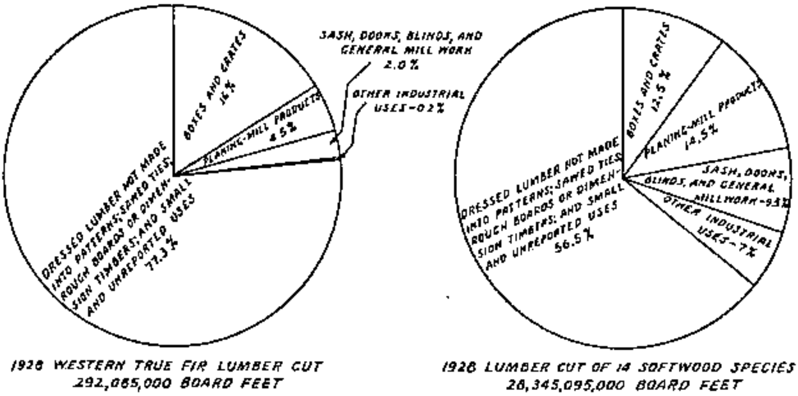


FIGURE 20.—The use of western true firs compared with that of other softwoods. A high percentage of the lumber cut of true firs is used in general construction, more than the average is used for boxes and crates.

container woods. The soft pines, however, have a more uniform texture, split less in nailing, and have a higher nail-holding power.

BOXES

White fir is grouped for box making with ponderosa pine, western white pine, northern white pine, sugar pine, and the other softer and lighter woods (*19*). The groupings are made in accordance with the nail-holding power and other properties of the wood (*19*). There are four groups and white fir is in the most favorable group 1. The woods in this group are relatively free from splitting in nailing, have moderate nail-holding power, moderate strength as a beam, and moderate shock-resisting ability. Boxes made of the woods within a group, however, are not necessarily equally serviceable.

A detailed study (*5*) was made by the Forest Products Laboratory to determine the suitability of several species, including white fir (*Abies concolor*) and lowland white fir, for manufacture of containers. The tests, as well as past experience in box design, indicate that standard canned-food boxes of white fir could be built into considerably better boxes by using smaller nails spaced closer than the standard of seven sixpenny nails to a nailing edge. Smaller nails will reduce splitting and more nails will increase holding power. The primary cause of failure when the boxes were tested to destruction was splitting of ends by the nails, nails pulling from end grain, and splitting of sides, tops, and bottoms at the nails.

The test demonstrated conclusively that good service cannot be expected from boxes built from green or wet lumber of any species. The boxes of white fir (*Abies concolor*) and lowland white fir made of green or wet lumber lost about three fourths of their resistance to rough handling when dried to about 10-percent moisture content in storage. On the other hand, nails in boxes made of lumber between

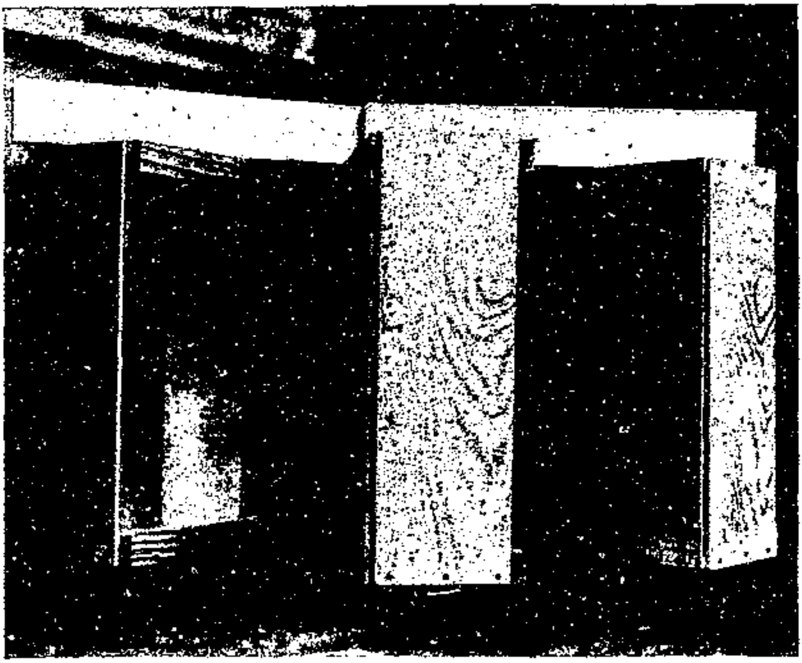


FIGURE 21.—High-quality white-fir boxes used for grape lugs.

12- and 15-percent moisture content did not pull when the boxes were tested to failure. The white fir (*A. concolor*) boxes withstood about the same rough handling as ponderosa pine boxes when both were made from lumber at about 15-percent moisture content.

A list of different kinds of boxes for which white fir is used would include practically every ordinary type of box made. White fir has, however, been most widely used in the manufacture of containers for foodstuffs (figs. 21 and 22).

A series of tests on white fir (*Abies concolor*) boxes was made to determine the possibilities of improving nail-holding power and of reducing splitting. The type of box, size of nail, and nail spacing were the same as those used in the previously mentioned tests. Three groups of 5 boxes each were tested. Each group had 3 boxes nailed with blunted nails, which were tapered and chemically treated (p. 31); the other 2 boxes in each group were nailed with cement-coated nails. All boxes were made from air-dry lumber at about

13-percent moisture content. One group of boxes was nailed and tested immediately, another was stored under damp conditions for 53 days and tested at a moisture content of about 23 percent. The other was stored under dry conditions the same length of time and tested at about 6-percent moisture. The conditioning of the boxes was intended to reproduce as nearly as practicable conditions of service—where boxes are nailed, packed, and shipped without storage to local or nearby regions; where they are placed in cold storage or shipped in refrigerator cars; and where they are stored in heated buildings or used under hot, dry conditions such as exist in some fields, orchards, and vineyards.

In general, the test results conform to the conclusions drawn from previous tests that white fir makes an excellent box. The boxes showed little tendency to split in nailing. Both the special blunted, chemically treated nails and the cement-coated nails held well and few failures resulted from nails pulling. The blunting of the nails increased the tendency of the wood to shear at the nails. The chemical treatment of nails increased nail-holding power sufficient to more than offset the loss of nail-holding power caused by blunting, except in boxes stored at 13-percent moisture and dried to 6-percent moisture. The amount of rough handling withstood by boxes of all three groups, and types of failure, indicated that they would give satisfactory service.

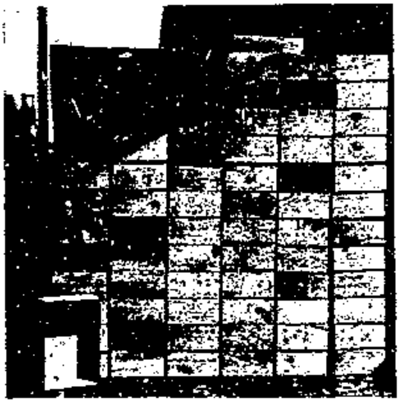


FIGURE 22.—Low-priced white-fir boxes used for the shipment of shooks for food boxes.

The tests indicate that it is not necessary to use a special nail to make a satisfactory box of white fir. If the lumber is properly seasoned and the proper size and number of nails are used (*19*), the ordinary cement-coated nail is satisfactory.

CRATES

Well-seasoned white fir is well adapted to all types of crates. It is equally adapted to crates for small-sized or light articles and for large, bulky, and heavy articles. Crates for odd-shaped articles, which require more cutting and hand fitting than the ordinary crate, can be made economically from white fir because of its easy working qualities. Its light weight adapts it to crating for all articles of light weight because the shipping charges on such articles depend largely on the weight of the crate.

White fir is especially adapted for melon and vegetable crates because of its lack of odor and resin and its light weight. Large quantities are used in California for shipment of melons, sweetpotatoes, lettuce, and celery. For these particular commodities white fir on its merits has successfully broken through the long-standing barrier of traditionally popular competitive species. Its popularity as a container for such commodities will increase as increasing use by the growers demonstrates its suitability.

PLANING-MILL PRODUCTS

About 4 percent of the lumber cut of western true firs (p. 2) goes into planing-mill products. This is only one third of the percentage of the average softwood used for this purpose. The small amount of white fir going into planing-mill products is due to the small percentage of the select grades obtained from white fir.

Planing-mill products include a wide variety of items. They are used for interior and exterior trim, flooring, roofing, and framing. The property requirements for all items of interior trim are practically identical. The requirements for many items of exterior trim are also identical. The items going into these uses can therefore be discussed in groups.

Practically all items of interior and exterior trim are manufactured from white fir. Table 23 lists the sizes and grades of the standard items that are available.

TABLE 23.—*Principal planing-mill products of white fir*

Product	Thicknesses, inches	Widths, inches	Grades
Finish, surfaced 2 sides or surfaced 4 sides.	13/16 to 2	4 to 12	C and Better, D Select.
Baseboard	(1)	(1)	Do.
Casings	(1)	(1)	Do.
Frame material	(1)	(1)	Do.
Miscellaneous moldings	(1)	(1)	Do.
Battens	(1)	(1)	Do.
Bevel siding	3/16 x 7/16	4, 5, 6	Do.
Rustic siding	(1)	(1)	Do.
Drop siding	9/16, 13/16, 1, 1 1/4	3, 4, 5, 6, 8	No. 2 Common or Better.
Flooring	9/16, 13/16, 1, 1 1/4	3, 4, 5, 6, 8	No. 3 Common or Better.
Partition	9/16, 13/16, 1, 1 1/4	3, 4, 5, 6, 8	Do.
Ceiling	(1)	(1)	Do.
Dressed and matched	13/16, 1, 1 1/4, 1 1/2, 2	4 to 12	All grades.
Shiplap	13/16, 1, 2	4 to 12	Do.
Grooved roofing	1 to 2	4 to 10	No. 3 Common or Better.
Do	Greater than 2 inches	4 to 10	No. 2 Common or Better.

[1] All standard patterns and sizes.

Local demand has resulted in the regular stocking by some retail yards of various special patterns in white fir, such as hollow-back baseboards, round-edge casing, two-lap drop siding, V-grooved ceiling, grooved roofing, partition, stops, hook strip, and quarter-round and half-round moldings. Some of these items are shown in plate 8.

Almost any yard regularly handling white fir carries surfaced 4 sides or surfaced 2 sides C and Better trim, common shiplap, and 2 or 3 grades and sizes of dressed and matched stock in addition to common boards and dimension.

Practically any pattern made in pine may be obtained in white fir from the larger operators, who ordinarily carry most of their white fir in the rough until orders are received. The range of stock carried in white fir is confined mostly to thicknesses of 2 inches and under and widths from 3 to 12 inches. Thicker and wider material is produced, but usually on special order.

INTERIOR TRIM

The requirements for all items of interior trim are practically identical. Finish, baseboard, casing, partition, and ceiling all must stay in place and take and hold enamel or natural finishes. Resistance to marring and denting are also desirable. Interior trim, however, is chosen primarily for appearance.

The white firs can be used for either enamel or natural finishes. The figure, while pronounced enough to give a pleasing effect with natural finishes, especially when accentuated by staining, is not sufficiently pronounced to make it hard to cover with enamel. No trouble will be experienced from grain raising, which is objectionable with either enamel or natural finish, provided the wood is thoroughly dry when dressed and put in place, and all boards are turned bark side out. Dressed wet there is not only a tendency for grain to rise, but the wood fuzzes making it difficult to obtain the desired smoothness of finish. Figure 23 and plate 9 show white fir used for interior trim. White fir is a stable wood and will stay in place well if dry when installed because the shrinkage is small, especially in edge-grained material. Moreover, straight-grained white fir has little tendency to warp. The wood of the white fir, however, is soft and is consequently readily marred or dented. In this respect white fir is similar to ponderosa pine and inferior to the hemlocks and hard pines.

EXTERIOR TRIM

Siding is the principal item of exterior trim made from white fir. Bevel, rustic, and drop siding are the three principal patterns. Some white-fir finish is used for trim.

The most important property requirements for exterior trim are stability, ability to take and hold paint, and ease of fabrication. Dry white fir is a stable wood, it has small shrinkage and little tendency to warp. The wood weathers rather rapidly. If left unprotected by paint, large open cracks will develop. A good three-coat paint job applied soon after construction and then maintained will practically eliminate weathering (p. 32). Repainting should not be postponed until bare wood is exposed, but should occur when a close examination reveals fine cracks in the paint coat. White fir holds paint well. Its ability to hold paint is a very desirable asset in exterior trim. The ease with which white fir is cut, sawed, and fitted makes it popular with builders. In this respect white-fir trim is very similar to trim of the spruces and hemlocks.

FLOORING

Unless it has received a preservative treatment white fir (p. 32) is unsuited for flooring used where the decay hazard is high, such as in exposed porches. Little white fir is used for finished floors in small houses. The wood mars and dents more readily than Douglas fir or western larch, and the small percentage of the material in the select grades limits the amount suitable for such floors. In recent years, however, some of the lighter weight, light-colored, softer conifers have been successfully used for fine finished flooring, notably western hemlock. Judged by its properties edge-grained white fir could be used where the wear is not heavy, such as in the second floor of a dwelling. Service records are not available to confirm this conclusion and until a few trial installations are made the wood cannot be recommended for such floors.

White fir flooring is used principally in rough floors. Most of it is of No. 2 Common or Better grade. The knots and other defects present in the grade, while objectionable in floors with natural finish, are acceptable in some painted floors, such as in cottages and protected porches.

Recent observations indicate that woods as soft as white fir can be used where mechanical wear is heavy. But where there is a moderate decay hazard, mechanical wear rather than decay is often

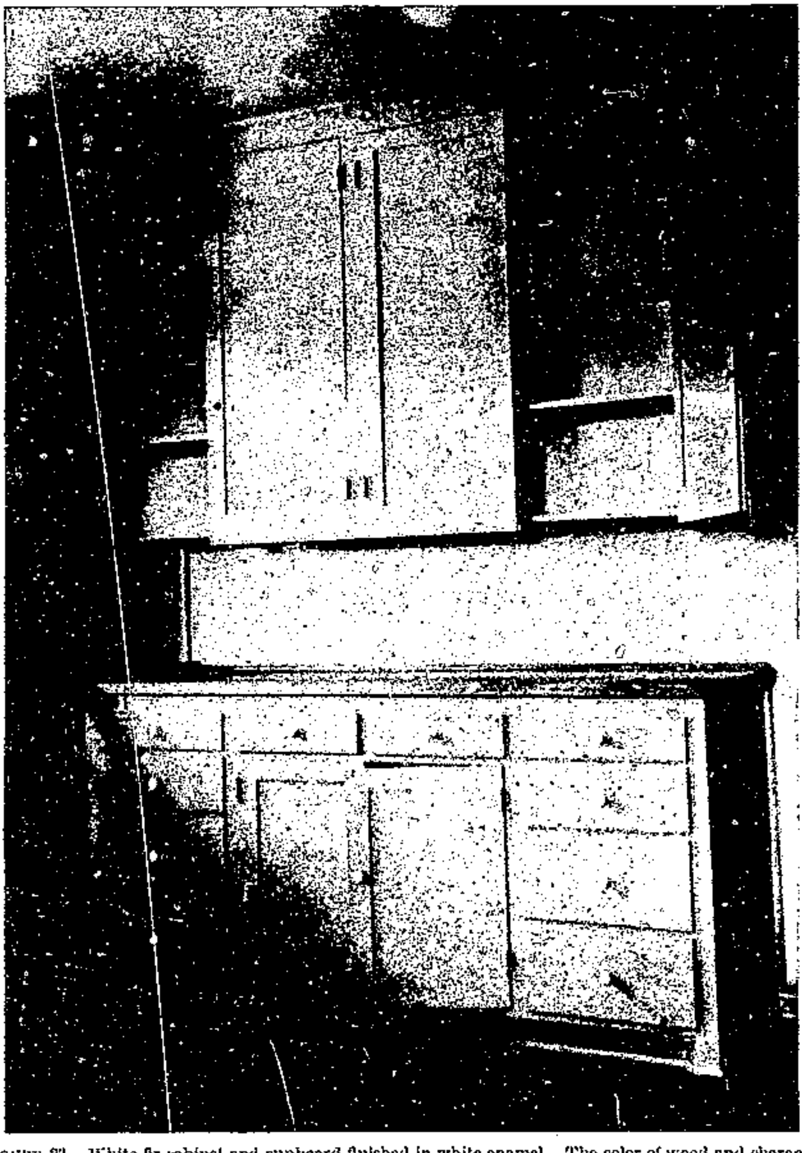


FIGURE 23.—White fir cabinet and cupboard finished in white enamel. The color of wood and character of figure make a good base for enamel finish.

responsible for replacement of white fir. The softer woods mash or crush and do not wear down so rapidly as harder softwoods that sliver and splinter. There is some evidence that white fir will give equal or better service than heavier and harder softwoods under heavy mechanical wear, but additional service records are necessary before it can be unqualifiedly recommended. It cannot be recommended as an alternate for the tougher hardwoods such as oak or black gum. Figure 24 shows heavy white fir flooring for mill construction.

SASH, DOOR, BLINDS, AND GENERAL MILLWORK

About 2 percent or 6,000,000 board feet of the western true firs go into sash, door, blinds, and general millwork. The statistical data do not indicate how much of this is obtained from white fir.

SASH, DOOR, BLINDS

Sash and door production from white fir is handicapped by the fact that most white fir producers have enough of the soft pines to

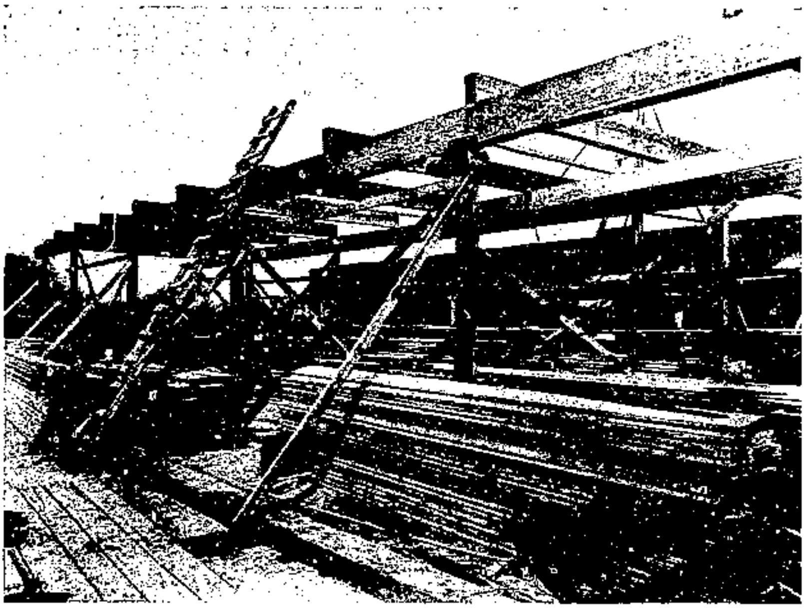


FIGURE 24.—Piles of heavy, tongue-and-groove white fir flooring awaiting installation in a factory.

fill all their orders. There is therefore little incentive for developing a market for white fir doors or millwork. White fir has the stability, painting, and finishing characteristics necessary for sash, doors, and blinds. White fir is equally suitable insofar as decay resistance is concerned as any woods used for this purpose in which unlimited amounts of sapwood are permitted. White fir is not so easy to work as the soft pines but is better adapted to natural finishes where a figured grain is desired. The tendency of white fir to check when exposed unpainted requires that all exposed white fir millwork be protected by paint or a natural finish (p. 39).

CORE STOCK

White fir makes a good core stock for veneer doors. The wood is easily glued under a wide range of gluing conditions, and it is stable when dry, having small shrinkage and little tendency to warp. Common lumber and tongue-and-groove stock are used for core stock.

FIRE DOORS

The properties of white fire are very similar to those of some of the species now listed as acceptable for tin-covered fire doors (*16*). White fir meets the requirements for low resin content as well or better than any species now in the acceptable list. Of the acceptable species only the cedars and western white pine, northern white pine, and sugar pine are lighter in weight. The nail-holding power of white fir is low. It is, however, higher than that of one acceptable species and is sufficient to hold three-ply cores together, especially as specifications (*16*) require through nailing and clinching of nails. If wood is dried to below 15-percent moisture content when metal covering is applied, the decay hazard becomes so low that species with low decay resistance can be used. The present specifications call for No. 1 Common or better. A select grade or specifically selected white fir would be required to meet the specifications because No. 1 Common is seldom segregated. Before a market for white fir can be developed with the manufacturers of fire doors, the wood must receive the approval of the National Board of Fire Underwriters.

GENERAL MILLWORK

The production of items of general millwork other than those just discussed is small and relatively unimportant. Bathroom cabinets, kitchen cabinets, cupboards, and other built-in products are made entirely of white fir or white fir mixed with one of the soft pines, principally ponderosa pine. Some window frames and pulley stiles are made but they are not readily available to consumers. Generally white fir makes excellent millwork but is handicapped by always being produced along with the more popular species for general millwork.

WHITE FIR FOR SMALL-HOUSE CONSTRUCTION

More white fir (p. 2) is used in the construction of small houses than for all other purposes. About three fourths of all commercial white fir lumber cut annually, or about one fourth of a billion board feet, goes into small-house construction. The percentage of white fir used for this purpose is larger than that of the average for the softwoods.

The species is used largely in the form of dimension and common boards. It is, therefore, used most in frames, subfloors, and sheathing. There are, however, houses in California built of white fir from cellar to attic, the only other wood used being in foundation sills and shingles.

Considerable difference of opinion exists concerning the merits of white fir for construction purposes. In some localities, the wood has established a desirable reputation as a construction material. In other localities, the wood is regarded as inferior for house construction. Where the wood has given satisfaction it has been dry and usually standard or oversized. Where dissatisfaction has been encountered, the wood usually has been found to be insufficiently seasoned. Other important contributing causes have been substandard sizes, poor grading, improper use because of lack of knowledge of properties and peculiarities of species, and poor or inefficient workmanship. Taken as a whole the complaints are not primarily an indictment of the wood, but show the necessity of improved seasoning, grading, handling, and a better knowledge of the properties. The complaints caused by inherent characteristics of the wood are minor, and their cause is known and a remedy is available. Thus, where the nail-holding power is inadequate it can be increased by the use of more nails or by the use of chemically treated nails with high holding power (p. 30). Splitting can be reduced by the use of blunt, tapered nails. Substandard sizes are largely responsible for inadequate strength or stiffness. A comparison of the properties of white fir with those of eastern spruce and eastern hemlock, two woods that are successfully used in house construction, indicates that white fir may be used for the same purpose.

The properties desired in building material may be divided into two groups—one containing those properties that tend to insure satisfactory service when the wood is in place, the other containing those properties that tend to facilitate construction and thus reduce costs. Strength, stiffness, nail-holding power, and stability are important properties in the first group. Light weight, softness, and ease of working are those of the second. A species cannot excel in the properties of both groups, since, for instance, if it has high strength it is comparatively heavy and hard.

The adequacy of the strength of white fir for structural purposes is shown by recommended working stresses (table 22). The working stresses recommended for white fir compare favorably with those of a number of species that have been successfully used in the construction of small houses. They are the same throughout as those for eastern hemlock, a wood used extensively in the Lake States in house construction. The working stresses of eastern spruce, which has for years been a standard construction material in New England, do not differ greatly from those for white fir. The working stresses for all of these woods are lower than those for Douglas fir (coast type) and southern yellow pine. The lower working stresses of white fir do not mean that the wood is unsuited for structural work but indicate the necessity for larger sizes to obtain strength and stiffness equal to that obtained with stronger woods. For example, a 2- by 8-inch white fir rafter is stronger and stiffer than a 2- by 6-inch rafter of a comparable grade of any species in table 22. It is evident, therefore, that adequate strength or stiffness may be obtained by proper design as well as by species selection.

The size of some items, such as studding, are largely fixed by common practice. American lumber standards sizes were established with a view to having the sizes adequate for the lighter weight, weaker species. White fir can in many items, therefore, be used in the same sizes as the heavier and stronger species. The value of the greater strength and stiffness of houses constructed of the heavier and stronger woods is difficult to evaluate. While oversized or extra standard sizes of white fir are not necessary to meet the requirements of houses constructed in accordance with accepted standards of good practice, substandard sizes, especially in the lighter weight and weaker species, such as white fir, are questionable.

FRAMING

Probably the largest single use of white fir is for framing for small houses. It is used for all items of framing, including studding, rafters, joists, sills, and plates. Although these uses differ in many respects, they have a number of common requirements, including nail-holding power, stability, ease of working, and light weight. White fir is light in weight, easy to work, stable, and dimension items have the reputation of being straight and easy to fabricate. Their strength, nail-holding power, and lack of decay resistance as compared with certain other species have been objected to by consumers in some localities. Trouble in these respects, however, may be due to many other factors than the inherent properties of the wood itself.

Bending strength is an important requirement of rafters, but less so of joists and studding. White-fir rafters to be the equal in strength of Douglas fir (coast type) or southern yellow pine of comparable grade should be, other dimensions being equal, about one sixth wider, or the span should be shortened about one third by bracing or otherwise. Thus, Douglas fir when the design calls for a 2- by 6-inch Douglas fir (coast type) rafter to obtain necessary bending strength,

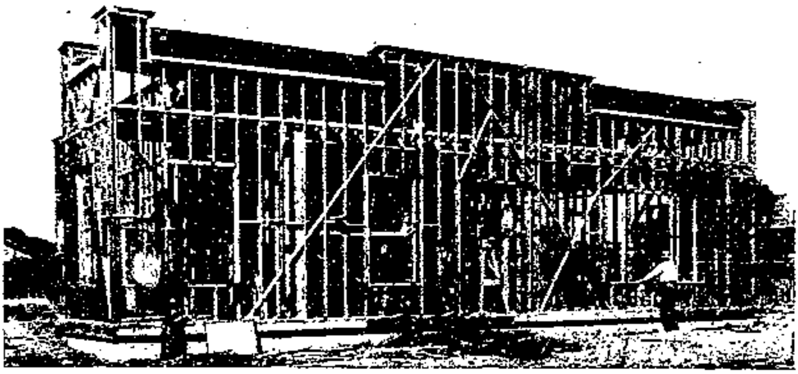


FIGURE 25.—White-fir studding. It is light in weight, straight, and the principal dimension item produced from the species.

a 2- by 7-inch rafter in white fir would be required to give the same strength. Since a 2- by 7-inch rafter is not a standard size, a 2- by 8-inch rafter would probably have to be used, even though it is larger than is required to obtain the necessary strength. The added strength and stiffness resulting from the extra inch has a value, but it is difficult to evaluate. On the other hand where load requirements call for nonstandard 2- by 5-inch Douglas fir (coast type) a standard 2- by 6-inch would probably be used, which is the same size as would be used with white fir.

Stiffness is the principal requirement of joists and studding in small buildings (fig. 25). The size required to obtain the desired stiffness is much larger than is necessary to carry any loads to which joists or studs are likely to be subjected. Joists and studs in small houses, therefore, seldom if ever break. Grade likewise is not very important in joists and studs, for knots, knot holes, and other defects have little influence on stiffness. White-fir joists to have the same stiffness as those of Douglas fir (coast type) or southern yellow pine should be one eighth deeper or the span would have to be about one eighth shorter. Thus, a 2- by 8-inch joist in Douglas fir (coast type), any grade, has about the same stiffness as 2- by 9-inch white-fir joist of any grade, other things being equal; or a white-fir joist on a 16-foot span has the same stiffness as one of Douglas fir (coast type) on a 14-foot span, other dimensions being the same. A white fir substandard joist is 1$\frac{9}{16}$ inches thick and is 4 per cent lower in stiffness and breaking strength than a standard 1⅝-inch thick joist of same depth, which is not an especially significant difference. On the other hand, a white-fir substandard 2- by 4-inch piece is about 12 percent lower in stiffness than one of standard size. It is difficult to determine what this difference in stiffness of joists and studs would mean in terms of service In the lighter weight, weaker softwoods, the

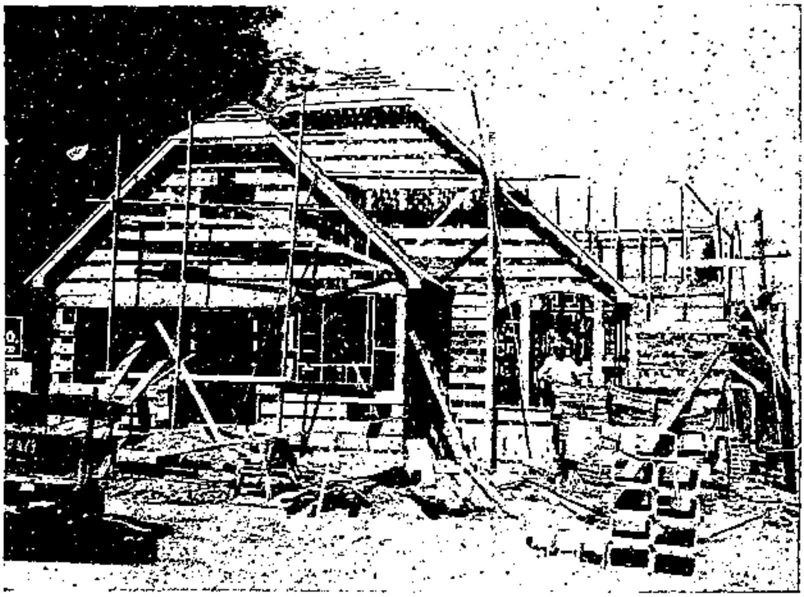


FIGURE 26.—White-fir sheathing and framing. Much of the species is used in light construction of this type in California.

use of the weaker, substandard sizes is questionable and cannot be recommended for first-class construction.

White-fir framing has acquired its best reputation where oversized 1¾- or 1⅞-inch thick dimension, principally 1⅞ inch, is used. This dimension is sold as "Valley dimension" by most of the mills in the Sierras of California. The 1⅞-inch stock is 15 percent higher than the standard 1⅝-inch stock in bending strength and stiffness when used on edge. When used flatwise or as studding it is about 50 percent higher in stiffness than stock of standard thickness.

Extra standard sizes in white fir are not ordinarily required for satisfactory service. Experience indicates that American lumber standard sizes will give satisfactory service. Standard-sized white fir is obtainable, but the common practice is to ship substandard size. The consumer should, therefore, specify standard size for framing material.

Experience with white-fir framing (fig. 26) throughout the country indicates that its nail-holding power is satisfactory. It will hold sheathing, siding, or other covering provided the framing is dry when covering is put in place. When and where more nail holding is required than is obtained with standard methods of nailing on covering, it is readily obtainable with white fir by the use of more nails or by the use of chemically treated nails (p. 31).

Decay resistance is not a requirement in most framing items. Sills in contact with the ground or which may be subjected to moist or wet conditions have a high decay hazard, and white fir is unsuited for such use unless treated with a preservative. On the other hand, most framing, once it is dry, remains dry. Under such conditions white-fir framing will last indefinitely.

SUBFLOORS AND SHEATHING

A little less than one fourth of the white-fir lumber produced in California and over one half of that produced in the Inland Empire is marketed as common boards and shiplap. These two items are used extensively for subfloors and sheathing in small houses.

Stiffness, insulation, and ease of working are the principal requirements for subfloors, and insulation and ease of working for sheathing. The denser species have the greater stiffness and the lighter-weight species are easier to work and have greater insulating value.

High nail-holding power is not considered an essential requirement, since the nail-holding power of framing should be relied upon to hold finish flooring and siding in place. The species characteristics usually given most consideration by builder and contractor are those which facilitate construction.

The characteristic defects in comparable grades of different species are also given some consideration in subfloors and sheathing. Small tight knots, even though numerous, are preferred to large or loose ones. The knots in white fir in the grades generally used for sheathing and subfloors are intermediate in size and number, but many of them may be loose, checked, or broken. This unfavorable characteristic of the knots as well as the lower strength and stiffness of white fir must be weighted against the favorable combination of light weight and ease of working and handling. What to use depends upon whether a tight grade is more important from a service standpoint than any difference in strength or stiffness.

Price and degree of seasoning, however, rather than the properties and characteristics, usually determine the choice of species for subflooring and sheathing. In large cities a difference as small as 25 cents per thousand board feet is usually sufficient to offset species differences with contractors and retail lumber dealers. In small towns, especially in farming sections, species differences are given more consideration, but even here $1 per thousand board feet difference in price is usually sufficient to overcome species preferences. The importance of well-seasoned sheathing and subflooring in obtaining a tight house or floor, while often ignored in the past, is rapidly being recognized by builders. Any species must be marketed dry if it is to hold its own as wood for subfloors and sheathing.

HEAVY CONSTRUCTION

Very little white fir is used for heavy structural work. Structural timbers are usually chosen for strength, that being the most important requirement. The greater strength of heavier and harder species usually outweighs the advantages the white firs have as a result of their light weight and ease of working. In or near regions of growth, however, a favorable combination of conditions has resulted in some use of white fir (fig. 27). Such favorable combinations of circumstances, however, are confined to places where the principal species associated in the forest with white fir are soft, lightweight woods of no greater strength.

White fir structural timbers go into two principal types of use—temporary bridges and trestles and mill construction. Logging railroads are the principal users of untreated white-fir timbers in bridges and trestles (fig. 28). The life required of timbers in logging railroads is usually short and white fir may be used successfully untreated. Treated white-fir timbers could be used in more permanent bridges

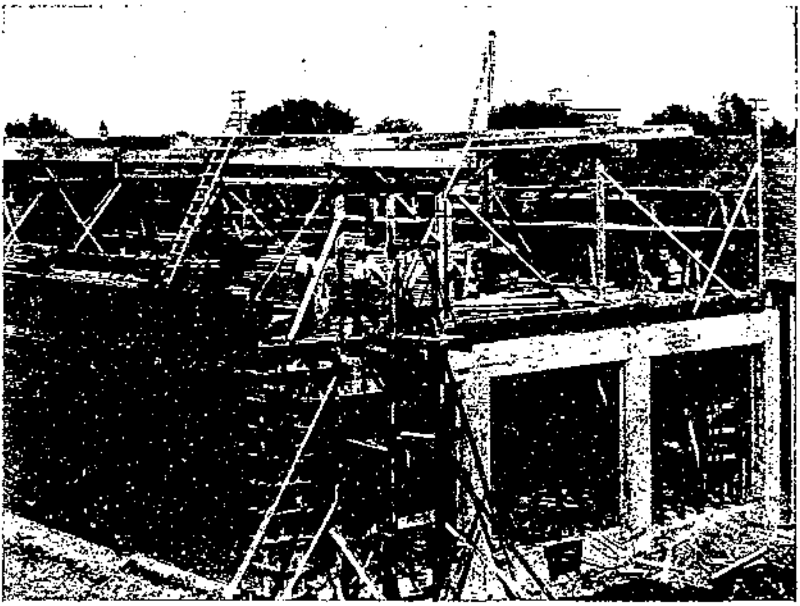


FIGURE 27.—White fir used for concrete forms and heavy mill construction.

and trestles. Little, however, is used for this purpose, for preservative treated white-fir timbers are not at present readily available and little effort has been made to develop this market. In mill construction white fir is used for posts, joists, girders, heavy flooring, and roofing. The number of installations is comparatively small. Two installations, 1 in a bakery (fig. 29) and 1 in a laundry (fig. 30), are known to have proved successful. Both of these types of occupancy subject timbers to exceptionally severe conditions. The condition of timbers and planks after 5 to 7 years' service indicates that checking and twisting are less than would be expected with a heavier and stronger species.

INDUSTRIAL USES

RAILROAD CROSSTIES

White fir (p. 2) furnishes only a small fraction of 1 percent of the crossties purchased annually (*26*). The 1927 census reports the purchase by steam railroads of about 70,000 white-fir crossties, about three fourths of which were treated with preservatives. In addition many were used by mills in their logging railroads and not reported.

Three strength properties are of special importance in appraising the mechanical properties of woods for crossties (*12*). These three properties—bending strength, hardness, and compressive strength—have been combined into a composite tie strength figure that gives an index of the suitability from the strength standpoint. Figure 31 compares the composite tie strength of white fir (*Abies concolor*) with that of a number of important tie woods. The composite tie strengths of white fir (*A. concolor*) and lowland white fir are about the same and are intermediate between the hemlocks, which are slightly higher, and the spruces, which are slightly lower. The composite tie strength of white fir is sufficient to meet the strength requirement of ties in main-line track, provided the ties are properly protected by tie plates.

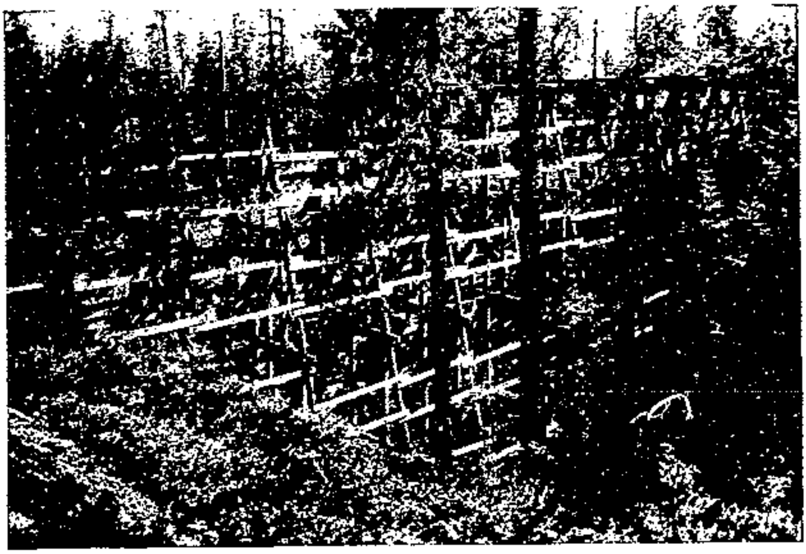


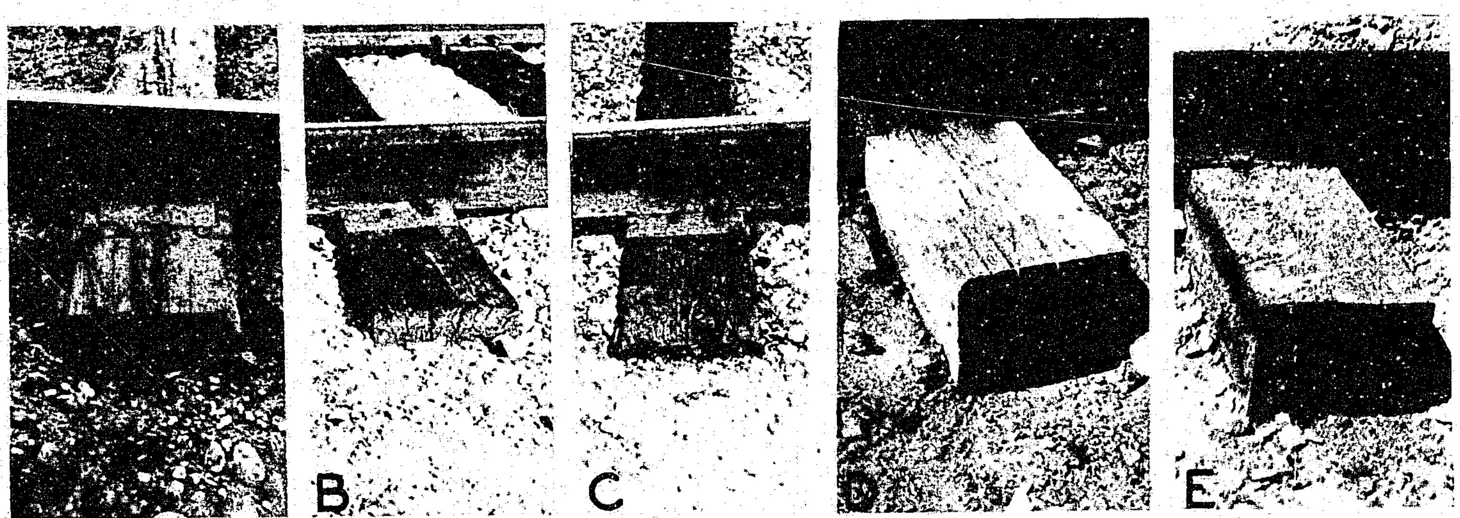
FIGURE 28.—White-fir timber and ties in trestles of logging railroad. White fir is often used untreated in logging roads where only a comparatively short life is required.

Unless treated with a preservative, white fir cannot be used successfully for ties in permanent track because of its low decay resistance. Both heartwood and sapwood are difficult to treat, being similar in this respect to Engelmann spruce. Experiments, however, have demonstrated that white-fir ties can be treated successfully (*10*). Untreated white-fir ties are extensively used in logging railroads because the life of such lines is short, and untreated white fir ties will generally last longer than the logging road is required.

Service records on about 14,000 white-fir ties are contained in table 24. An analysis of the service records shows that white-fir ties treated with either zinc chloride or creosote check badly. However, even though checked the ties treated with creosote, table 24, group 4, have given 13 years' service in main-line track under heavy traffic, and about 98 percent are still in place (pl. 10). The ties treated with zinc chloride, but no fuel oil, table 24, groups 5, 6, and 7, have only been in service about 7 years, but a high percentage are still in place. They,

WHITE FIR MOULDING, SIDE WALL, AND BASEBOARD IN NATURAL FINISH

The figure is sufficiently pronounced to give the effect desired in natural finishes on softwoods



THE USE OF FUEL OIL ALONG WITH PRESERVATIVES HAS DECREASED CHECKING IN WHITE FIR TIES

A, Creosoted white fir ties after 13 years' service. Though badly checked and split few ties have been removed. B, Creosoted white fir ties after about 5 years' service. While none of the ties have been removed from the test track they are badly checked and split. C, White fir ties in the same track and same period as B, but treated with a mixture of creosote, coal tar, and fuel oil. In excellent condition, practically no checking or splitting. D, White fir ties treated with zinc chloride after about 4 years' service. In fair condition. Some checking and some plate wear has taken place. E, White fir ties treated with zinc chloride and fuel oil. In good condition. Some checking, but not so much as ties in D, which have been in same track during same period of time.

like the creosoted ties of group 4, are badly checked. The ties of all groups are in a track where conditions are favorable to checking.

Where fuel oil was used in combination with the zinc chloride or creosote the ties are in good condition. Fuel oil used along with the preservative appears to reduce the checking materially (pl. 10). Groups 1, 2, and 3 of table 24 in which fuel oil was used with creosote are all in good condition with practically no checking or splits after 7 years' service. Likewise, the ties in group 8 of table 24 where fuel oil was used in combination with zinc chloride are in excellent condition after 7 years' service. On the other hand, where zinc chloride was used without fuel oil, groups 5, 6, and 7, the ties have checked and split badly. It appears, therefore, that the trouble from checking and splitting of white fir ties can be reduced by the use of fuel oil. The ties on which this conclusion is based have not been in service long enough to permit an estimate of the increased life that will result from the use of fuel oil where used with preservatives nor can the conclusion be considered final on such a short period of service.

FIGURE 29.—White-fir posts, girders, and joists in heavy mill construction in a bakery in California after 5 years' service. Little or no checking and twisting have taken place in straight-grain side cut pieces. The worst checking which has occurred is shown in the girder. The timbers on the whole show very little checking despite the combination of hot, dry climate with extreme artificial heat.

FURNITURE

The properties of white fir limit its use in furniture. Lack of color, small percentage of clear lumber, and the finishing characteristics prevent its use in expensive or highly polished furniture, except in concealed parts. Its light weight, freedom from resin, ease of working, stability, painting, and gluing characteristics adapt it to use as frames of overstuffed furniture, concealed parts of all types of furniture, and for furniture which is to be painted. Its properties also indicate it would make a good core for veneer panels. Only a small amount of white fir is now used for furniture. It is made chiefly into book racks, built-in cabinets, flower stands, benches, ironing boards, and similar articles to be used unfinished, stained, or painted. It is particularly suitable for shelves, drawers, and bins where foodstuffs are stored because of the wood's freedom from odor and pitch.

There is little prospect of any material increase in the use of white fir for furniture. There are a number of woods available that can be used satisfactorily in the same types and for the same parts of furniture as white fir. Many of these woods are grown nearer the large centers of furniture production than white fir and therefore make the entrance of white fir into this field difficult. The best prospects of increasing the use of white fir for furniture are in California and the Inland Empire.

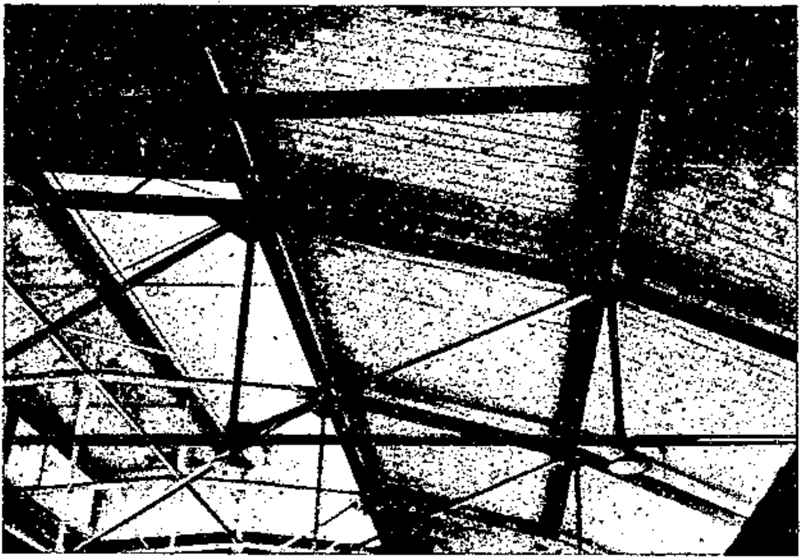


FIGURE 30.—This heavy tongue-and-groove No. 1 Common white fir roofing has given good service under the severe conditions imposed by a laundry in a hot, dry climate.

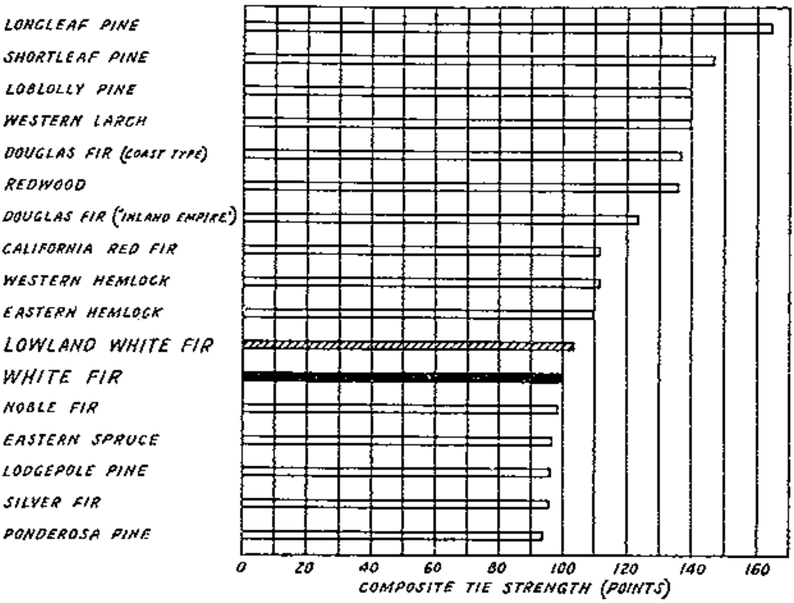


FIGURE 31.—Composite tie strength of white fir (*Abies concolor*) compared with that of a number of other species. The comparison is based on a combination of the three strength properties most important in ties.

TABLE 24.—*Service records of white fir and Engelmann spruce ties treated with preservatives* [1]

Group	Species	Treating process	Preservation and absorption	Ties	Location	Date set	Approximate service at last inspection [2]	Traffic	Rail weight	Removals	Cause of removal	Condition of ties in tract at last inspection
			Pounds per cubic foot	*Number*			*Years*		*Pounds*	*Number*		
1	White fir	Lowry	3.6 creosote, and 8.4 fuel oil.	782	Idaho	May 1924	7½	Medium	90	None		Excellent. Slight rail cut at joints.
2	White fir and Engelmann spruce.	do	8.6 creosote, and 0.4 fuel oil.	3, 131	do	March 1924	7½	do	90	None		Do.
3	do	Full cell	Creosote, coal tar, and fuel oil.[3]	720	do	December 1923	8	Heavy	100¼	None		Excellent. Rail cut on outside of curve.
4	Lowland white fir	Lowry	9.1 creosote	200	Montana	October 1915	13	do	100	5 4	Mechanical wear. Eliminate plate trouble.	Fair condition. Considerable checking and splitting. Some plate wear.
5	White fir and Engelmann spruce.	Burnett	0.5 zinc chloride	3, 197	Nevada	December 1924	7	Light	90	140	Decay	Very bad checking. Rotting very fast.
6	do	do	do	2, 915	Idaho	April 1924	7½	Medium	90	1	Broken	Fair. Considerable checking and rail cutting.
7	do	do	do	782	do	December 1923	8	Heavy	100¼	40	Checking and shatter.	Bad. Depreciating rapidly on account of checking and shatter.
8	do	Burnett (two-movement).	0.5 zinc chloride, and 3.5 to 4 fuel oil.	3, 166	Nevada	December 1924	7	Light	90	None		Excellent.

[1] Compiled from 1930 Proceedings of American Wood-Preservers' Association (*2*).
[2] Last inspection on all groups except group 4 made October 1931 by G. W. Lorenz, of the Union Pacific System. Last inspection of group 4 made in 1928 by Forest Service.
[3] Absorption not reported. Treatment 30 percent creosote, 7.5 percent coal tar, and 62.5 percent fuel oil.

REFRIGERATORS

About 500,000 board feet of the western true firs (p. 2) are used annually for refrigerators. The properties of the wood that adapt it to this use are lack of odor, freedom from resin, light weight, thermal insulating properties, and ease of working. White fir may be used for the same parts of refrigerators as those made from spruce.

OTHER INDUSTRIAL USES

Small quantities of the western true firs are used in wooden ware, novelties, signs, car construction, instruments, silos, and tanks. The reported consumption of the western true firs in all these uses totals less than 100,000 board feet annually. All of these uses except car construction are comparatively small consumers of wood, and there is little likelihood of any of them furnishing a market for a considerable quantity of white fir. The total amount of softwood used by these industries in 1928, excepting car construction, was less than the white fir lumber cut for that year.[13] The heavier and stronger softwoods are preferred for most car-construction and repair work, douglas fir and southern yellow pine furnishing over 90 percent of the softwoods used. White fir is used for special parts of cars, such as lining for refrigerator cars and running boards on the top of freight cars.

REPORTED MISCELLANEOUS USES FOR WHITE FIR

A partial list of miscellaneous uses for white fir (p. 2) has been compiled by the Forest Service. Some of these uses have been discussed, others have not, either because of lack of knowledge of their required properties or because their requirements are enough like some uses already discussed for the comparison and analysis to apply in part or with slight changes. The list may be useful as a reference and indication of possible markets that might be developed. It should be remembered, however, that the fact that a species of wood has been used for a purpose does not indicate that it is the best wood for the purpose. In fact, a brief inspection of the list will reveal a number of uses for which other species are obviously better suited than white fir.

Altars, church
Appliances, laundry
Backing, furniture
Backs, sign, and dresser drawer
Baseboards
Baskets, candy, fruit, and veneer
Batens
Beams, railroad car brake
Benches
Blinds
Boards, barn, base, trim, and roof
Bodies, automobile and buggy
Bottoms, show case
Boxes, food, and canned goods
Boxes, heavy shipping
Broom handles
Brackets, cornice
Buckets
Cabinets, built-in and kitchen
Car, decking, siding, lining, and strips
Cars, electric
Cases, packing, piano, shipping, and shoe
Casing, house
Caskets and outside boxes
Ceiling, boat
Clapboards
Concrete forms
Construction, car
Cooperage, slack and tight
Cores, veneer
Corners, interior house base trim
Crates, fruit and vegetable
Crating, furniture and granite
Cross arms, telephone and telegraph
Dimension
Doors, house, and freight car
Drawers, furniture
Finish, car
Finish, house exterior and interior

[13] See footnote 12, p. 54.

Flooring and subflooring
Frames, suit case, door, refrigerator, and window
Freezers, ice cream
Gates, irrigation, car door, and fruit shipping
Girders
Goods, dairy
Handles, paint and sweeping
Heads, cheesebox
Instruments, musical
Joists
Lath
Legs, refrigerator and table
Lining, freight and refrigerator car
Logs, house
Lumber, rough
Matches
Moulding, house
Newels
Novelties
Oars, boat
Pails
Partitions
Parts, vehicle
Pipes, water
Planking, bridge, platform, and warehouse
Plates, house
Poles
Posts
Pulp, paper
Radio, aerial posts
Rafters
Railing
Refrigerators and kitchen cabinets
Roofing, freight car
Sash, doors, blinds, and window
Scaffolding
Shade rollers
Shakes
Sheathing
Shelves
Shiplap
Shooks, box
Siding, bevel, two-lap, freight car, log cabin, and rustic
Silos
Slats, window shade
Staves, silo
Steps
Studs
Supplies, dairy, and apiary
Subflooring
Tables
Tanks, oil well and windmill
Timbers, small
Ties, railroad
Tops, furniture
Towers, cooling
Toys
Traps, lobster
Trays, raisin
Trunks
Vehicles
Windmill, tanks, and silos
Woodenware and novelties

PULP AND PAPER

White fir (p. 2) is admirably adapted to the manufacture of pulp and paper (*29*). Both white fir (*Abies concolor*) and lowland white fir are readily reduced by any of the standard mechanical or chemical processes. With the standard sulphite process white fir produces an unbleached pulp of excellent color and strength. The fibers are somewhat coarser than spruce fibers, but the pulp is easily bleached. The pulp yield is between 45 and 55 percent on a weight basis. Sulphite pulp from lowland white fir requires 15- to 25-percent bleach, and that from white fir (*A. concolor*) requires 10 to 15 percent. Pulps suitable for use in news, wrapping, book, and other high grade printing papers can be produced from both species.

A very strong unbleached pulp is produced from white fir with the sulphate process. The yield of strong pulp is from 45 to 50 percent with lowland white fir and 48 to 53 percent with white fir (*A. concolor*). The pulp is suitable for high grade wrapping papers and fiber board. The yield of pulp for bleaching is 35 to 45 percent and 38 to 43 percent, respectively. Sulphate pulps from both woods require 20- to 30-percent bleach.

Both white fir (*A. concolor*) and lowland white fir produce pulp of excellent color and standard strength by the mechanical process. From 15 to 25 percent more power is required than for white spruce. The pulp is suitable for all uses requiring ground wood.

In spite of the excellent pulping properties of white fir there is no early prospect for the extensive utilization of the stands of white fir in the Inland Empire and California for this purpose. Neither region has a local market for pulpwood. The availability of large quantities of mill and woods waste suitable for pulp production in the Pacific Northwest, the cost of logging white fir logs or woods waste, the problem of transporting pulp overland to markets at a cost which will enable it to compete with water-borne pulp from Washington and Oregon, and the initial investment required for construction of a pulp mill make it improbable that any appreciable quantity of white fir in California or the Inland Empire will be used for pulp production in the near future. Lumbermen and timber owners in making their plans for handling their white fir stands should not rely on the early development of a market for pulpwood as a panacea for the utilization problems presented by their white fir stands.

SUMMARY

California and the Inland Empire have forests containing 50 billion feet of white fir (*Abies concolor*) and lowland white fir. These woods grow and are harvested along with other species. For a number of years existing conditions have made it difficult, if not impossible, profitably to market white fir lumber. On the other hand there are serious objections both from forest management and utilization points of view to leaving the trees in the woods.

The lumber is relatively new and little known to many wood users, especially in the eastern and middle-western markets. The entrance of white fir lumber into these markets has created a number of problems to users. Detailed information furnished here on the properties, characteristics, and use of the wood will aid the consumer in determining its suitability for various uses and in obtaining long and satisfactory service from it.

Existing markets were found to be adversely affected by prejudices against white fir lumber. Investigation showed that these prejudices were caused largely by the results of improper manufacturing and marketing practices, such as marketing of insufficiently seasoned lumber, substandard sizes, and poor or inadequate grading. Control of these factors is in the hands of the manufacturers. Application of the information presented here on seasoning, grades, and influence of substandard sizes on strength and serviceability will help in overcoming these prejudices. No profitable market for white fir lumber can be developed so long as these prejudices exist.

The solution of the problem of the timberland owners and foresters is closely tied up with the problems of the lumber manufacturer and the consumer. Any improvement in the markets and the use of white fir lumber or in the character of service it renders will materially aid in the solution of the forest problem. An adequate and profitable market for white fir lumber would solve the forest-management problem.

A profitable market cannot be established for white fir lumber so long as better known and stronger competitive woods which are more favorably situated as regards quality, quantity production, and markets are sold at a loss. However, the adverse lumber market existing for the last 5 years must change and with the change will come the opportunity for consumers, manufacturers, and foresters to apply the information here presented to the solution of the perplexing problems in use, marketing, and management of white fir.

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