Storage of Lumber

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STORAGE OF LUMBER

By

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Surveys the most effective current techniques for protecting the quality of stored lumber. Physical properties of wood which are basic to the storing of lumber in commerce are explained. Causes of storage losses in lumber are discussed. Individual chapters deal with protection of wood in specific storage environments, such as in yards, at manufacturing plants, or in transit.

KEYWORDS: Degrade, drying, lumber, storage, wood properties

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PREFACE

"How can I cut down grade loss in my stored lumber?" Forest Service specialists in wood drying receive similar questions by phone or mail in research centers across the Nation. But such questions cannot be answered without more information. Are we talking about green or dried lumber? Air dried or kiln dried? What species? How long will the storage period be? What is the intended end use of the lumber? What climate prevails in the storage region?

Questions of lumber storage can lead into the larger subject of lumber processing, and are often too complex to permit simple answers. Yet such questions are of crucial importance because degrade and decay during storage are a major cause of lumber losses. Such lumber waste becomes intolerable as demands increase upon our Nation's limited supplies of sawtimber. The issue demands a comprehensive, practical publication, and thus researchers from the Forest Service, U.S. Department of Agriculture, have compiled this handbook. It should help to fulfill the Forest Service's objective of conserving, and thereby extending, our Nation's forest resources.

Studies have shown that lumber can be stored with little waste if techniques are applied based on a scientific knowledge of wood properties. Chapters 1 through 4 of this handbook explain physical properties of wood which are basic to storing lumber commercially. The first four chapters will help answer such questions as these: Why does wood gain or lose moisture? What conditions must be met to keep kiln-dried lumber dry? What causes staining, decay, or warp? How do hardwoods and softwoods differ in their storage properties?

The remaining chapters of this handbook deal with specific storage situations. Through text and photographs, they give practical details of the better handling, packaging, and storage procedures used in the lumber industry today. Specific problems are discussed, such as the merits and limitations of package wrapping, the protection of lumber when in transit, and ways of protecting lumber from rain soaking at construction sites.

This book also gives recommendations for better storage at the end of several chapters, suggestions for additional reading, and a glossary of terms.

CHAPTER 1: PROTECTING LUMBER IN STORAGE

A flatcar piled high with packages of lumber moves across the Midwest, each package protected in its own jacket of wrapping. Millwork awaits use at a construction site, covered by a tarpaulin and resting on small timbers to prevent ground contact. Workmen dip packages of green lumber into a fungicide solution prior to shipment. These are examples of effective storage and handling in today's lumber industry.

When is lumber said to be in storage? Between cutting and use, lumber undergoes a complex series of stages in processing and transport. During this time, lumber is frequently stored. After drying and planing, softwood lumber may be stored before shipping, and then stored again in trucks, railroad cars, or a ship's hold as it moves toward a destination. Hardwood lumber is usually dried at the producing sawmill and moves as rough lumber to the using factories. Finally, lumber may be stored at wholesale and retail distribution yards, at woodworking plants, and at the construction site.

The moisture content of lumber must be controlled in storage. Moisture changes in lumber may at times be the direct cause of grade loss. For example, the best lumber will be unsuitable for many uses if its moisture content goes too high. Also, moisture changes in lumber may be an indirect cause of deterioration. For example, rapid and uneven moisture changes can cause checking and warpage. Also, lumber with a moisture content of over 20 percent may develop stain or decay. (The figure of 20 percent includes a safety factor; lumber's moisture content is measured as a percentage by weight of the completely dried wood substance.) Most insect damage to lumber can be avoided if it is well dried.

Controlling moisture content in stored lumber, as it moves from sawmill to its final destination, should be the major concern of the processor, agent, and user.

Green and Partially Dried Lumber

Green or partially dried lumber usually undergoes controlled drying when in storage, and is usually stickered and given some protection from weather (fig.1). Green lumber bulk-piled for extended storage during warm weather is in danger from decay, stain, and insect attack. For this reason, green lumber should be stickered for drying as soon as possible after sawn. When such lumber must remain bulk-piled in warm weather, such as when shipped in the green state, it is often protected by chemical treatment (chapter 5).

Dry, High-Grade Lumber

At times the maximum moisture content acceptable for construction lumber is set by industry practice, and at other times by standards and codes. Certain industry grading rules, for example, require that softwood dimension lumber used in the framing of houses be below 19 percent moisture content. Lumber for use in the heated interiors of buildings should properly be still drier; its moisture content should not exceed 8 percent.

Therefore, those who handle dried high-grade lumber must be careful that it not take on excessive moisture in storage or transport. For example, finished lumber at a construction site should not be allowed to undergo soaking from rain because this would jeopardize its structural performance.

The problem is especially acute with kiln-dried lumber to be used in an interior location. If such

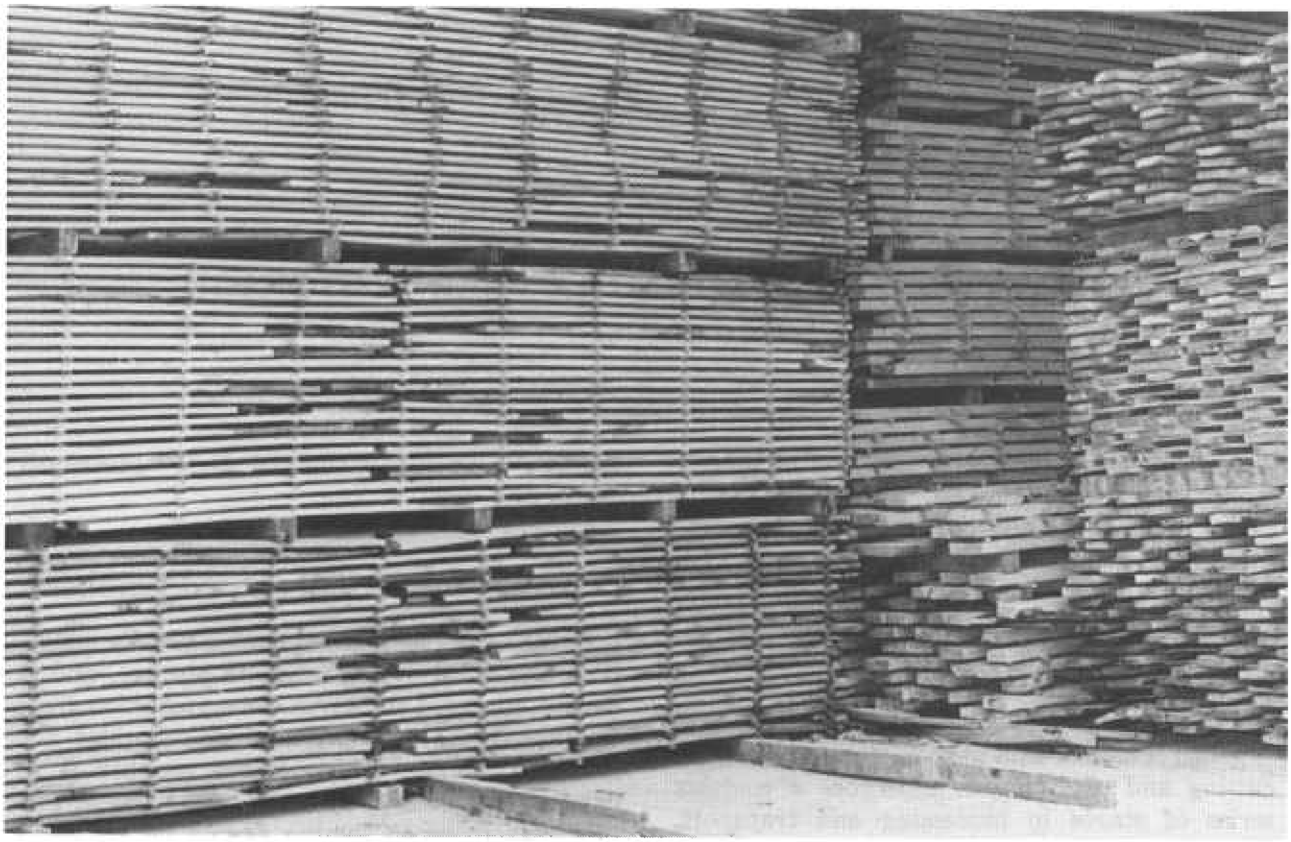

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Figure 1.—Green lumber will lose moisture when it is stored, and should be stickered as shown here for controlled, even drying.

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Figure 2.—Pallet packages of lumber stored in an open shed. Some packages have been unitized with iron bands (center). Others are clad in plastic film for additional protection.

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Figure 3.—Kiln-dried, finished softwood lumber stored in a large closed shed. The strapped packages are transported by an overhead gantry crane.

lumber becomes wet enough to require redrying, additional labor and expense are required. Also, the lumber will again undergo some degrade from the drying process and refinishing may be required.

Dry, high-grade lumber is best protected from moisture regain when stored as solid packages under roof (fig. 2). Closed storage sheds offer the best protection from moisture regain during long-term storage (fig. 3).

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Figure 4.—A forkloader places a wrapped package of lumber in a wide-door boxcar. The paper wrap will temporarily protect the lumber when stored outdoors at its destination.

Lumber During Transport and Handling

Lumber handling has become mechanized to reduce overall costs at sawmills, distribution yards, factories, and construction sites. Transport methods have changed to speed up the loading and unloading of trucks, boxcars (fig. 4), flatcars, and ocean-going vessels. The merits of mechanized handling will diminish if lumber's moisture content increases during this handling.

High-quality lumber can be protected in several ways during transport. Tight boxcars and dry ship holds can minimize moisture regain. Packages of lumber exposed during transport, such as on open flatcars or tractor-trailer trucks, can be temporarily protected by sheet wrapping (fig. 5). Sheet wraps can also protect lumber at unloading points or during temporary storage at distribution yards (fig. 6).

Unprotected Lumber Outdoors

High-quality lumber will endure for a short time storage conditions which, if sustained, would cause grade and footage losses. How tolerant any given lot of lumber may be to lack of protection, such as when transported on open trucks, depends upon the time exposed, the weather, and qualities of the lumber itself. Generally, thicker pieces of wood, such as dimension lumber, will regain moisture more slowly than thinner pieces, such as nominal 1-inch boards. Hardwoods are more resistant to mois-

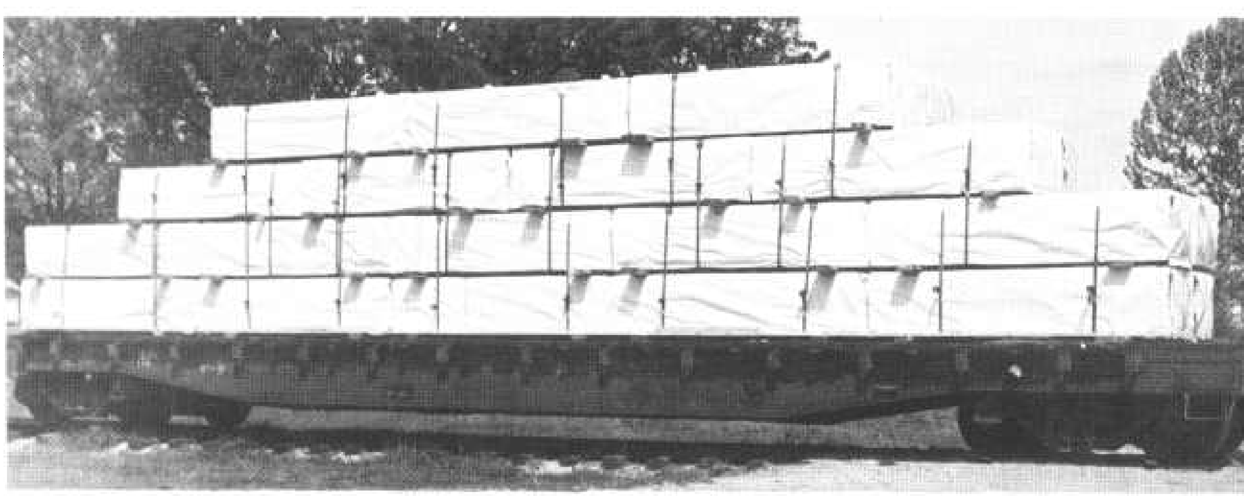

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Figure 5.—Wrap of waterproof paper protects packages of dried softwood lumber on a railroad flatcar.

ture regain than softwoods, dense woods more resistant than less dense, and heartwood more resistant than sapwood.

Benefits of Protective Storage

Control of atmospheric conditions during lumber storage, principally relative humidity, can create a moisture balance in the lumber suited to its end use. Thus the lumber's commercial quality can actually be improved by storage.

Dry lumber is usually bulk-piled when stored so that the overdried boards can absorb moisture from adjacent underdried boards. Moisture content differences between boards of the lot are thereby lessened. The moisture gradient within individual boards also tends to flatten out during storage. That is, the difference in moisture content between the shell and core of each board is lessened.

Storing dry, casehardened lumber in an atmospherically controlled shed or warehouse will usually result in only slight stress relief. However, if such lumber is stickered in an open shed the regain of moisture by the surfaces will reduce casehardening stresses. At one time this was called "tempering."

Hazards of Careless Storage

Well-dried lumber that becomes saturated with water, such as from rain, melting snow (fig. 7), or contact with wet ground, can warp and otherwise deteriorate. Bulk-piled lumber is in more danger from wetting than when stickered because water cannot easily evaporate from the bulk pile.

M 143 995

Figure 6.—Wrap which protected a package of kiln-dried lumber during transport is being removed prior to storage in a closed shed.

High relative humidity alone will not elevate moisture levels of dried lumber sufficiently to cause serious decay, but may permit some mold to develop. High humidity may also raise the moisture content of kiln-dried lumber enough so that the lumber must be redried to be used in an interior service location.

Bulk-piled lumber in bins or unit packages absorbs moisture at all exposed faces of the pile. This moisture moves toward the pile interior. Movement is more rapid along the grain, and the penetration of moisture absorbed at the open cell ends will be the greatest. Moisture entering through the ends of the boards will cause swelling, increasing the width and thickness of the ends over the rest of the board. Moisture regain by the boards on the top, bottom, and edges of the pile increases the moisture content range of the lot. Damp outside boards may create problems in subsequent processing.

When 1-inch softwood lumber, kiln dried to 8 percent or less, is solid piled outdoors under a pile roof in humid weather, average moisture content can increase at the rate of about 2 percent per month during the first 45 days. An absorption rate of about 1 percent per month then may be sustained throughout a humid season.

Comparable rates for open sheds are about 1 percent per month and for closed sheds 0.3 percent per month. Total lack of protection, with wetting by rain, will considerably increase these rates.

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Figure 7.—Finished lumber being stored outdoors in bad weather without adequate protection. Such storage results in needless waste.

CHAPTER 2: MOISTURE CHANGES IN STORED LUMBER

If moisture content in stored lumber becomes greater than about 25 percent, lumber becomes susceptible to decay, stain, or insect attack. Furthermore, uneven wetting or drying of lumber will cause warp. Grade loss due to moisture change can be prevented, but methods differ for green, air-dry, and kiln-dry lumber.

Green lumber loses moisture to the air during storage, and if dried unevenly will warp. Stickering green lumber prevents warp by allowing air to circulate through the pile. Moisture can then evaporate evenly from all faces of the boards, and uneven shrinkage stresses are prevented.

Kiln-dry lumber tends to take on moisture from the air; storage procedures should thus minimize or prevent moisture regain. If kiln-dry lumber regains much moisture, the expense and effort of the kiln-drying process may have been wasted.

Techniques for controlling moisture movement in lumber fall into three categories: (1) determining the moisture content of stored lumber; (2) predicting and, in some instances, controlling moisture loss or regain; and (3) calculating the dimensional changes in lumber caused by changes in moisture content.

Wood Properties and Moisture Movement

Wood will either lose or absorb moisture when exposed to certain conditions of temperature and relative humidity; this property is known as hygroscopicity. Changes in moisture content cause wood to shrink and swell, creating problems during processing and final use.

Free Water and Bound Water

The moisture in freshly cut (green) lumber is often called sap. Sap is simply water with certain materials in solution. Water in green wood exists in two forms: As liquid in the cell cavities, known as "free water," and as moisture in the cell walls, known as "bound water."

The moisture content of wood is the weight of the water which wood contains divided by the weight of the completely dried wood substance. Wood's moisture content is always expressed as a percentage. Average moisture content of living trees will vary by species from about 30 percent to more than 200 percent (table 1).

Green moisture content of wood from different locations within the same tree can vary considerably. For instance, in softwood species green moisture content for sapwood is much higher than for heartwood. Green moisture content of sapwood and heartwood does not differ so much in hardwoods; some green hardwoods will even have a higher moisture content for heartwood.

Growing conditions of the individual tree will also affect green moisture content. These conditions include soil characteristics, climate of the locale, and, in some instances, the altitude of the growth site.

Fiber Saturation Point

When green lumber dries, free water in cavities of the surface cells will leave first. No bound water will leave a cell until all the free water has evaporated. Wood's moisture condition when all free water has evaporated but the cell wall remains saturated is called the fiber saturation point (FSP). In general, the FSP prevails at a cell moisture content of about 30 percent; it may vary to some extent from species to species. When the cell walls are dried below the FSP, shrinkage begins. As adjacent cells in the wood dry below the FSP, changes in the physical and mechanical properties of the wood occur.

Moisture Diffusion Characteristics

The rate at which lumber loses or regains moisture is directly affected by the moisture diffusion characteristics of the particular wood. Understanding moisture movement in wood can help avoid grade losses caused by uneven moisture changes, such as warp, checking, and splitting.

Table 1.—*Average moisture content of green wood by species*

Species		Moisture content[1]		
Common name	Botanical name	Heartwood	Sapwood	Mixed heartwood and sapwood
		Pct	*Pct*	*Pct*
	SOFTWOODS			
Baldcypress	*Taxodium distichum*	121	171	---
Cedar:				
Alaska—	*Chamaecyparis nootkatensis*	32	166	---
Atlantic white—	*Chamaecyparis thyoides*	---	---	35
Eastern redcedar	*Juniperus virginiana*	33	---	---
Incense—	*Libocedrus decurrens*	40	213	---
Northern white—	*Thuja occidentalis*	---	---	55
Port-Orford—	*Chamaecyparis lawsoniana*	50	98	---
Western redcedar	*Thuja plicata*	58	249	---
Douglas-fir:				
Coast type	*Pseudotsuga menziesii*	37	115	---
Fir:				
Balsam	*Abies balsamea*	120	140	---
California red	*A. magnifica*	---	---	108
Grand	*A. grandis*	91	136	---
Noble	*A. procera*	34	115	---
Pacific silver	*A. amabilis*	55	164	---
Subalpine	*A. lasiocarpa*	---	---	47
White	*A. concolor*	98	160	---
Hemlock:				
Eastern	*Tsuga canadensis*	97	119	---
Western	*T. heterophylla*	85	170	---
Larch, western	*Larix occidentalis*	54	110	---
Pine:				
Eastern white	*Pinus strobus*	---	---	68
Jack	*P. banksiana*	---	---	70
Lodgepole	*P. contorta*	41	120	---
Ponderosa	*P. ponderosa*	40	148	---
Red	*P. resinosa*	32	134	---
Southern:				
Loblolly	*P. taeda*	33	110	---
Longleaf	*P. palustris*	31	106	---
Shortleaf	*P. echinata*	32	122	---
Slash	*P. elliottii*	30	100	---
Sugar	*P. lambertiania*	98	219	---
Western white	*P. monticola*	62	148	---
Redwood:				
Old-growth	*Sequoia sempervirens*	86	210	---
Young-growth	*S. sempervirens*	100	200	---
Spruce:				
Engelmann	*Picea engelmannii*	51	173	---
Red	*P. rubens*	---	---	55
Sitka	*P. sitchensis*	41	142	---
White	*P. glauca*	---	---	55

Table 1.—*Average moisture content of green wood by species*—continued

Species		Moisture content [1]		
Common name	Botanical name	Heartwood	Sapwood	Mixed heartwood and sapwood
		Pct	*Pct*	*Pct*
	HARDWOODS			
Alder, red	*Alnus rubra*	---	97	---
Ash:				
Black	*Fraxinus nigra*	95	---	---
Green	*F. pennsylvanica*	---	58	---
White	*F. americana*	46	44	---
Aspen:				
Bigtooth	*Populus grandidentata*	95	113	---
Quaking	*P. tremuloides*	95	113	---
Basswood, American	*Tilia americana*	81	133	---
Beech, American	*Fagus grandifolia*	55	72	---
Birch:				
Paper	*Betula papyrifera*	89	72	---
Sweet	*B. lenta*	75	70	---
Yellow	*B. alleghaniensis*	74	72	---
Butternut	*Junglans cinerea*	---	---	104
Cherry, black	*Prunus serotina*	58	---	65
Cottonwood:				
Black	*Populus trichocarpa*	162	146	---
Eastern	*P. deltoides*	160	145	---
Elm:				
American	*Ulmus americana*	95	92	---
Rock	*U. thomasii*	44	57	---
Hackberry	*Celtis occidentalis*	61	65	---
Hickory	*Carya* spp.	71	49	---
Magnolia, southern	*Magnolia grandiflora*	80	104	---
Maple:				
Bigleaf	*Acer macrophyllum*	77	138	---
Red	*A. rubrum*	---	---	70
Silver	*A. saccharinum*	58	97	---
Sugar	*A. saccharum*	65	72	---
Oak:				
Northern red	*Quercus rubra*	80	69	---
Northern white	*Q. alba*	64	78	---
Southern red	*Q. falcata*	83	75	---
Southern white (chestnut)	*Q. prinus*	72	---	---
Pecan	*Carya illinoensis*	71	62	---
Sweetgum	*Liquidambar styraciflua*	79	137	---
Sycamore, American	*Platanus occidentalis*	114	130	---
Tanoak	*Lithocarpus densiflorus*	---	---	89

Table 1.—*Average moisture content of green wood by species*—continued

Species		Moisture content[1]		
Common name	Botanical name	Heartwood	Sapwood	Mixed heartwood and sapwood
		Pct	*Pct*	*Pct*
	HARDWOODS—continued			
Tupelo:				
Black	*Nyssa sylvatica*	87	115	---
Water	*N. aquatica*	150	116	---
Walnut, black	*Juglans nigra*	90	73	---
Willow, black	*Salix nigra*	---	---	139
Yellow-poplar	*Liriodendron tulipifera*	83	106	---

[1] Based on weight when ovendry.

Moisture diffuses through wood from zones of higher to zones of lower moisture content. Thus, when lumber is drying the moisture in the wet interior of a board moves towards the drier surface. If dry lumber is exposed to high relative humidity or wetting while in storage, moisture diffuses from moist surfaces of the boards to the drier interior. The greater the difference in moisture concentration, the more rapid will be the diffusion rate in both desorption and absorption.

The moisture diffusion rate varies with wood temperature. Cold wood in storage responds more slowly to changes in atmospheric conditions, but moisture will move more rapidly in warm wood.

Moisture diffusion in wood is also influenced by the wood's specific gravity. In general, the moisture diffuses more rapidly in the lighter, low specific gravity woods than in the heavier, high specific gravity woods. This accounts for faster moisture regain by softwoods in situations where dry lumber is stored under humid conditions.

Moisture content changes more rapidly in permeable than in impermeable woods. Thus, the sapwood of most species dries faster than the heartwood and, conversely, regains moisture more rapidly.

Equilibrium Moisture Content

Wood at or above the fiber saturation point, such as green wood, will lose moisture when exposed to any relative humidity below 100 percent. Also, totally dry (ovendried) wood will absorb moisture when exposed to any relative humidity except zero. At a constantly maintained temperature and relative humidity, any wood will reach a point where it neither loses nor gains any moisture. When wood is in moisture balance with the relative humidity of the air surrounding it at a given temperature, the wood is said to have reached its equilibrium moisture content (EMC).

The relationship between wood EMC and the temperature and relative humidity of air is shown in figure 8. The graph shows that at temperatures below 120° F (49° C) the EMC of wood is closely related to the relative humidity.

Air temperature is of secondary importance when determining EMC. For example, at 20 percent relative humidity and a dry-bulb temperature of 40° F (5° C), the wood EMC condition is about 4½ percent. Elevating the temperature 60° F (or 33° C) would reduce EMC by only half a percent (to 4 pct).

On the other hand, if the relative humidity varies from low to high at the same temperature, the EMC will change considerably. For example, at 70° F (21° C) and 20 percent relative humidity, the EMC is just under 4½ percent; but at the same temperature and 80 percent relative humidity, the EMC is 16 percent. (Determining EMC so as to control moisture changes in stored lumber will be explained later in this chapter.)

Determining Wood's Moisture Content

The moisture content of wood is expressed as a percentage by weight of the dry wood substance. Moisture content is usually determined by one of two methods: Ovendrying or use of electric moisture meters. The ovendrying method involves determining the weight of the wood substance after complete drying in an oven (i.e., until constant weight is attained). Ovendrying has the advantage of being the more accurate method, but is time-consuming and requires that a piece be cut from the wood to be tested.

Electric moisture meters give rapid and reasonably accurate readings throughout the range of 7 to 25 percent moisture content, but are subject to error if improperly used. Some models do not damage the wood being tested; others require that needlelike electrodes be driven into the wood.

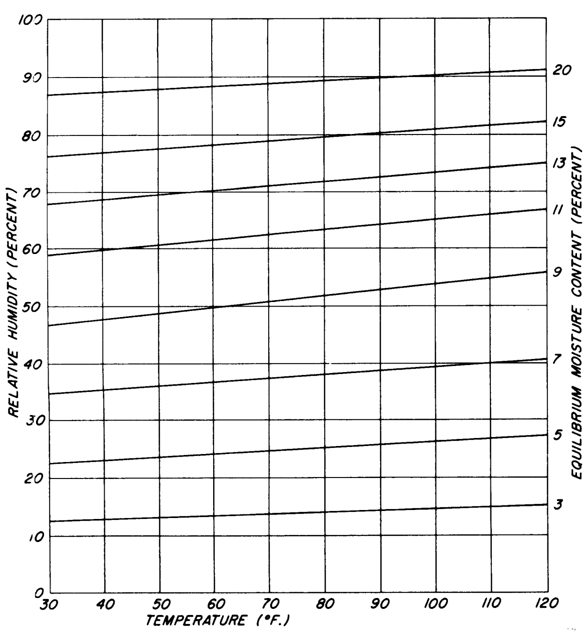

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Figure 8.—Equilibrium moisture content of wood as related to air temperature and relative humidity.

Wood that contains large amounts of volatiles such as pitch or preservatives must be tested for moisture content by a distillation method.

Ovendrying Method

The ovendrying method requires that a cross section be cut from the board at some distance, say 18 inches, from an end. This cross section must remain in the oven for at least 12 hours and usually more. The ovendrying method is accurate throughout the whole range of moisture content. It consists of the five following steps:

(1) Cut a cross section about 1 inch thick along the grain.

(2) Immediately after sawing, remove all loose splinters and weigh the section.

(3) Put the section in an oven maintained at a temperature of 217.4° ± 3.6° F (103° ± 2° C), and dry until a constant weight is attained.

(4) Weigh the dry section to obtain the ovendry weight.

(5) Subtract the ovendry weight from the initial weight, and divide the difference by the ovendry weight, multiplying the result by 100 to obtain the percentage of moisture in the section. This is the moisture content of the section and is usually assumed to be representative of the board. The formula for this computation is:

Moisture content in percent

$$= \frac{\text{Initial weight} - \text{ovendry weight}}{\text{Ovendry weight}} \times 100.$$

A shortcut formula convenient to use with slide rules or calculators is:

Moisture content in percent

$$= \left(\frac{\text{Initial weight}}{\text{Ovendry weight}} - 1\right) \times 100$$

Balances used in weighing specimens for moisture content determinations include the triple-beam balance (fig. 9) and the pan-type or torsion balances. Where a considerable number of specimens are weighed in and out of the drying oven, a direct-reading automatic balance is very convenient.

The oven used for drying the moisture sections should be large enough to accommodate a

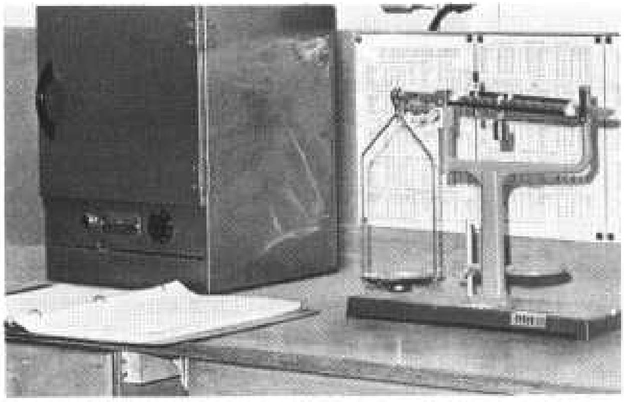

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Figure 9.—Layout for determining moisture content of wood samples by ovendrying. Shown are a triple-beam balance and a small electric oven.

number of specimens, with room to provide spaces between them. The temperature of the oven needs to be controlled with a reliable thermostat at a setting within the limits of 217.4° ± 3.6° F (103° ± 2° C). Excessive temperatures will char the specimens, introducing errors in the moisture analysis. Too low a temperature may not evaporate all the moisture in the specimen. The oven should be well ventilated to allow the moisture being evaporated to escape.

Electric ovens are most generally used. When the volume of specimens to be ovendried daily is relatively small, a natural-circulation electric oven is adequate. Some ovens contain fans to circulate the heated air; when large numbers of specimens are being ovendried, electric ovens with fans are recommended.

Microwave ovens are sometimes used to dry the sections. Drying time is reduced to minutes, but destructive distillation of the wood may introduce errors in moisture content calculations. With experience in operating the microwave oven, however, these errors can be avoided.

Electrical Methods

Electric moisture meters are being extensively used, particularly the portable or hand meters. Two types, each based on a different fundamental relationship, have been developed: (1) The resistance type, which uses the relationship between moisture content and direct current resistance (fig. 10); and (2) the dielectric type, which uses the relationship between moisture content and the dielectric loss factor of the wood (fig. 11).

Resistance-type moisture meters are wide-range ohmmeters. Portable, battery-operated models are available. Most models have a direct-reading meter calibrated in percent for one species; the manufacturer provides correction tables for other species. The manufacturer usually provides a temperature-correction chart or table when tests on wood warmer than 90° F (32° C) or cooler than 80° F (27° C) are made.

Electrical resistance of wood decreases as wood warms and increases as it cools. A rule-of-thumb temperature correction is to subtract 1 percent moisture content from the meter reading, corrected for species, for every 20° that the wood temperature is above 80° F. Add 1 percent for every 20° that the wood is below 80° F.

Resistance-type meters are generally supplied with pin-type electrodes that are driven into the wood being tested. The most common consist of four needles that extend about 5/16 inch beyond their mounting chucks. Long, two-pin electrodes which have insulated shanks except for the tip are also available for use on lumber thicker than 1 5/8 inches.

When lumber with a normal drying distribution is tested, valid estimates of the average moisture content of the cross section are obtained by driving the pins deep enough in the lumber so that the tip reaches one-fifth to one-fourth the thickness of the board. If the lumber is regaining moisture or the lumber surface has been wetted, the meter indications are likely to be much higher than the actual average moisture content. In this case, insulated shank pins should be used.

The useful range of resistance-type moisture meters is from about 7 to 25 percent moisture content. Meter readings greater than 30 percent can only be considered as gross approximations of the real moisture content of the wood. When the electrodes are withdrawn, care is essential to prevent pin breakage or bending.

The dielectric moisture meter uses surface contact-type electrodes. The electrode is an integral part of the instrument (fig. 11). The lumber being tested is penetrated by the electric field radiating from the electrode about 3/4 inch into the wood, so that thicknesses to about 1 1/2 inches may be tested. The moisture content of the surface layers of the lumber, however, has

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Figure 10.—Moisture meters of the resistance type.

a predominant influence on the meter readings because the electric field is stronger near the electrode. The roughness of the lumber and the electrode design may also influence meter readings.

The effect of wood temperature on the dielectric loss factor and dielectric constant is not well understood, so temperature correction charts or tables are not provided with dielectric meters. The manufacturers do, however, provide species correction tables for converting the meter scale reading of the instrument to moisture content.

The useful range of the dielectric moisture meter is from 0 to 25 percent moisture content.

Predicting and Controlling Moisture Change

Being able to derive the equilibrium moisture content (EMC) of lumber in storage can be very useful to those responsible for the storage facility. Average temperature and relative humidity of a locale can be used to determine the EMC, and thus the eventual moisture content which lumber will attain when stored outdoors in that locale.

Furthermore, calculations involving EMC can be used to determine the temperature required in a heated, closed shed to attain a desired moisture content in lumber stored there.

Determining EMC

The EMC may be determined for lumber at any ambient temperature and relative humidity. Where atmospheric conditions are constant, such as in heated or air-conditioned sheds, tempera-

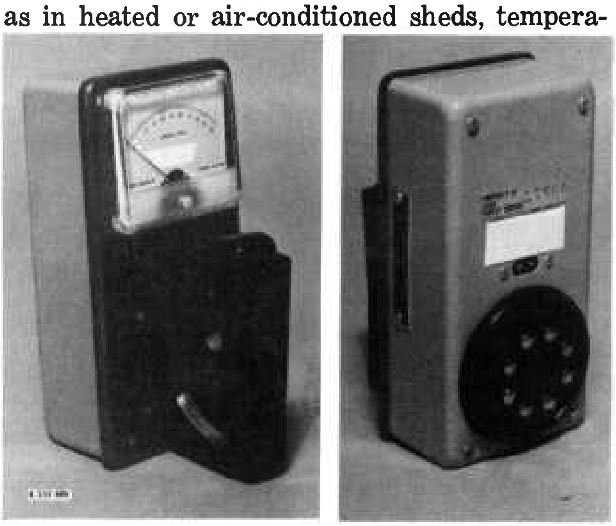

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Figure 11.—A dielectric moisture meter.

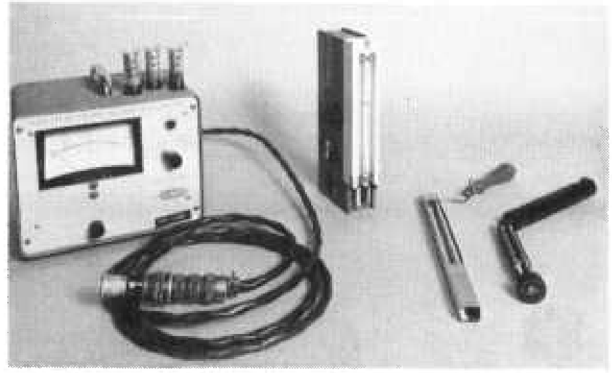

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Figure 12.—Humidity-measuring instruments (left to right): Electric hygrometer showing sensor head and three adsorbent-salt cartridges; blower-type psychrometer which is portable and battery powered; two sling psychrometers which are twirled to aerate the wet-bulb wick.

ture and relative humidity may be measured with a sling- or blower-type psychrometer or a hygrometer (fig. 12). Readings of the psychrometer's dry-bulb and wet-bulb thermometers must be interpreted by a chart supplied with the instrument to give the relative humidity. An electric hygrometer can give relative humidity directly within seconds of being turned on.

To approximate the EMC of wood stored in outdoor areas, it is possible to obtain average values of temperature and relative humidity for the geographical area and season (chapter 3). With such figures, the approximate EMC for lumber stored under exterior conditions can be simply derived.

Controlling EMC in a Heated or Air-Conditioned Shed

A desirable EMC for lumber can be prescribed when the storage environment can be controlled, such as in a heated or air-conditioned shed. Kiln-dry lumber can then be stored without significant change in moisture content.

For example, assume that the outdoor air is at 50° F (10° C) and the relative humidity is about 80 percent. From figure 13, the wood EMC condition is seen to be about 17 percent. Further assume that kiln-dry lumber averaging 7 percent moisture content is stored in a closed shed, and that the shed will be heated to prevent moisture regain.

When indoor shed air is heated, its absolute humidity remains the same as that of outdoors. The absolute humidity of outdoor air at 50° F

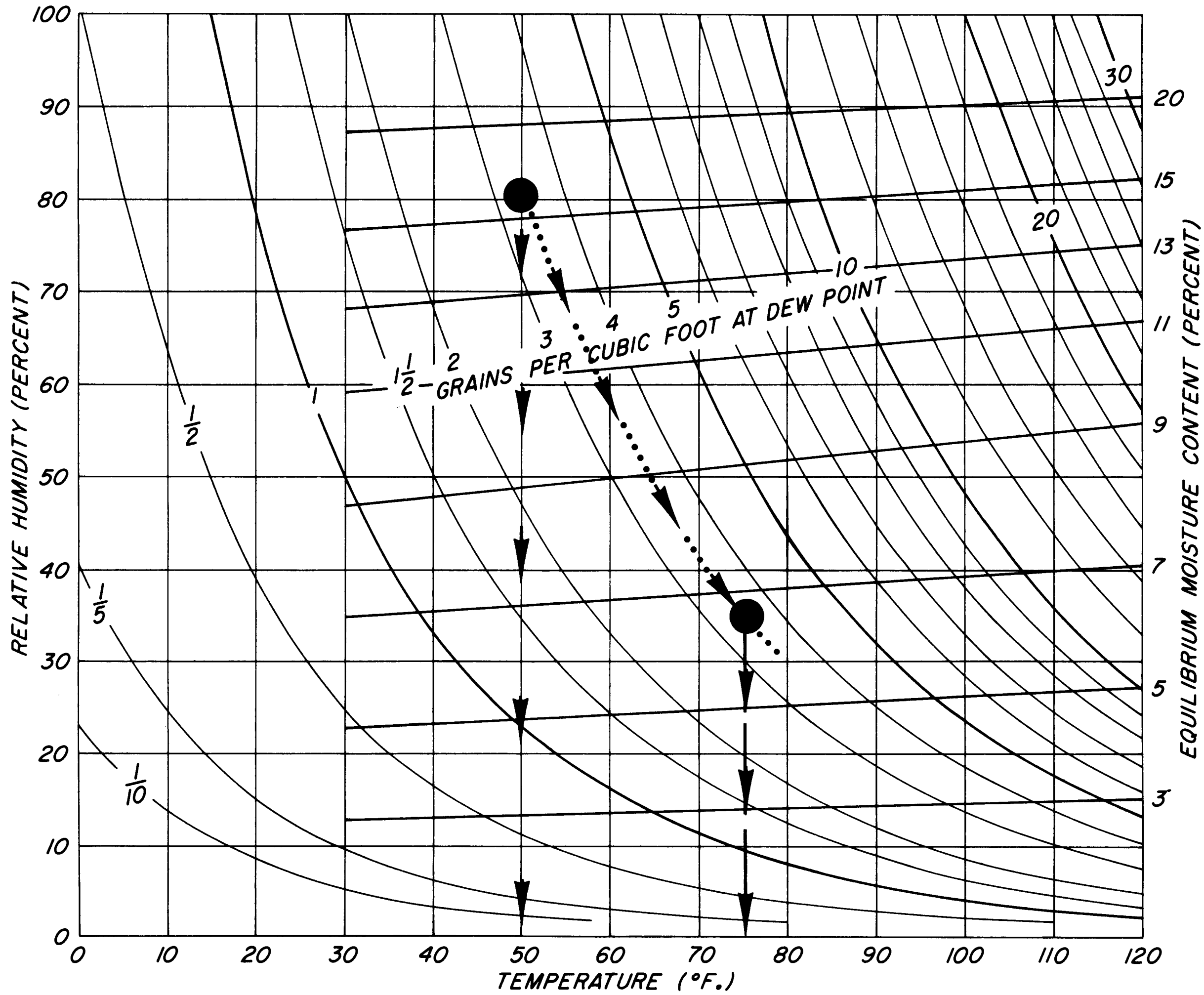

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Figure 13.—Psychrometric chart illustrating the temperature elevation required to attain 7 percent EMC conditions, given an air temperature of 50° F (10° C) and relative humidity of 80 percent.

(10° C) and 80 percent relative humidity is about 3.5 grains per cubic foot (fig. 13). At this absolute humidity and a wood EMC value of 7 percent, the dry-bulb temperature is about 75° F (25° C). This means that if the closed shed air is heated 25°—from 50° to 75° F (10° to 24° C)—and circulated around the dry lumber, moisture regain by the lumber is prevented.

The heating in a closed storage shed may be regulated manually or with automatic control equipment. Because the EMC is far more dependent upon humidity than upon temperature, a humidistat rather than a thermostat is the best automatic system to use. (See "Closed, Heated Shed," chapter 3.)

If the weather is warm and humid, heating the shed air will effectively depress its relative humidity but may increase the temperature to an uncomfortable level for workers inside. Assume that the outdoor temperature is 90° F (32° C) and the relative humidity is about 78 percent. The EMC condition of the outdoor air is then 15 percent. To attain a 7 percent wood EMC condition in the shed requires a temperature increase to 115° F (46° C). But workmen may object to working in that warm a shed.

One solution is air-conditioning, but the increased costs may not be justified. However, at some woodworking plants, year-around air-conditioning is installed to control the temperature and relative humidity where wood is processed. Storage rooms for kiln-dry lumber are often included in these temperature- and relative humidity-controlled areas.

Predicting Dimensional Changes in Wood

When the cells in the surface layer of a board dry below the fiber saturation point (FSP)—that is, below about 30 percent moisture content—the cell walls shrink. This shrinkage is restrained by the wet core of the board, yet the stresses in the surface layer caused by cell-wall shrinkage can be sufficient to squeeze the wet core. Thus, a slight overall shrinkage of the board can be observed although its average moisture content is still considerably greater than 30 percent. For most practical purposes, however, the shrinkage of wood is considered as being proportional to the moisture lost below 30 percent.

Shrinkage Characteristics

The shrinkage of wood varies with species and with the orientation of the cells—tangential, radial, or longitudinal (fig. 14). Shrinkage across the width of a board sawed tangentially to the annual growth rings (plain sawed) is about twice as much as in a board sawed radially, or parallel to the rays (quartersawed). Longitudinal shrinkage or shrinkage in length is generally very small (0.1 to 0.2 pct of the green dimension).

Reaction wood, such as compression wood in softwoods and tension wood in hardwoods, shrinks considerably more in the longitudinal direction than normal wood. Juvenile wood found near the pith of the tree also has an appreciable longitudinal shrinkage. Table 2 gives the total tangential and radial shrinkage values for many commercial species. The values are expressed as a percentage of the green dimension. Thus a plain-sawed board that is 10 inches wide when green, of a species having a 10 percent total tangential shrinkage, will shrink about 1 inch in width when dried to 0 percent moisture content.

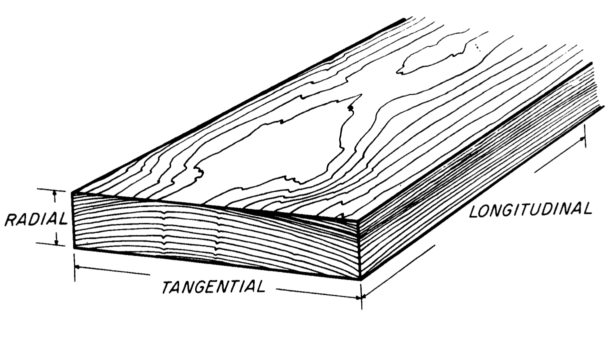


Figure 14.—Shrinkage directions in a plain-sawed board.

Dimensional Change Formula

The values of table 2 can be used to calculate the radial or tangential dimensional change of wood in going from one moisture content condition to another. The wood species, essential grain pattern, present dimension, and moisture content must be known to calculate the shrinkage or swelling that will occur if the item changes moisture content.

The formula is

$$\Delta D = \frac{(M_F - M_I)D}{\left(\frac{FSP(100)}{S_T \text{ or } S_R} - FSP\right) + M_I}$$

ΔD = The shrinkage or swelling in any unit of length,
M_I = the initial moisture content in percent,
M_F = the final moisture content in percent,
D = the dimension at the initial moisture content in units of length,
FSP = the fiber saturation point in percent (30 for most woods [1]), and
S_T and S_R = the total tangential or radial shrinkage values.

Neither the initial nor the final moisture content values can exceed the FSP. Examples of the use of this formula to determine dimensional changes follow:

Example No. 1.—Determine the width of the ends of packaged flat-grained oak flooring strips machined to 2¼ inches at a moisture content of 6 percent, then stored in a warehouse where moisture pickup causes the exposed end grain to reach 12 percent moisture content. Some pieces are of northern red oak and some of southern red oak. Because the pieces are flat grained, the total tangential shrinkage values of 8.6 percent for northern red oak and 11.3 percent for southern red oak are used (table 2). A value of 30 is used for FSP. The initial moisture content is 6 percent and the final moisture content is 12 percent. The dimension at the initial moisture content is 2.25 inches.

[1] Twenty-two percent is used for redwood, northern white-cedar, and western redcedar.

Table 2.—*Total shrinkage values of domestic woods*[1]

Species	Shrinkage to 0 percent moisture content	
	Radial	Tangential
	Pct	*Pct*
SOFTWOODS		
Baldcypress	3.8	6.2
Cedar:		
Alaska—	2.8	6.0
Atlantic white—	2.9	5.4
Eastern redcedar	3.1	4.7
Incense—	3.3	5.2
Northern white—	2.2	4.9
Port-Orford—	4.6	6.9
Western redcedar	2.4	5.0
Douglas-fir:		
Coast	4.8	7.6
Fir:		
Balsam	2.9	6.9
California red	4.5	7.9
Grand	3.4	7.5
Noble	4.3	8.3
Pacific silver	4.4	9.2
Subalpine	2.6	7.4
White	3.3	7.0
Hemlock:		
Eastern	3.0	6.8
Western	4.2	7.8
Larch, western	4.5	9.1
Pine:		
Eastern white	2.1	6.1
Jack	3.7	6.6
Lodgepole	4.3	6.7
Ponderosa	3.9	6.2
Red	3.8	7.2
Southern:		
Loblolly	4.8	7.4
Longleaf	5.1	7.5
Shortleaf	4.6	7.7
Slash	5.4	7.6
Sugar	2.9	5.6
Western white	4.1	7.4
Redwood:		
Old-growth	2.6	4.4
Young-growth	2.2	4.9
Spruce:		
Engelmann	3.8	7.1
Red	3.8	7.8
Sitka	4.3	7.5
White	4.7	8.2
HARDWOODS		
Alder, red	4.4	7.3
Ash:		
Black	5.0	7.8
Green	4.6	7.1
White	4.9	7.8
Aspen:		
Bigtooth	3.3	7.9
Quaking	3.5	6.7
Basswood, American	6.6	9.3
Beech, American	5.5	11.9
Birch:		
Paper	6.3	8.6
Sweet	6.5	9.0
Yellow	7.3	9.5
Butternut	3.4	6.4
Cherry, black	3.7	7.1
Cottonwood:		
Black	3.6	8.6
Eastern	3.9	9.2
Elm:		
American	4.2	9.5
Rock	4.8	8.1
Hackberry	4.8	8.9
Hickory, pignut	7.2	11.5
Magnolia, southern	5.4	6.6
Maple:		
Bigleaf	3.7	7.1
Red	4.0	8.2
Silver	3.0	7.2
Sugar	4.8	9.9
Oak:		
Northern red	4.0	8.6
Northern white	5.6	10.5
Southern red	4.7	11.3
Southern white (chestnut)	5.3	10.8
Pecan	4.9	8.9
Sweetgum	5.3	10.2
Sycamore, American	5.0	8.4
Tanoak	4.9	11.7
Tupelo:		
Black	5.1	8.7
Water	4.2	7.6
Walnut, black	5.5	7.8
Willow, black	3.3	8.7
Yellow-poplar	4.6	8.2

[1] Expressed as a percentage of the green dimension.

Substituting in the formula will yield the northern red oak dimensional change:

$$\Delta D = \frac{(12 - 6)\ 2.25}{\left(\frac{30(100)}{8.6} - 30\right) + 6} = \frac{13.50}{325} = 0.041 \text{ inch}$$

The positive value denotes swelling. The ends of the pieces of strip flooring are 0.041 inch wider than the inner portion due to moisture absorption by the end grain.

The total tangential shrinkage value for southern red oak is greater than northern red oak; substituting in the formula:

$$\Delta D = \frac{(12 - 6)\ 2.25}{\left(\frac{30(100)}{11.3} - 30\right) + 6} = \frac{13.50}{242} = 0.056 \text{ inch}$$

The endwise moisture absorption gradient with its accompanying swelling may create difficulties in the installation of the flooring.

Example No. 2.—Determine the shrinkage in width of a nominal 2- by 8-inch Douglas-fir plain-sawed joist machined to a width of 7½ inches at a moisture content of 19 percent and then dried to 12 percent moisture content in a retail lumberyard. In this example, FSP = 30, M_I = 19, M_F = 12, D = 7.5, and, from table 2, S_T = 7.6 percent. Substituting in the formula:

$$\Delta D = \frac{(12 - 19)\ 7.5}{\left(\frac{30(100)}{7.6} - 30\right) + 19} = \frac{-52.5}{384} = -0.137 \text{ inch}$$

The width of the joist at the lower moisture content is 7.500 − 0.137 inches or 7.363 inches.

CHAPTER 3: EFFECTS OF CLIMATE ON LUMBER STORAGE

Air temperature, relative humidity, and rainfall of the storage region affect procedures to protect lumber stored outdoors.

Relative Humidity

Relative humidity has a much greater effect on wood's equilibrium moisture content (EMC) than does temperature (fig. 15). That is, the more humid a region, the more rapidly dry lumber will take on moisture when yarded there. Seasonal estimates of the average wood EMC for a region can be helpful when trying to control moisture change in lumber stored outdoors. Such estimates are supplied later in this chapter.

Storage methods to retain low moisture content in kiln-dry lumber will differ sharply between humid regions such as Florida and dry regions such as New Mexico. Likewise, storage requirements may differ from month to month in regions where average relative humidity varies considerably with seasons, such as in inland California. Procedures explained in this handbook should be qualified in terms of average relative humidity of the storage region, especially where relative humidity differs greatly from the national average.

Temperature

Air temperature affects stored lumber because warming speeds up moisture diffusion and thus increases lumber's rate of moisture change. Thus, if moisture differences between boards in the lot need to be reduced, storage of lumber in warm air temperatures is advantageous.

Warm temperatures also increase the hazard of fungal infection in stored lumber. All lumber is practically immune to fungal infection below 30° F (−1° C). When green lumber is solid piled, mold, stain, and decay fungi will grow at temperatures from 40° to 100° F (about 5° to 38° C) with rate of attack increasing rapidly at higher temperatures in this range. Dipping or spraying freshly sawed lumber with an approved fungicide appreciably reduces the likelihood of fungal growth. If, however, treated lumber is held too long in the bulk pile in warm weather, fungi can grow rapidly (chapter 5).

Rainfall

When lumber is stored outdoors with good protection, rainfall does not greatly affect its moisture content. Bulk-piled green lumber is often temporarily stored outdoors unprotected before stacking for air drying or kiln drying. Some wetting of green lumber is not considered hazardous. If, however, green lumber has been treated with a fungicide for extended green storage or shipment, protection from rain is needed. Rain would leach the chemicals from the exposed boards.

Bulk-piled dry lumber should be protected from rain, preferably in storage sheds. Redrying bulk-piled lumber that has been wetted by rain is difficult. Bulk-piled lumber that was thoroughly soaked must be stickered before it is redried, and redrying will bring further shrinkage and drying loss. Also, if rain-soaked lumber increases its moisture content to 20 percent or more, fungi may grow, causing stain and decay.

Average EMC Conditions by Region and Season

The estimated wood EMC conditions for spring, summer, fall, and winter for the United States are given in table 3. Average temperatures and relative humidities reported by the Weather Bureau for the four seasons have been converted to wood EMC values. The States of Alaska, Washington, Oregon, California, and Texas are divided into coastal and inland regions; Arizona into a lowland and a highland area; and Hawaii into windward and leeward locations.

Five designations—arid, dry, moist, damp, and wet—are arbitrarily established for classifying the average wood EMC conditions of the outdoor air. In a specific location, actual EMC values may differ from the table 3 values in some years. More localized EMC values can be determined

Table 3.—*Estimated average wood EMC conditions for the United States*

State	Spring[1]		Summer[1]		Fall[1]		Winter[1]	
	Average EMC[2]	Designation[3]	Average EMC[2]	Designation[3]	Average EMC[2]	Designation[3]	Average EMC[2]	Designation[3]
	Pct		*Pct*		*Pct*		*Pct*	
Alaska								
Coastal	16.3	Wet	18.1	Wet	19.0	Wet	17.2	Wet
Inland	14.2	Damp	15.6	..do..	16.8	..do..	14.7	Damp
Alabama	13.7	..do..	13.9	Damp	14.4	Damp	13.3	do.
Arizona								
Lowland	6.7	Arid	6.6	Arid	8.0	Arid	8.9	Dry
Highland	7.2	..do..	7.0	..do..	8.5	Dry	9.2	do.
Arkansas	13.3	Damp	13.7	Damp	13.9	Damp	13.4	Damp
California								
Coastal	13.5	..do..	14.0	..do..	13.1	..do..	14.1	do.
Inland	11.5	Moist	8.4	Dry	10.7	Dry	16.1	Wet
Colorado	10.8	Dry	8.7	..do..	9.6	..do..	10.5	Dry
Connecticut	12.4	Moist	13.8	Damp	15.0	Damp	12.2	Moist
Delaware	13.3	Damp	13.4	..do..	14.6	..do..	14.1	Damp
Florida	14.2	..do..	15.7	Wet	15.5	Wet	14.2	do.
Georgia	13.7	..do..	14.2	Damp	14.5	Damp	13.2	do.
Hawaii								
Leeward	12.4	Moist	12.1	Moist	13.4	..do..	13.2	do.
Windward	15.6	Wet	16.8	Wet	16.8	Wet	16.1	Wet
Idaho	11.7	Moist	8.3	Dry	10.1	Dry	16.2	Wet
Illinois	12.4	..do..	13.3	Damp	12.9	Moist	14.9	Damp
Indiana	13.5	Damp	14.0	..do..	14.2	Damp	15.1	Wet
Iowa	11.9	Moist	13.4	..do..	12.9	Moist	14.2	Damp
Kansas	14.1	Damp	11.9	Moist	12.6	Moist	12.9	Moist
Kentucky	13.4	..do..	13.7	Damp	13.5	Damp	14.6	Wet
Louisiana	13.6	..do..	13.9	..do..	15.0	..do..	14.0	Damp
Maine	13.7	..do..	14.9	..do..	16.2	Wet	13.2	do.
Maryland	12.9	Moist	13.4	..do..	14.0	Damp	14.2	do.
Massachusetts	13.5	Damp	14.4	..do..	14.2	..do..	13.2	do.
Michigan	12.5	Moist	13.0	Moist	14.0	..do..	15.5	Wet
Minnesota	12.0	..do..	13.7	Damp	14.5	..do..	13.8	Damp
Mississippi	13.7	Damp	14.3	..do..	15.2	Wet	13.6	do.
Missouri	12.9	Moist	13.2	..do..	12.6	Moist	13.5	do.
Montana	11.4	..do..	9.4	Dry	11.4	..do..	13.4	do.
Nebraska	13.0	..do..	12.3	Moist	12.5	..do..	13.0	Moist
Nevada	9.4	Dry	6.4	Arid	8.8	Dry	11.7	do.

Table 3.—*Estimated average wood EMC conditions for the United States*—continued

State	Spring[1] Average EMC[2]	Spring[1] Designation[3]	Summer[1] Average EMC[2]	Summer[1] Designation[3]	Fall[1] Average EMC[2]	Fall[1] Designation[3]	Winter[1] Average EMC[2]	Winter[1] Designation[3]
	Pct		*Pct*		*Pct*		*Pct*	
New Hampshire	12.2	Moist	11.1	Moist	14.5	Damp	13.6	Damp
New Jersey	11.8	..do..	12.0	..do..	12.8	Moist	12.7	Moist
New Mexico	9.0	Dry	7.9	Arid	9.3	Dry	10.1	Dry
New York	13.1	Damp	12.8	Moist	14.1	Damp	14.8	Damp
	Pct		*Pct*		*Pct*		*Pct*	
North Carolina	13.3	Damp	14.8	Damp	14.7	Damp	13.2	Damp
North Dakota	11.4	Moist	11.3	Moist	13.2	..do..	13.6	do.
Ohio	12.9	..do..	13.4	Damp	14.0	..do..	15.2	Wet
Oklahoma	14.6	Damp	12.6	Moist	13.3	..do..	14.3	Damp
Oregon								
Coastal	14.7	..do..	12.4	..do..	14.9	..do..	18.7	Wet
Inland	11.9	Moist	8.1	Dry	9.6	Dry	16.0	do.
Pennsylvania	12.5	..do..	12.7	Moist	13.6	Damp	13.3	Damp
Puerto Rico								
Windward	14.9	Damp	15.7	Wet	16.0	Wet	15.5	Wet
Rhode Island	12.4	Moist	13.4	Damp	13.6	Damp	12.7	Moist
South Carolina	13.8	Damp	14.6	..do..	14.6	..do..	13.5	Damp
South Dakota	12.4	Moist	11.7	Moist	11.7	Moist	12.8	Moist
Tennessee	13.3	Damp	13.7	Damp	14.2	Damp	13.8	Damp
Texas								
Coastal	15.1	Wet	14.2	..do..	16.1	Wet	15.5	Wet
Inland	12.0	Moist	10.2	Dry	12.5	Moist	12.3	Moist
Utah	10.1	Dry	7.2	Arid	9.7	Dry	13.9	Damp
Vermont	12.0	Moist	12.7	Moist	14.2	Damp	14.0	do.
Virginia	12.9	Moist	13.9	Damp	14.0	Damp	12.2	Moist
Washington								
Coastal	14.2	Damp	13.8	..do..	15.7	Wet	17.0	Wet
Inland	11.6	Moist	9.6	Dry	12.5	Moist	17.9	do.
West Virginia	11.8	..do..	13.5	Damp	12.7	..do..	12.1	Moist
Wisonsin	13.2	Damp	13.5	..do..	14.5	Damp	14.6	Damp
Wyoming	12.1	Moist	9.7	Dry	10.8	Dry	11.5	Moist

[1] Spring is March, April, and May; summer is June to August; fall is September, October, and November; and winter is December, January, and February.

[2] The EMC values were compiled by E. C. Peck of the Forest Products Laboratory from normal temperature values and 1957–58 relative humidities for geographically distributed cities in each State or area (U.S. Weather Bureau, Climatological Data, National Summary).

[3] Arid—8 pct wood EMC and less; dry—8.1 to 11.0 pct wood EMC; moist—11.1 to 13.0 pct wood EMC; damp—13.1 to 15.0 pct wood EMC; and wet—15.1 pct wood EMC and higher.

from average temperature and relative humidity values supplied by the closest major weather station.

During the spring months, Arizona is designated arid. The rest of the Southwestern States, except for Texas and California, fall into the dry designation. The coastal areas of Texas and Alaska are designated wet. The remainder of the country is divided almost equally between the moist and damp designations.

During the summer months, the States west of the Mississippi River are much drier than during the spring months. East of the Mississippi River, conditions are a trifle damper than in the spring months. Florida is the only Eastern State rated wet. During the same season, the Southern States, Lake States, and the Atlantic coastal areas are generally designated damp. The Great Plains States and the Northeast generally fall in the moist category.

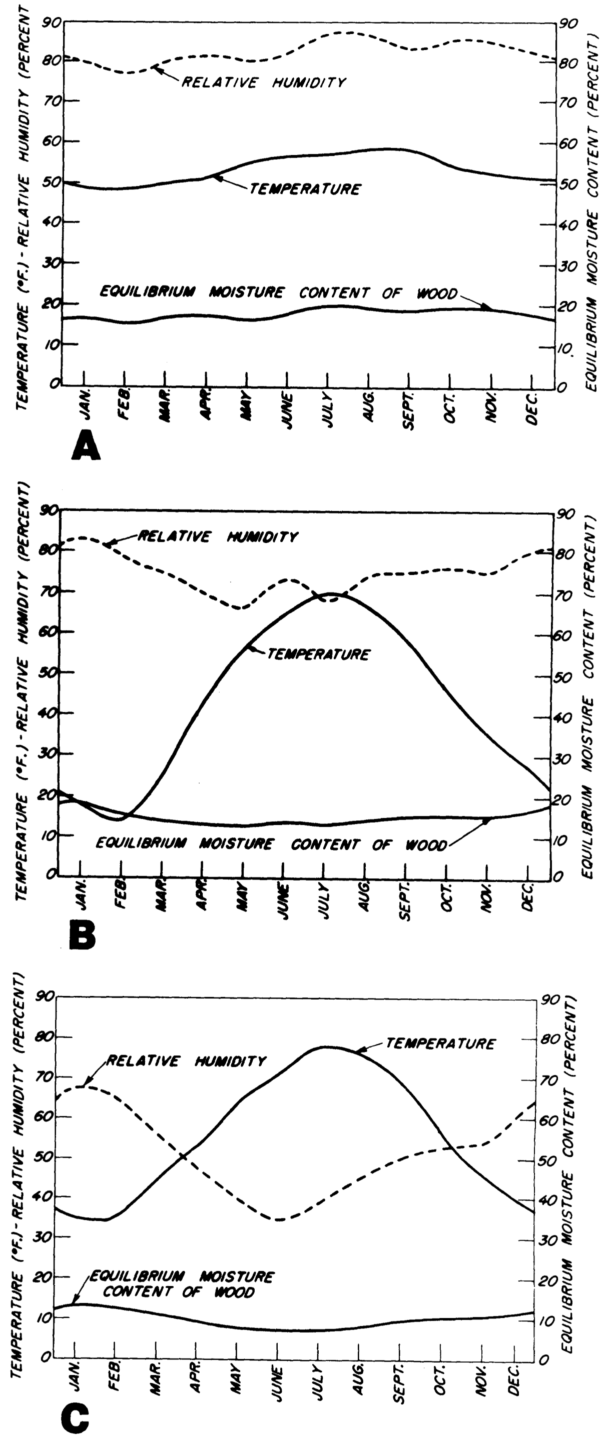
Fall is considerably damper than spring and summer throughout the whole country. Many of the Western States shift from arid to dry in fall while some even change from dry to moist. The regions rated moist and damp change little between fall and other seasons.

For the United States as a whole, the weather is damper during the winter months than in the fall. No States are arid in winter and only three States are designated dry. The greatest change occurs in States west of the Rocky Mountains and south of the Great Lakes. A considerable portion of the Pacific Northwest shifts to the wet designation in winter.

The climate of Alaska is generally wet throughout the year. All parts of that State exceed an EMC of 15.0 percent, except that the inland region in the spring and winter has EMC conditions just under 15.0 percent.

The climate of Hawaii is relatively moist overall, but varies widely depending on location in the State. The hot, humid climate of Puerto Rico places this island in the wet designation much of the year despite localized variations.

The potential of a locale for lumber drying or moisture regain is established by its average wood EMC values. Rate of moisture change, however, is influenced by the temperature of the storage location. Local conditions may shift the average EMC conditions to some extent. Weather data published in local newspapers can be used to determine the local EMC conditions.



M 119 434, M 119 431, M 119 437

Figure 15.—Wood EMC is determined more by relative humidity, less by temperature. This principle is illustrated for: (A) California's redwood region; (B) the North Central States; and (C) Colorado, Utah, Arizona, and New Mexico.

CHAPTER 4: TECHNIQUES FOR STORING LUMBER

Between cutting and use, lumber will probably be stored a number of times: At the sawmill, during transport, at lumberyards, and at the construction site. During each of these storage periods, the goal of the manager or supervisor should be to minimize grade and footage losses.

At sawmills, green lumber is stored before being stacked for air drying or kiln drying, or before shipment. Softwood sawmills store rough lumber before finishing in the planer mill. Once the lumber has been planed it is often stored indoors, but outdoor storage with protective packaging is also becoming common.

At hardwood sawmills, green lumber is usually not stored long before stickering because of the danger of fungal staining. Air-dry rough hardwood lumber is usually bulk-piled and stored in open sheds, or outdoors under a protective cover. Kiln-dry rough hardwood lumber usually awaits shipment or factory processing in closed sheds.

Green, rough lumber is seldom protected when transported from sawmill to drying yard. However, dry lumber, whether rough or finished, is usually protected by tarpaulins during truck transport, by waterproof paper packaging during flatcar shipment, or by being loaded into tight boxcars (fig. 16).

Dry lumber at woodworking plants is most often stored in sheds, although unit packages of softwood lumber in waterproof wrap are stored outdoors for limited periods (fig. 17). Lumber stored at construction sites is seldom adequately protected, but should be. By scheduling lumber shipments the contractor can at least keep the volume of exposed lumber to a minimum until the roof of the structure is installed and lumber storage space in the building becomes available.

Storing Lumber Outdoors

Lumber is often stored outdoors, sometimes because shed or warehouse facilities are not available. Unprotected storage outdoors is satisfactory for such lumber items as small timbers and lumber for less exacting uses, although precautions to prevent stain, decay and insect infestation may be necessary. But kiln-dry lumber stored outdoors without protection will show a rapid increase in moisture content. Rain wetting of any dried lumber is detrimental and tends to increase the degree of checking.

Protection against rain is more important for solid-piled lumber than for stickered packages, because rainwater cannot evaporate readily from solid piles. Furthermore, rain that penetrates bulk-piled lumber may in time increase the moisture content of the wood to a point where stain and decay fungi can grow. Some rain is likely to penetrate outdoor piles of lumber despite protecting pile covers. Consequently, extended outdoor storage of dry lumber, especially in solid piles, is hazardous.

If green or partially dried lumber is to be stored outdoors for some time, the processes of

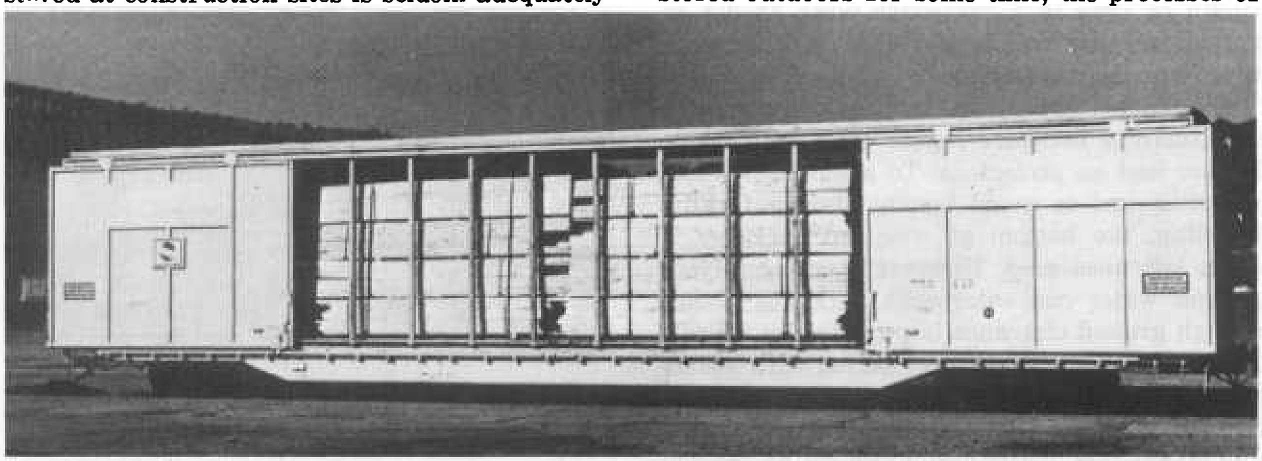


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Figure 16.—Wide-door boxcar loaded with packages of finished lumber. The sides close completely, minimizing moisture regain during shipment.

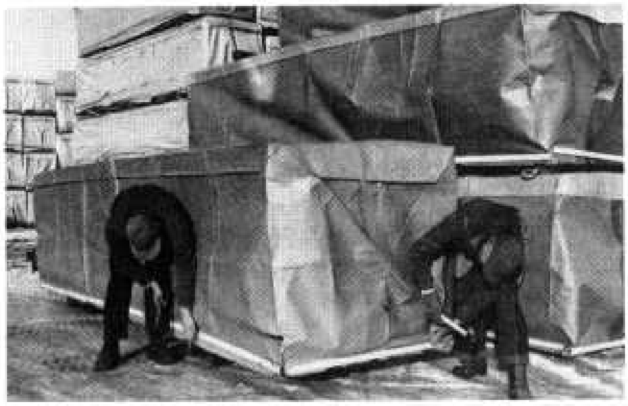

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Figure 17.—Waterproof kraft-paper wrap being installed on a package of lumber. The wrap does not cover the package bottom, and thus will not be damaged by forklift handling.

M 144 023-2

Figure 18.—Single-film polyethylene serves as a tarpaulin to protect dried lumber packages during short-term storage.

yarding lumber for air drying are involved and the recommendations in Agriculture Handbook 407, "The Air Drying of Lumber," apply.

Temporary Protection

Plastic-coated paper wrap for the unit packages of lumber (fig. 17) will adequately protect kiln-dried softwood lumber under short-term storage conditions such as the following: Long-haul transport on flatcars; interim storage at distribution centers; and short-term outdoor storage, such as at construction sites.

But coated paper wrapping should not be considered a substitute for storage sheds when long-term storage of dried lumber is involved. The wrap can deteriorate during long-term exposure. The fragility of paper wrap must also be taken into account during handling. At the least, lumber which is stored outdoors for any length of time in a protective wrap should be periodically inspected, and rips in the wrap taped or otherwise mended.

Dilapidated wrapping that holds rainwater may increase moisture regain more than if the lumber had no protection. To avoid such water retention and to avoid tearing during forklift handling, the bottom of wrapped packages is often left uncovered. However, dampness from ground water can enter such packages if not enough ground clearance is provided by the pile foundation. The safe storage period with waterproof wrap will depend on the weather (chapter 3), and upon the rate of wrapper deterioration due to exposure, mechanical handling, or damage by birds and animals.

Tarpaulins are often used for protecting bulked dry lumber temporarily stored outdoors. Water-repellent-treated canvas, single-film polyethylene (fig. 18), and laminated polyethylene films with scrim reinforcing are used as protective tarpaulins.

Lumber Storage Yards

The outdoor storage yard can be located at the sawmill, the wholesale or retail lumberyard, the custom kiln-drying plant, or the woodworking factory. Conventional air drying is often

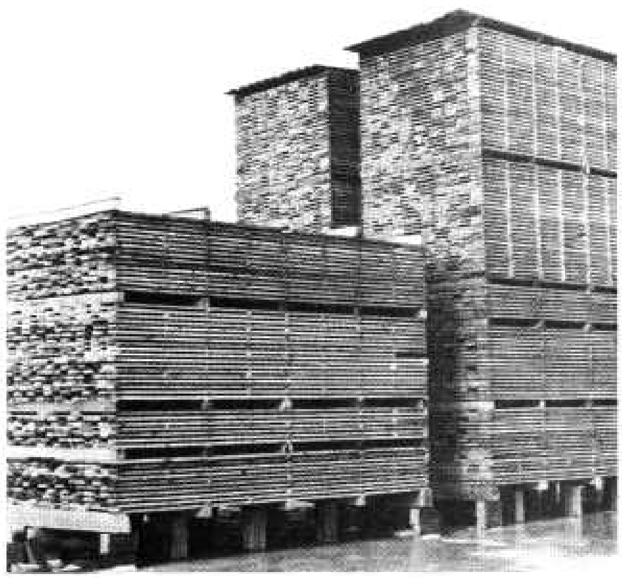

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Figure 19.—Stickered lumber yarded for air drying. The well-braced pile foundations of stringers and crossbeams prevent tipping. Most piles are covered with a prefabricated board and batten roof.

practiced at such a yard (fig. 19). Thus the best location is on high, level ground which is well drained and not obstructed by trees or buildings. A yard surface that is smooth and firm, particularly along the alleys, facilitates moving lumber packages. The yard layout should be oriented to the prevailing winds to accelerate the drying of stickered lumber. Vegetation can be controlled with weed killers. Routine maintenance should remove debris, which harbors stain and decay fungi and poses a fire hazard.

An air-drying yard for storing stickered lumber packages is often laid out so that rows of piles run between main alleys. The rows may be short or long depending upon the amount of lumber to be stored in each row. A number of rows between cross alleys constitutes a lumber storage block.

A line-type storage yard may be used if a large amount of lumber is stickered for air drying and accessibility is highly important. With this type of layout, two lines of pile foundations are built between two main alleys to accommodate packages of lumber (fig. 20). All piles of packages are accessible from the main alleys. The main alleys in both row-type and line-type forklift yards are usually 24 to 30 feet wide. The cross alleys are often as much as 60 feet wide to separate the blocks and check the spread of fire. A lumber storage yard which is completely paved facilitates lift-truck operation and allows easier yard rearrangement with changes in lumber inventory.

The main alleys are oriented in terms of the yard site available. In a forklift yard of stickered lumber, particularly a line-type yard, the movement of air through the packages is stimulated by placing the main alleys parallel to the prevailing winds. Where rainwater evaporation or snow and ice melt are important considerations, however, the main alleys are usually oriented north and south.

Use of Pile Covers

High-grade lumber stored in the yard, whether solid piled or stickered, should be protected from the weather. Lumber exposed to alternate wetting and drying will check, split, warp, and discolor. Piles of stickered lumber in the storage yard can be provided with pile covers as in conventional air-drying yards (fig. 19). Pile covers of various designs and materials are placed on the pile's top package before lifting that package into place.

Panel-type pile covers can also be used to roof stored, solid-stacked packages of rough or finished dry lumber. The covers must be raintight and project beyond the pile ends and sides to prevent rain entry into the bulked packages.

Piling Methods

Whether lumber should be solid piled or stickered depends upon its moisture content, intended use, and estimated duration of storage. Lumber with an average moisture content of 20 percent or more which is to be held in storage

M 135 029

Figure 20.—Stickered unit packages of hardwood lumber piled on permanent foundations in a "line-type" forklift yard.

for some time, particularly in warm weather, should be stickered as for conventional air drying. Such lumber is likely to seriously deteriorate if held very long in a solid pile. Mold and stain will develop, followed by decay.

If the moisture content of stored lumber averages less than 20 percent, mold, stain, and decay fungi will not grow. The intended use of this lumber, however, may be such that further drying is required. If so, stickering for outdoor storage may effect further drying depending upon initial moisture content of the lumber and the prevailing climate.

Kiln-dried lumber will tend to regain moisture when stored outdoors, particularly during cool, damp periods. Thus solid piling may be preferable to stickering. But kiln-dry lumber which is solid piled must be protected from rain.

Pile Foundations

A pile of air-drying lumber requires some type of foundation to insure ample ground clearance for good ventilation under the pile. A line-type forklift yard will have permanent foundations (figs. 19, 20), whereas a row-type yard can have either permanent or portable foundations (fig. 21). Foundations should be strong, resistant to decay, and high enough to provide a clearance of at least 12 to 18 inches between the lumber and the ground. More clearance is needed if the yard is not paved.

In a line-type yard, posts or piers support stringers of timbers or railroad rails. The stringers are parallel to the lumber. Crossbeams placed on the stringers support the lumber packages.

In a row-type yard, posts on footings support the stickered packages at the outer sticker tiers. A removable foundation is used to support the center of the pile to prevent sagging and permit forklift entry (fig. 21).

Storing Solid Packages

Unit packages of bulk-piled lumber intended for forklift truck or carrier handling are often built with tie strips to keep the edge boards from falling off. In addition, the unit package is often strapped at two or more points to make a compact, rigid-handling parcel. The tie strips are also used to separate quantities of lumber within the package.

The tie strips should be vertically alined if a number of layers are stripped, and should also be alined with the supporting beams of the pile foundations or carrier bunks. Packages in the pile should be separated by bolsters—usually 4 by 4's—alined with the supporting beams. Sagging is thereby prevented.

The size of the unit-handling package is determined by the weight-carrying capacity of the lumber-handling equipment being employed. When forklift trucks are used, the height that packages can be piled is limited by the reach of the fork-elevating mechanism, seldom more than 30 feet. Piles higher than this of 4-foot-wide packages tend to tip over unless tie bolsters are used. Excessive loading may crush tie strips or boards in the lower levels of the pile.

Storing Stickered Packages

Stickered packages are seldom strapped because they do not have the stiffness that a solid package exhibits. A stickered package must be well supported by a good foundation that has supporting crossbeams at most of the sticker tiers. Bolsters between the packages in the pile should be in good vertical alinement with the sticker tiers to effectively restrain warp.

Storing Lumber in Sheds

Storage sheds offer lumber the best protection from weathering, and also eliminate the expense of making, storing, handling, and maintaining pile covers. Losses in grade and footage through outdoor air drying have stimulated an increased interest in using open sheds for drying. Open sheds provide permanent roofs, and can also be used for storing air-dry lumber. Further modification—by closing up open sheds, installing fans to create air circulation around the stored lumber, and adding heat—can appreciably lower the moisture content of stored lumber.

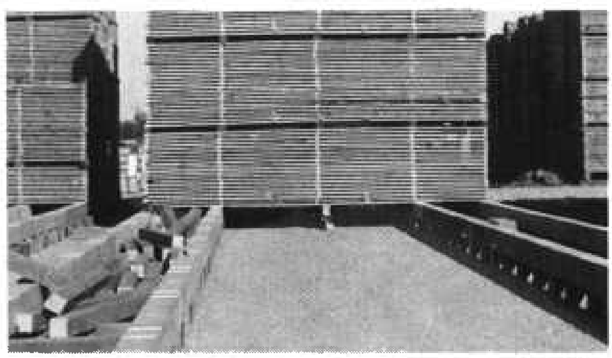

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Figure 21.—Foundations of a row-type forklift yard. Piers on footings have painted marks to aline lumber packages. A removable center foundation permits forklift entry.

Open Sheds

An open shed is a roofed lumber storage yard. All lumber items except those kiln dried to moisture contents of less than 12 to 14 percent can be stored in open sheds. The atmospheric conditions within an open shed are substantially those found outdoors. If the outdoor air can circulate through and around stickered packages, the lumber will dry to as low a value as it does in an exposed air-drying pile. The drying period in an open shed is usually shorter and the lumber brighter than if stored outdoors because wetting and rewetting are prevented.

Bulk-piled, kiln-dry lumber will regain moisture with extended storage in an open shed, although more slowly than if stored unprotected. Increase will be greatest in the outer tiers of a solid pile. For example, surfaced boards of 1- by 8-inch kiln-dry Douglas-fir averaged 6.9 percent moisture content when put in storage at a western sawmill. Moisture content of the boards increased by 3.4 percent when stored for 1 year as a carrier package in an open shed. The two outer tiers of boards in the five-tier package increased 3.8 percent in moisture content, the center tier 2.7 percent (fig. 22).

A shed may be open on all sides or on one side only (fig. 23). Where unit packages are handled by forklift truck, access to the shed is provided by one or two open sides. The rows of piled packages may run across the shed in bays between the roof supports. Where lumber is handled manually in and out of bins, as at some retail lumberyards, a driveway between the open sheds provides access. The roofs of these open sheds usually extend far enough over the driveway so that trucks can be loaded and unloaded in rainy weather.

Open sheds at the larger lumber-producing sawmills are usually paved for forklift trucks and other carrier vehicles. Cranes operating within open storage sheds for dry, rough lumber are generally of the monorail or bridge type, and pile foundations are built up on the graded ground. At small sawmills and retail lumberyards, open sheds are not always paved, although the roadways may be graded or graveled. Open storage sheds at wholesale lumberyards and woodworking factories usually have paved floors and driveways.

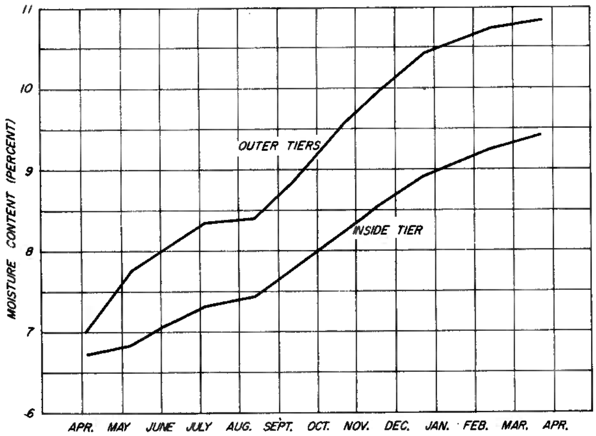

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Figure 22.—Change in the average moisture content of surfaced 1- by 8-inch Douglas-fir boards stored as a carrier package in an open shed.

Closed, Unheated Sheds

Closed, unheated sheds (fig. 24) are generally used for storing kiln-dry lumber. The object during storage is to maintain the percent moisture content attained by the drying process. Thus, lumber should be solid-piled in closed, unheated sheds, with only enough tie strips to stabilize the package or to designate species, quantities, grades, or items within it.

Kiln-dry lumber stored in an unheated, closed shed will absorb some moisture, but less than if it were stored outdoors. For example, 1-inch southern pine boards in a solid pile went from $7\frac{1}{2}$ to $10\frac{1}{4}$ percent average moisture content during 1 year of storage in a closed shed. Similar lumber which was solid-piled outdoors for the same period reached a moisture content of $13\frac{1}{2}$ percent.

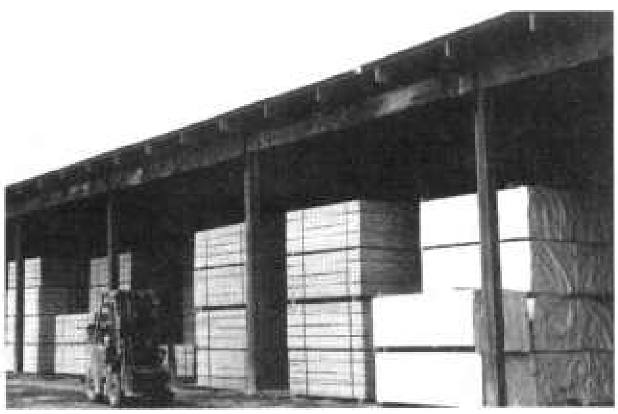

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Figure 23.—Open storage shed for packages of dry, surfaced lumber.

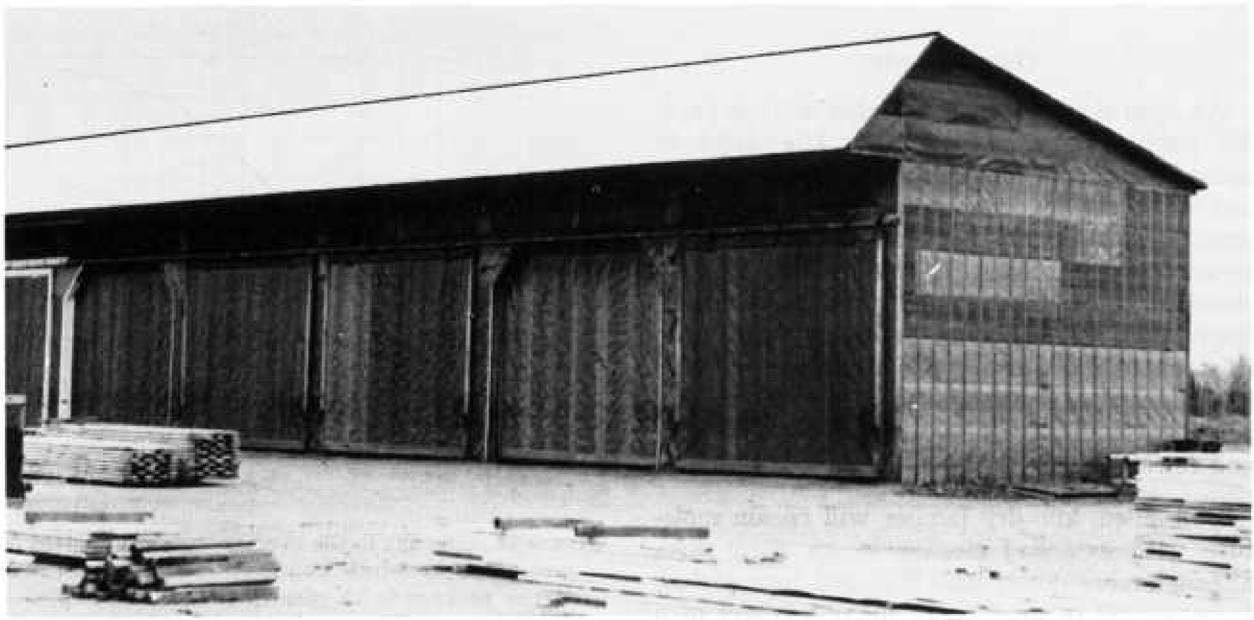

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Figure 24.—Closed, unheated storage shed at a distributing yard.

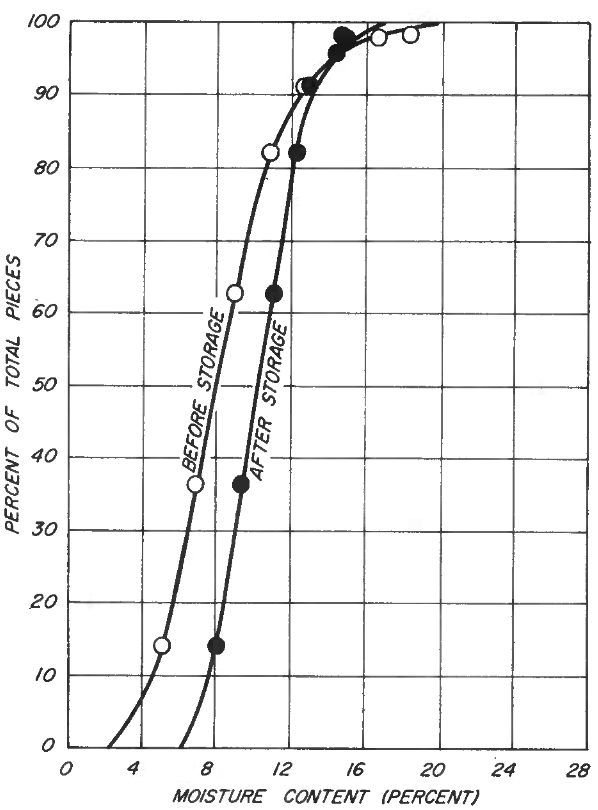

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Figure 25.—Range of moisture content in Douglas-fir 1- by 6-inch boards before and after 1 year of storage in a closed, unheated storage shed. The lumber was stored as unit packages 8 tiers wide and 45 layers high.

Storage in an unheated, closed shed will also decrease the moisture gradient in stored lumber—that is, the difference between the most moist and least moist boards in the package. For example, solid-piled packages of rough 1- by 6-inch kiln-dry clear Douglas-fir boards were stored in a large, unheated storage shed for 1 year. Curves showing the range of moisture content before and after the storage period are seen in figure 25. The range in the lumber's moisture content before storage was about 20 percent; it was 13 percent after storage. Although the range was reduced, the reduction was generally at the expense of the dry boards in the unit packages. Ninety-five percent of the boards in the packages underwent an increase in moisture content.

The roof and walls of a closed shed absorb solar radiation and in turn heat the air inside. The warmed air, however, tends to remain in the upper parts of the shed. To be effective in lowering the equilibrium moisture content conditions around the stored lumber, the warm air must be moved downward and circulated by fans. Forced circulation, even without additional heating, is beneficial. Forced circulation, together with an additional source of heat, will convert a closed, unheated shed to a closed, heated shed.

Closed, unheated sheds for lumber storage should be floored or paved if the handling equipment operates on the floor surface. If the closed shed is not paved, it should be located on a high, well-drained site. Sometimes the closed shed will have an elevated wood-decked tramway and wood floor if it is built over low ground. In that case, good ventilation of the space under the floor is essential.

Large, closed, unheated sheds with overhead bridge cranes (figs. 26, 27) are not floored except where surface equipment operates to load railroad cars and trucks. The pile foundations in unpaved sheds should be so designed and constructed that air can circulate freely under the bottom packages.

At some sawmills, lumberyards, and woodworking factories, lumber is moved in and out of racks or bins in the unheated, closed sheds. Aisles or driveways are provided for transporting the lumber to and from the bins, so that it can be solid piled in the bins without difficulty. Some items at sawmills and wholesale and retail yards are placed on end in stalls (fig. 28). Paving the floor of these stalls assures dry ends.

Closed, unheated sheds beside railroad sidings often have an elevated floor to facilitate lumber handling in and out of boxcars. The crawl space under the elevated floor needs to be well ventilated.

Closed, Heated Sheds

If the air in a shed is heated, EMC conditions are lowered. Moisture regain by stored dry lumber can thereby be prevented (chapter 2).

Closed lumber sheds can be heated to lower the wood EMC by steam-heating coils, radiators,

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Figure 26.—Dry, finished softwood lumber stored as unit packages in a large, unheated shed at a western sawmill. High, close-spaced stacks are made possible by use of an overhead crane.

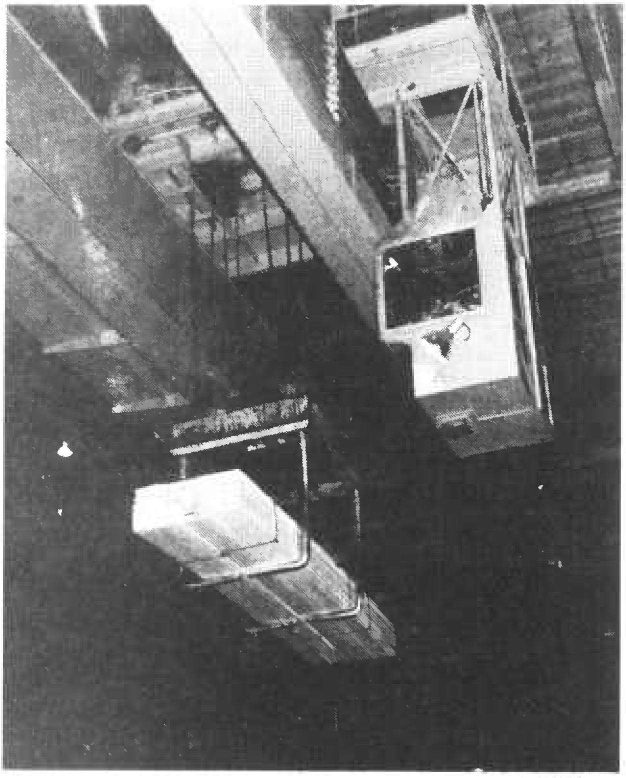

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Figure 27.—Bridge crane servicing a large, unheated storage shed.

or unit heaters. Gas-fired unit heaters are sometimes installed. It is essential that some air circulation be created by strategically located fans. The heat supply can be controlled manually or automatically. Manual control requires frequent observations of outdoor and indoor wet- and dry-bulb temperatures so that the relative humidity in the shed can be estimated and valve settings adjusted accordingly.

Temperature control in closed, heated sheds is often by a simple thermostat which regulates either the heater or the heater fan. With changing outdoor temperature and relative humidity, the thermostat in the storage area needs to be frequently reset to maintain the desired wood EMC.

Differential thermostats require less adjustment than simple thermostats in controlling shed heating. They automatically maintain shed temperature a fixed number of degrees higher than the outdoors temperature. Differential thermostats will maintain an approximate EMC level without periodic readjustments. They are inexpensive, and are available from a number of national suppliers.

Humidistats will initiate heating when the relative humidity goes above the adjusted set point, and can control the EMC of lumber accurately enough to seldom need readjustment. For example, a 7 percent EMC can be maintained in a closed storage shed over a wide temperature range if the relative humidity is kept at about 35 percent.

Kiln-dried lumber is often stored in cooling sheds pending removal for factory processing or shipment. Cooling sheds may be either open sheds or closed, unheated sheds (fig. 29). Excessive moisture regain can occur when open cooling sheds are used for temporary lumber storage. However, open cooling sheds can be converted to closed sheds; if this is done, humidistat control of heated, circulated air is often desirable. Such humidistat control will maintain low moisture levels indefinitely in kiln-dry lumber.

Closed, heated sheds are seldom insulated because generally they are heated only 10 or 15 degrees above the temperature of the outside air. Such a temperature elevation will usually protect even kiln-dry lumber from moisture regain.

If closed, heated sheds are used for air drying, the shed should not be so tight that all air exchange with the outside is prevented. In that event, humidity from the drying lumber would

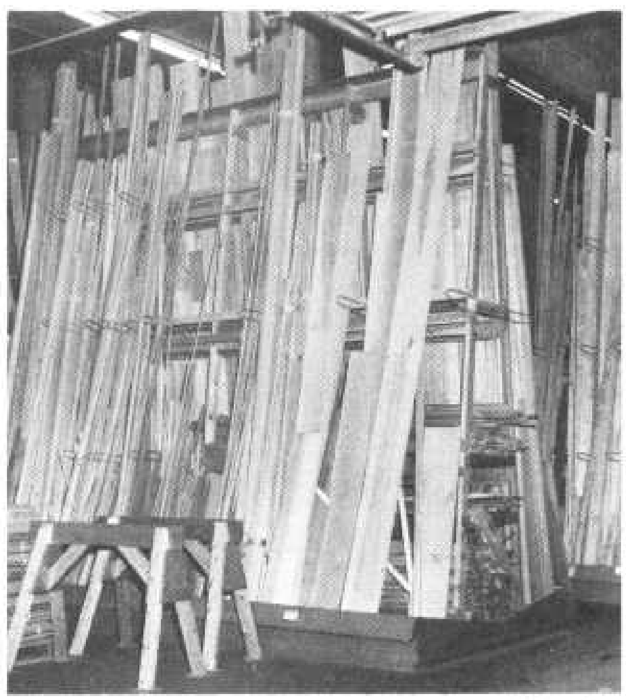

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Figure 28.—Molding stock stored on end and in bins at a retail lumberyard.

elevate the EMC and defeat the purposes of the heating.

Storing Plywood

Plywood in storage must be protected from changes in moisture content. A closed, unheated shed is fully satisfactory for storing plywood except for certain times of the year in humid areas such as the Gulf Coast, where storage in a closed and heated shed would be better. Plywood must not be stored outside except for very short periods unless fully protected by a good pile roof or by complete coverage with a waterproof wrapper.

Plywood's moisture content is normally below 20 percent, so the material is usually stored in solid packages. Occasionally, however, some plywood may be received that has a moisture content of 20 percent or more. Such material must be stickered sheet by sheet.

Plywood, especially the thinner sheets, has a tendency to sag between supports. If the storage period is quite long, this sag may develop into permanent deformation. Therefore, plywood sheets should be stored on a platform foundation (fig. 30). A platform should also be used between packages in the pile.

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Figure 29.—Stickered lumber undergoing conditioning in a closed, unheated cooling shed.

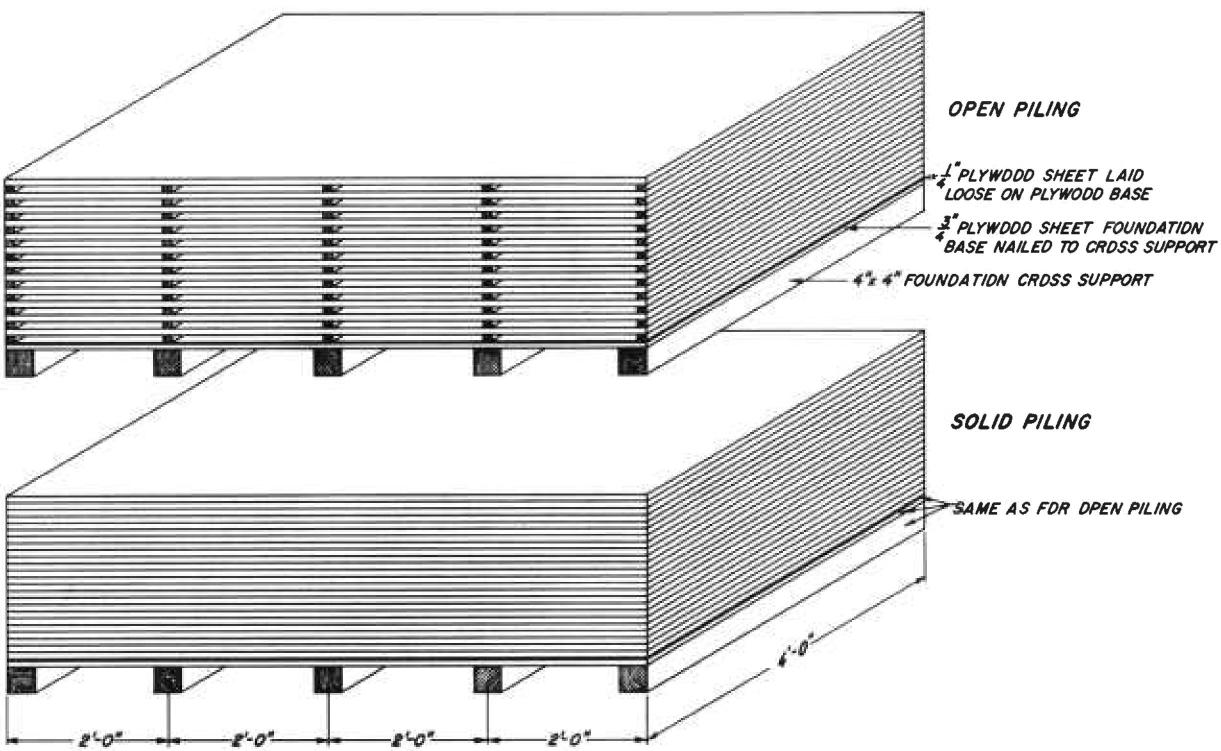

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Figure 30.—Plywood correctly piled on a platform foundation. Solid piling is adequate unless plywood is over 20 percent moisture content.

When solid piling all thicknesses of plywood, the spacing of the cross supports must not exceed 2 feet on centers. Stickered packages of plywood may require closer spacing of cross supports, depending on the plywood sheet thickness. If the wet plywood is less than ½-inch thick, the maximum spacing of stickers is 18 inches on center for plywood to be open piled. If the plywood is ½-inch thick or thicker, a sticker spacing of 2 feet is permissible. All stickers must be vertically alined so that the weight of the plywood will be transmitted directly to the foundation supports. This spacing prevents deformation of the sheets.

CHAPTER 5: TREATING STORED LUMBER[2]

Fungal infection and insect attack both pose serious hazards to stored lumber. Fungal infection was found to be the principal cause of degrade in a study of grade loss in 1-inch southern pine lumber. Insect infestation also causes serious losses in stored lumber, particularly in the warmer parts of the U.S.

For protection from fungi and insects, lumber may require a dip or spray treatment in a chemical solution at the storage installation. In some cases this treatment will supplement an earlier dip or spray at the sawmill.

To minimize fungal and insect attacks on stored lumber, air-drying yards should be kept sanitary and as open as possible to air circulation. Recommended practice includes locating yards and sheds on well-drained ground. Remove debris, which is a source of infection, and weeds, which reduce air circulation. Piling methods should permit rapid drying of the lumber and also protect against wetting.

Open sheds should be well maintained with an ample roof overhang to prevent wetting from rain. In areas where termites or water-conducting fungi may be troublesome, stock to be held for long periods should be set on foundations high enough to be inspected from beneath.

When Is Chemical Treatment Needed?

Prompt drying will often protect untreated lumber from attack by stain, decay, and some insects. For instance, untreated material uniformly below 20 percent moisture content is immune from attack by fungi. With protective storage it will keep that immunity. However, dried lumber which regains moisture to a level of more than 20 percent again becomes susceptible to stain and decay.

The sapwood of all wood species is more susceptible than heartwood to decay, stain, or insects. Therefore, the hazards are highest for woods which usually contain a high percentage of sapwood. The heartwood of such species as redwood, the cedars, and some white oaks has high natural resistance to fungi and most insects. But few products—even from these woods—are of heartwood only.

Damp weather can increase the damage from stain and decay fungi. Rainfall and humid conditions increase the hazard to unprotected wood in both open and solid piles.

Air temperature is highly important: The stain and decay fungi grow most rapidly at 70° to 90° F (21° to 32° C), no more than one-fifth as rapidly at 50° to 60° F (10° to 16° C), and cease growth at about 32° F (0° C). As a result, wood at about 25 to 30 percent moisture content, stored in solid piles in warm weather, may show evidences of stain within a week and early decay infection within a month. The initial infections, which are not visible, probably started shortly after the wood was sawed. With temperatures of 50° to 60° F (10° to 16° C), similar deterioration requires five or more times as long. At 32° F (0° C) or below, the lumber can remain in solid piles indefinitely without adverse effects.

High humidity favors subterranean termites, but does not affect drywood termites or powder-post beetles. The influence of temperature on insect activity, however, is pronounced. Insects are inactive at temperatures of 50° F (10° C) or below, but increase their activity rapidly as the temperature rises about this level. Insects will approximately double their activity with each increase of 10° above 50° F, reaching maximum activity levels at about 80° F (27°C).

[2] Mention of chemical treatment in this chapter does not constitute a specific recommendation. Only those chemicals registered by the U.S. Environmental Protection Agency may be recommended, and then only for uses prescribed in the registration, and in the manner and at the concentration prescrbed. The list of registered chemicals varies from time to time. Prospective users, therefore, should get current information on registration status from the Environmental Protection Agency, Washingon, D.C.

When and Where Is Treatment Applied?

Stain and decay in lumber are normally controlled at sawmills, collection points, and drying yards by drying the wood as rapidly as possible below 20 percent moisture content. Lumber to be air-dried may be treated with fungicidal solution by dip or spray before the drying period begins. Sometimes an insecticide is mixed into the solution if insects are likely to be a problem.

The layer of wood chemically protected by a dip or spray is only "skin deep," and will not stop fungi or insects that have already entered the wood. This is why stock is dipped as soon as possible after it is sawed. To illustrate how quickly the dipping must be accomplished, the safe times are estimated as: 1 day with temperatures of 80° F or above; 2 days at 70° F: 1 week at 60° F; and 1 month at 50° F. Longer delays at these temperatures progressively lower the benefit from surface treatments.

Generally, dip or spray treatments immediately after cutting are designed to protect green stock only when it is drying. If treated green lumber is not air-dried to below 20 percent moisture content, prolonged storage may require redipping or respraying of the lumber.

Efficient management of a lumber storage yard can eliminate situations which encourage growth of stain or decay fungi in stored lumber. When lumber is brought to a yard, an estimate should be made as to how long the storage period will be. The superintendent, using this estimate, will be able to prescribe recommended storage practices. He should also consider the time needed to ship the lumber to destination points, for during this time protection is also needed.

Lumber properly dipped in an antistain solution at the sawmill can be stored in solid piles for up to 1 month in warm weather if further drying is not required. If longer bulk storage is anticipated, dip-treated stock should be redipped. Additional dipping can protect pines and hardwoods from stain and decay for 6 to 8 weeks in warm weather and western softwoods other than pines for 4 to 6 months.

If the lumber was not dipped at the sawmill, dipping at the storage yard may still protect it from fungi during bulk storage provided the stock is not already infected. Infection would not occur if daytime temperatures in the interval between sawing and receipt at the yard did not exceed about 40° F (5° C). If temperatures were higher, however, fungus infection may have already taken place, and solid piling should be avoided. Instead, lumber may be dipped in a fungicidal solution and open-piled.

Because a number of factors affect safe storage time, all dipped bundles should be labeled with the date on which they were treated. Representative ones should be opened from time to time to determine the condition of the stock. Any lumber that shows signs of being inadequately protected should be designated for early use, redipped, or stickered for air drying.

Applying Chemical Treatment

Lumber to be dipped at the storage installation will probably be in unit packages. Thus the dipping procedures explained here will be for unit packages. When lumber is dipped, the amount of solution absorbed will be about 4 to 8 percent of the wood weight, depending on type of wood and moisture content at the time of treatment.

Treating Area and Equipment

Location of the treating plant affects the costs and efficiency of the treating operation. Ready access of the plant to packaging and storage areas—and to railroad spurs or shipping docks—will keep costs to a minimum and insure an efficient handling operation.

Equipment for treating lumber often includes an electric hoist that runs on a monorail attached to the ridge of a long, open shed. The treating vat can be installed in or above the ground but should be located in the center of the shed. This leaves protected areas in both ends of the shed where untreated packages can be brought in or the treated packages loaded out. Dead or electrically operated rollers are often used in both ends of the shed.

The vat should be sufficiently large to admit the largest unit package to be dipped and should hold sufficient solution to treat a number of packages without replenishment. Provision also should be made for easily adding and removing the treating solution. A well-designed vat would be about $1\frac{1}{2}$ times the height and width of the largest package to be dipped and about 3 feet longer. A drainboard wide enough to accommodate several packages should be provided at the removal side of the vat to free the hoist for continuous treating.

Some type of hold-down device, such as weights or a heavy iron cradle, is required to keep the packages submerged in the solution. Weights should be attached to the pallet that supports the packages, not to the load in such a way as to compress the packages against the vat bottom. In fact, the boards should be compressed against one another as little as possible to allow the treating solution to penetrate between them.

The vat should be supplied from a mixing tank of known capacity. This tank will carry extra treating solution which can be prepared without interrupting treating operations. Steam or electrical heating coils would be a desirable supplement to the mixing tank to insure that chemicals dissolve rapidly and completely.

Dipping Operation

Packages of lumber should be submerged in the protective solution for at least 5 minutes, and for up to 15 minutes if long storage periods are expected. Packages treated in a waterborne solution should be turned on edge with the board faces parallel to the sides of the vat. This can be done as the packages are placed in the vat. Packages treated with an oil-borne solution need not be turned entirely on edge during treatment. However, some means should be provided to tilt the bundles as they are immersed to let air escape from the voids and to allow solution to flow in.

Packages removed from the treating solution should be drained for a sufficient time to recover most runoff. A drainage period at least as long as the treating period usually will be adequate.

Treating for Insect Control

Insects can extensively damage stored lumber under certain conditions. Treatment may be needed to control such damage in both dry and green wood, regardless of the wetness or dryness of the storage location.

The principal insects that attack stored wood vary in their need for moisture. Ambrosia or pin-hole beetles invade green or partially dried wood, but usually are only a minor hazard in lumber stored away from forested areas or sawmills.

Among the most troublesome insects are those belonging to the powder-post beetle group. These insects chiefly attack partially dried sapwood and are particularly damaging to such large-pored hardwood species as oak, ash, hickory, walnut, and pecan.

The principal other insect that might attack stored lumber is the termite. There are two general types—the subterranean and the drywood termite. Practically all woods are susceptible to their attack. Subterranean termites are by far the most prevalent type in the United States. They must have contact with some source of moisture, almost always the ground. Drywood termites occur only in limited areas along the Gulf and Pacific Southwest coasts, particularly in Florida and southern California. Drywood termites and powder-post beetles are the only pests that primarily attack dry wood.

Properly applied treatments which are commercially available generally provide protection to stored lumber against powder-post beetles and termites.

It is important to realize that the dip treatments described here apply only to the protection of the products in storage. Preservation of wood for use requires different types of solutions and methods of application.

For wood that might be treated only because of a subterranean termite hazard, a more efficient method of protecting the lumber would be to treat the ground under the storage piles or sheds.

Precautions With Chemicals

All treating solutions should be so handled that none, or as little as possible, gets on workers' skin and clothing. In particular, contact of the skin with the dry chemicals should be avoided.

When lumber dipped in water solutions is to be painted, sufficient time must be allowed during storage or before painting to allow the wood to dry adequately. Only rather short drying periods will be necessary to remove excess moisture resulting from treatment with waterborne chemicals because the increase in moisture content from dipping or spraying will be small. Residual oil should be cleaned from any dry hardwood lumber to be painted.

CHAPTER 6: AT SAWMILLS—LUMBER HANDLING AND STORAGE

Lumber storage varies from total outdoor exposure at small, portable sawmills to a high degree of protection under roof at large, permanent sawmills. Procedures will differ according to whether hardwood or softwood lumber is being sawn, and whether the sawmill uses a central yard or does its own drying and planing. The mill's degree of modernization will also affect procedures.

Softwood Sawmills

Small Sawmills

Portable or semipermanent sawmills producing softwood lumber are usually located near the source of logs. The rough green lumber is usually assembled into a unit package for transport to an air-drying yard near the mill site, or is trucked to a central yarding location. The solid-piled unit packages of green lumber are exposed to the weather.

Green lumber at these small mills is seldom treated with a fungicide, but often should be, because extended storage in the bulked handling package increases the hazards of stain development (chapter 5). If the lumber is air dried at the sawmill, the rough, dry lumber is trucked to the buyer without protection. If the small sawmill owner also operates a planer, the finished lumber should be tarpaulin-protected on the delivery trucks, but is not so protected in most cases.

Green lumber is often trucked from small softwood sawmills to a central yard. The lumber is sorted and stacked at this yard for either air drying or kiln drying. A sorter is usually used to segregate thicknesses, widths, lengths, and sometimes grades. The sorted lumber is usually built into solid packages and moved by lift truck to the stacker station. There, the solid packages are made into stickered packages for drying. These stickered packages may be placed on piles in the air-drying yard, or may be stacked on kiln trucks for drying in track-type dry kilns. The stickered packages may also be placed in a package-loaded kiln for drying.

Portable softwood sawmills not delivering their lumber to a concentration yard either sell green lumber or air dry the sawed lumber at the mill location. Mill-run lumber to be air dried is trucked to a yard site where hand-built air-drying piles are erected. The lumber may be flat piled, crib piled, or end piled.

Large Sawmills

At large softwood sawmills, lumber moves through two separate sequences of procedures, or "processing flows". First, fresh-cut lumber moves in a series of steps from the saw to either dry kilns or an air-drying yard. Then the completely dried lumber moves through another processing flow to be finished, regraded, packaged, strapped, and stored for shipment as remanufactured lumber.

Lumber sawn at the larger softwood sawmills is immediately sorted. The lumber is usually stacked mechanically for kiln drying soon after sorting. The kiln truckloads or stickered unit packages often stand outdoors awaiting kiln space or the accumulation of a kiln charge. Degrade from exposure in the upper courses of such packages or kiln truckloads has justified the construction of open sheds at many softwood sawmills. After kiln drying, rough softwood lumber is usually stored in open cooling sheds before processing in the planer mills.

Dry, rough lumber to be held for some time is stored in sheds. Lumber to be processed and shipped is taken to the planer mill, usually by lift truck or carrier. Dry, finished lumber is held in a closed shed.

At large softwood sawmills, green lumber is transported from sorter to stacker by transfer chains or transfer-track-type dump buggies. Conventional green chains may be roofed, but the pulled lumber is often exposed to the weather. Edge, drop, and tray sorters are not usually roofed. Rough, dry lumber is moved from a dry sorting chain to storage in closed sheds by lift truck, carrier, or monorail.

In softwood operations which are large and modernized, the rough kiln-dried lumber is transferred from the unstacker to the planer by transfer chains. The finished and remanufactured lumber is regraded, packaged, strapped, and is then stored in closed, unheated storage sheds.

Kiln-dry rough lumber is usually kept under roof. However, outdoor areas between the planer mill and finished lumber sheds are sometimes used for storing finished lumber as wrapped carrier packages (fig. 31).

Some of the larger softwood sawmills enclose the sorting equipment and store stickered kiln-truckloads of lumber under cover at the loading end of the battery of dry kilns. Kiln-dry rough lumber is sometimes left on sticks and stored in an open shed until needed in the planer mill. Most often, however, the rough, dry lumber is regraded, packaged, and stored in a closed "rough dry shed."

At the larger softwood sawmills, however, the trend is toward a reduction in dry, rough lumber inventory with an increasing inventory of finished planer-mill products. The rough dry shed is being eliminated. The finished lumber is packaged and strapped to stabilize the package, and stored in large closed sheds equipped with bridge cranes. The loading dock for both railroad car and trailer truck loading is part of these closed sheds.

Hardwood Sawmills

Sawmills cutting hardwood lumber are usually permanently located and set up. Green lumber at hardwood sawmills, large and small, is almost always handled and stored outdoors. The sawmill and green chain may be under roof, but the bulk-piled sorted lumber is exposed without protection until transferred either to the air-drying yard, with or without a pile roof, or to the dry kiln.

M 142 881

Figure 31.—Wrapped unit packages of dry, finished softwood lumber stored outdoors at a sawmill. Note roofs on top of piles to provide additional protection.

M 140 707

Figure 32.—Forklift truck placing stickered package of hardwood lumber on pile bottom in line-type air-drying yard.

Small Sawmills

At small hardwood sawmills, the sawed lumber is often sorted into three or four segregations at the back end of the mill. This sorted lumber is then stacked into unit-handling packages in stalls which are sometimes provided with sticker guides. The unit packages are transported from the stacking location to the air-drying yard by forklift truck and placed on the pile foundations (fig. 32).

A forklift truck transports the stickered, air-dried packages to a station where inspection for grade and tally is carried on while unstacking. Air-dried rough hardwood lumber often awaits shipment outdoors in solid piles or packages without protection. The air-dried lumber is usually shipped from the sawmill by truck without protection

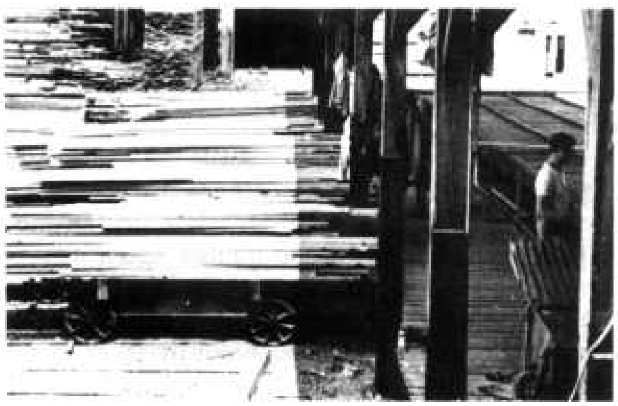
The small hardwood sawmill seldom has indoor storage facilities for air-dried lumber. A small remanufacturing plant to trim and rip air-dried hardwood lumber may be located in an open shed, but lumber storage space is usually quite limited.

Large Sawmills

At larger hardwood sawmills, the lumber is sorted into various classifications on a green chain (fig. 33). Some lumber items may be stickered in stalls with sticker guides set up alongside the green chain. The packages are built up on kiln trucks and tracks so that the completed package can be rolled out for forklift truck pickup and transport to the air-drying yard. When hardwood lumber is to be stacked on kiln trucks for kiln drying or air drying (fig. 34), a forklift moves solid-piled packages from the green chain to the stacker.

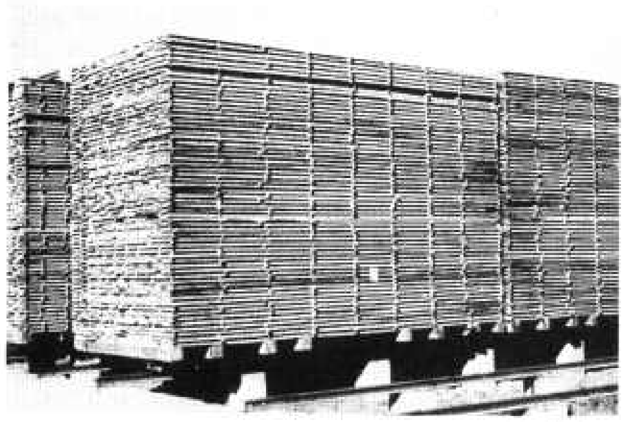
At sawmills where the hardwood lumber is stacked in hand-built piles for air drying, the lumber is solid-piled on dollies or carts at the green chain and pulled by tractor to the pile location. At a hardwood mill with dock-type air-drying yards, the bulk-piled sorted lumber on carts or wagons is tractor-drawn on the elevated tram to the pile location. All too often, more concern for protective storage would reduce degrade in the yarded lumber.

Large hardwood sawmills may have a closed shed for storing air-dried rough lumber. Lumber not meeting the requirements of a shipment is accumulated there until ordered. Hardwood sawmills with dry-kilns will have sheds for cooling and storing kiln-dried rough lumber awaiting shipment. Kiln-dried hardwood lumber is not ordinarily stored for inventory purposes at hardwood sawmills unless a factory, such as a flooring plant, is operated in connection with the sawmill. Kiln-dried rough hardwood lumber is usually kept under cover until loaded into tight boxcars.



M 140 709

Figure 33.—Green chain at a hardwood sawmill. The graded lumber is bulk piled on dollies that can be moved out far enough for a forklift truck to pick up the parcel and transport it to the stacking stalls.



M 142 891

Figure 34.—Green hardwood lumber being air-dried on kiln trucks.

Recommendations

Softwoods

Green lumber.—Treat green lumber with a fungicide if bulk storage is extended, particularly during the warmer months (chapter 5). Species like the white pines must be stacked for drying soon after sawing to avoid brown stain.

Kiln-dried lumber.—Store dry lumber, both rough and finished, under cover. Keep shed access doors closed during off-work periods. Inspect wrapped packages of finished lumber stored outdoors for wrapper breaks and tears. Redry wetted lumber.

Hardwoods

Green lumber.—Stack for air drying or kiln drying soon after sawing. Treatment with a fungicide may be necessary during warmer months to prevent sap stain (chapter 5).

Air-dried lumber.—Store under cover to prevent moisture regain. Covers on outside bulk-piled stock should effectively prevent rainwater entry. Keep bulked piles off of the ground to allow ventilation. Air-dried lumber can be stored in closed sheds, either bulked or on sticks. Keep shed doors closed when possible.

Kiln-dried lumber.—Store as bulked lumber in closed, heated sheds.

CHAPTER 7: IN TRANSIT—LUMBER HANDLING AND STORAGE

If carelessly shipped, dry lumber can regain enough moisture to require redrying, and green lumber can stain or decay. Such waste is totally unnecessary. With proper transport procedures, even kiln-dried lumber can cross the United States—or be shipped to foreign ports—without any appreciable loss of quality.

Nationwide, a vast inventory of lumber is in transit at any one time by railroad, truck, or ship. Lumber moves from sawmills to locations of end use either directly or through wholesale and retail lumberyards. Softwoods are usually shipped as finished lumber. Hardwoods more often move from the sawmill to the woodworking plant as rough lumber, although kiln drying and surfacing in transit may sometimes be involved. Coastal sawmills ship lumber by ocean-going vessels to domestic and foreign ports.

Present-day lumber shipments are usually unitized for mechanical handling. The strapped unit-handling packages are loaded by forklift into wide-door railroad boxcars, onto flatcars, and onto trucks. Ocean-going vessels are loaded by ship gear.

On the eastern seaboard of the United States, lumber from the Pacific Coast is readily available because of low-cost sea transport via the Panama Canal. Often green lumber is shipped by sea because weight is not a major expense in this type of shipping. On the other hand, lumber crossing the United States by rail is usually kiln dried because rail rates are based on weight. Railroads place southern and northeastern suppliers in a favorable shipping cost position for Eastern markets.

Generally, when 1-inch dry softwood lumber is shipped in tightly closed boxcars (fig. 35), in enclosed trucks, or in packages with complete and intact wrappers, average moisture content changes can generally be held to 0.2 percent per month or less. In holds of ships, dry material usually absorbs about 1.5 percent moisture during normal shipping periods. If green material is included in the cargo, the moisture regain of the dry lumber may be doubled. (On deck, the moisture regain may be as much as 7 percent. However, dried lumber is seldom stowed on deck.)

Truck Transport

Changing transportation costs have led to increased use of trucks for transport of lumber and wood-based products. Trucks have become a major means of lumber transport for regional remanufacture plants, for retail supply from distribution yards, and for hauls where the distance from primary manufacture to customer is within about 1,500 miles.

Considerable quantities of air-dried lumber are shipped by truck from sawmills to factories or custom kiln-drying plants. Tractor-trailer units are usually used for this purpose, and in most instances the trailer is a flatbed unit that can be loaded and unloaded by lift truck. The lumber is anchored to the trailer by chains tightened with load binders.

Few data are available on moisture changes during truck shipment. Time in transit is short,

M 144 032

Figure 35.—Dry, finished softwood lumber being loaded into a tight boxcar. A straddle carrier prepares tc deliver additional lumber.

seldom exceeding a week even on longer hauls, so little change in lumber's moisture content would be expected from atmospheric humidity. However, trucked lumber can be wet by rain or splashed-up road water.

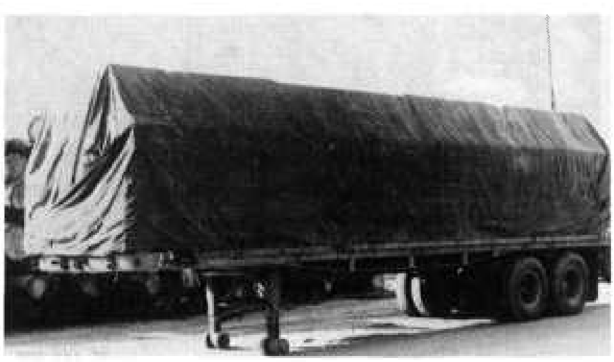
High value, air-dried lumber is often protected by covering the load with canvas tarpaulins (fig. 36). Lower grade lumber is seldom protected at all, especially on short hauls. Some protection is recommended during truck transport within a wet or moist climate zone during wet periods. Precautions should also be taken when a shipment is going to cross several climate or elevation zones.

Rail Transport

Some years ago both the U.S. Forest Products Laboratory and the Canadian Western Forest Products Laboratory studied the changes in moisture content of softwood lumber shipped in tight railroad boxcars from West Coast sawmills to Midwestern United States and Eastern Canadian markets.

The U.S. Forest Products Laboratory studies involved five boxcar loads of 1-inch clear Douglas-fir shipped from a West Coast sawmill to the Chicago, Ill., area during late winter and spring months. The time in rail transit averaged 18.5 days, the shortest period being 14 days and the longest 22 days. Table 4 shows the average moisture content at the time of loading and the change while in transit.

Average moisture content of the five carloads of kiln-dry boards at the time of loading was 8 percent, and the average gain in moisture content was 0.2 percent. These values are based on an average of 18 test boards distributed throughout the boxcar load in each shipment. The test boards were checked for moisture content by the ovendry method both before loading and when unloaded. Moisture content changes in the test boards did not correlate with their position in the boxcar.



M 142 893

Figure 36.—Packages of kiln-dried hardwood lumber on a truck-trailer are covered with a tarpaulin.

In a different study, test boards in a carload of Douglas-fir quarter-round and crown molding, which were at 8 percent moisture content when loaded, regained 0.8 percent in moisture in a 20-day transit period from the West Coast to the vicinity of Chicago. Thus, no significant change in moisture content of dry lumber need be expected during the usual haul in tight boxcars.

Table 4.—*Gain in lumber moisture content during U.S. rail shipment*

Carload shipment No.	Month shipped	Average moisture content when loaded	Gain in moisture content in transit
		Pct	*Pct*
1	January	8	0.2
2	February	8	.3
3	February	10	.3
4	March	9	.1
5	March	7	.3
Average		8	+0.2

The rail shipments studied by the Canadian Western Forest Products Laboratory involved 19 boxcar loads of softwood lumber with an average transit time from Vancouver to Montreal or Ottawa of 20 days. The shortest transit period was 12 days and the longest 25 days. Shipments were made during each season of the year. The test boards for each shipment, 18 to 33 in number, were distributed uniformly throughout the lumber in each boxcar. The changes in moisture content during these rail shipments of kiln-dried lumber are presented in table 5. It was concluded that kiln-dried lumber will arrive at its destination in eastern Canada in satisfactory condition.

A study of moisture changes in rail shipments of kiln-dried hardwood lumber was conducted by the U.S. Forest Products Laboratory. These shipments were of kiln-dried pecan lumber, transported in wide-door boxcars (fig. 37) from

M 142 879

Figure 37.—Wide-door box car designed for fork truck handling of packages of kiln-dried lumber. Note corner irons and ratchet-type load binders.

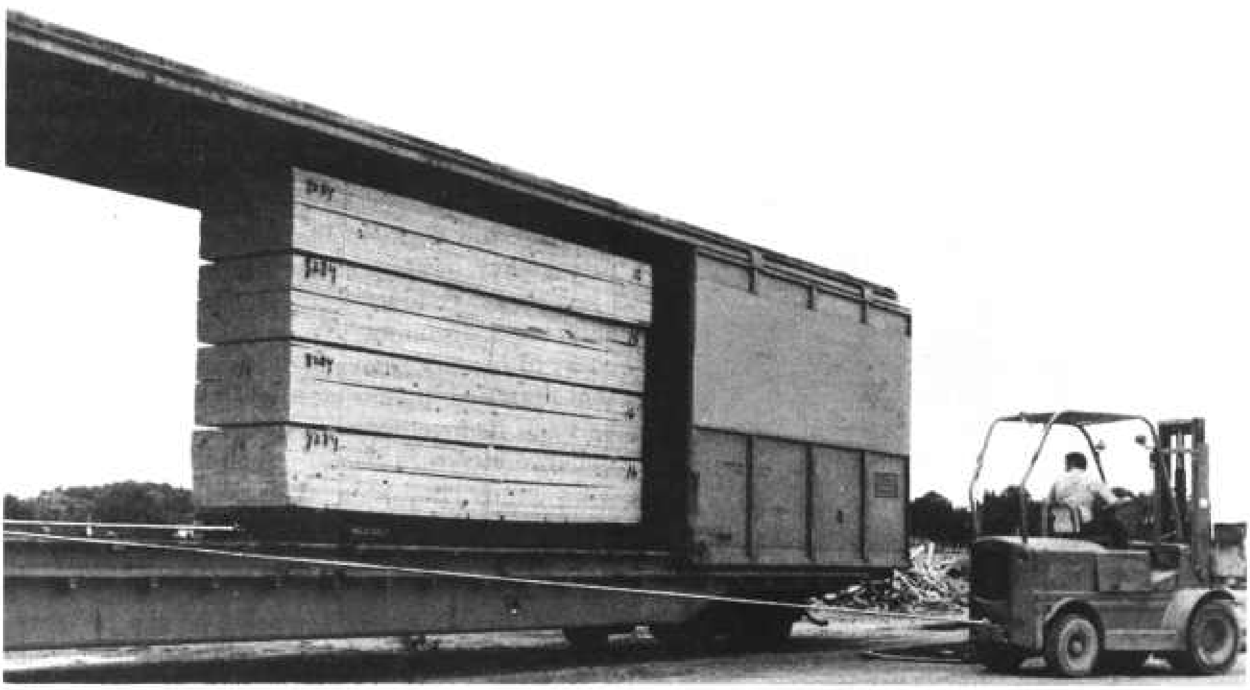
Table 5.—*Gain in lumber moisture content during Canadian rail shipment*

Species	Size	Number of shipments	Average moisture content		
			Loaded	Unloaded	Gain
	In.		*Pct*	*Pct*	*Pct*
Douglas-fir	1	7	7.4	8.8	1.4
Douglas-fir	2	4	9.7	10.5	.8
Western hemlock	1	4	8.6	9.4	.8
Sitka spruce	1	4	7.3	8.2	.9

midsouth Mississippi to a furniture company in North Carolina, a distance of about 900 miles. Each load of unitized lumber packages contained four test boards for moisture analysis. Test shipments were made from June through November, with the results summarized in table 6.

Changes in moisture content were not considered commercially significant, and the lumber was moved into furniture production without additional processing. Since these studies were conducted, the furniture company has utilized roller-bed boxcars for these shipments of kiln-dried pecan lumber (fig. 38).

Some shippers use "chain" flatcars for lumber shipments (fig. 39). These flatcars are loaded with unit packages of bulked lumber by lift truck. When the carload is in place, it is anchored or bound to the car by chains thrown over the load and tightened with ratchet load binders. These chain cars may or may not have bulkheads at the flatcar ends.



M 144 081

Figure 38.—Roller beds of another wide-door boxcar are shown in action. After the center of the car has been unloaded, a truck draws a roller bed of lumber out of the car end, using a cable that passes through a pulley in the left section of the car.

Table 6.—*Gain in moisture content of rail-shipped pecan lumber*

Month of shipment	Moisture content		
	At point of shipment	At point of receipt	Gain
	Pct	*Pct*	*Pct*
June	6.5	6.66	0.41
July	6.23	6.38	.15
August	6.23	6.21	—.02
September	5.59	6.05	.46
October	6.24	6.53	.29
November	6.29	6.71	.42

Air-dried hardwoods are often unitized and shipped on chain flatcars without protection. These cars move to woodworking plants where the stock is kiln dried. Air-dried hardwood lumber is often shipped on chain cars to custom kiln-drying plants. Gondola cars are also sometimes used for bulk-shipping lumber.

Conventional flatcars have become more widely used for the transport of dried lumber because of several advantages. Improvements in unitized package wrapping have made it possible to obtain these advantages without much increase of moisture content, even on long hauls. Flatcars can save handling time and shipping cost. The load of lumber per flatcar may be twice that per conventional boxcar. Flatcars tend to offer lower per-unit freight rates and can be loaded by lift trucks to save handling time.

M 135 004

Figure 39.—Strapped unit packages of air-dried hardwood lumber loaded on a bulkhead chain car.

Unitized packages on flatcars are usually protected, either partially by tarpaulins or entirely by flexible, waterproof packaging which completely "tailor-wraps" each package. One common type of waterproof packaging uses composite kraft paper that is glassfiber-reinforced and polymer-coated (fig. 40). The packaging is frequently supplied with additional reinforcement at stress points such as edges and corners. Improvements in packaging materials have made possible the shipment of kiln-dry lumber with little change in moisture content and a good retention of brightness by the boards.

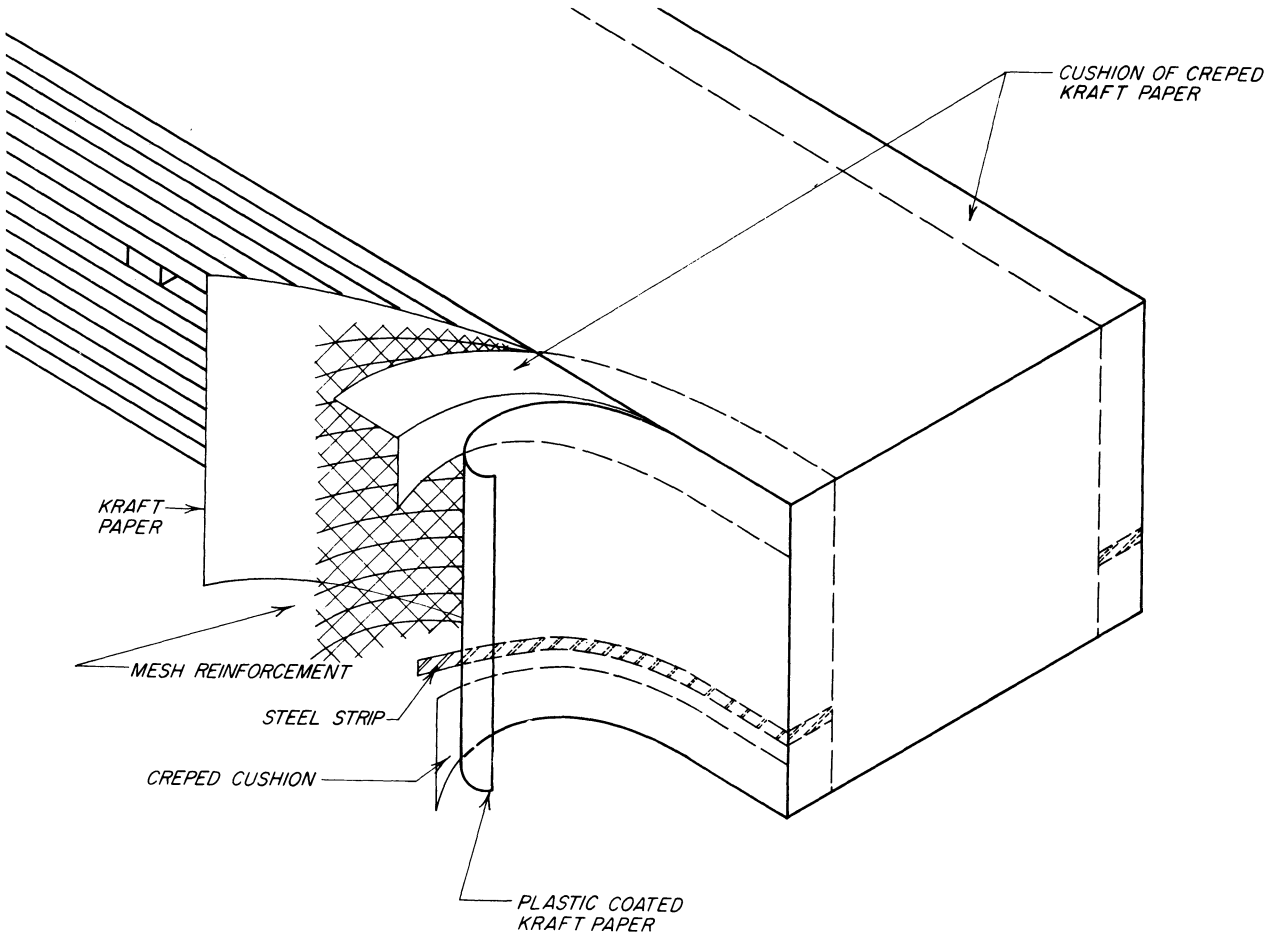
Wrapping for unitized packages of lumber should be free from rips to be effective. Rain which enters the rips is held by the sheeting and the package may act as a humidifier. If so, moisture regain may be higher than if the lumber were unprotected (chapter 3).

Ship Transport

Lumber transported from the United States by ship falls into one of two categories: (1) Pacific Coast softwood lumber, usually green, destined for the U.S. Eastern Seaboard States; (2) dried, finished lumber for foreign ports. Green lumber is often stored on deck, exposed to the weather; seasoned lumber is usually stowed below decks in ship holds, either by itself or together with green lumber.

A study conducted in Canada involved 33 shipments of lumber from the Canadian west coast to five different ports. The study concluded that seasoned lumber stored below decks, either by itself or together with green lumber, will not undergo moisture regain of serious proportions. This study indicates that well-dried lumber may undergo significant moisture regain if stored on deck, although it is not commonly so stored.

Each test shipment consisted of one or more strapped unit packages containing 48 end-coated, 4-foot sample boards. Moisture content and weight of each board in the package were determined when the test packages were assembled. Douglas-fir and western hemlock were used in



M 143 905

Figure 40.—Details of one type of plasticized kraft-paper wrapping. This reinforced wrap protects utilized packages of lumber during shipment on railroad flatcars and beds of open trailer trucks.

the tests. The test packages were stored in the ships' holds or below decks with commercial shipments of dry or green lumber. Test packages of kiln-dried lumber were stowed on deck with green lumber in ocean shipments to South Africa and Montreal, Canada.

Upon arrival at the port of destination, the individual boards making up the test packages were weighed and their moisture content determined. The moisture gains for the various shipments are presented in table 7.

Stowage of 1-inch kiln-dried lumber together with green lumber below decks resulted in almost twice the overall gain in moisture content as compared with dry lumber stowed alone. But even when green and dry were stored together, moisture regain in the dry lumber was not enough to seriously impair lumber quality.

Kiln-dried lumber stowed on deck, even though protected from direct contact with the weather, regained almost four times more moisture than did dry lumber stowed with other dry lumber below decks. However, on-deck storage of kiln-dried lumber is not a common practice.

Similar tests were made with 2-inch instead of 1-inch Douglas-fir lumber. The 2-inch kiln-dried lumber had a moisture content of 9 to 10 percent when stowed. Shipments were to the same ports as with the 1-inch lumber, except not to Trinidad. The overall average moisture gains for these shipments of 2-inch lumber were as follows:

Stowed below decks with dry lumber___1.3 percent

Stowed below decks with green lumber__2.4 percent

Stowed on deck with green lumber_____4.2 percent

The average moisture content of this 2-inch lumber at the time the test packages were loaded was slightly higher than the 1-inch lumber, and the moisture regain somewhat less. The moisture increase for 2-inch kiln-dried lumber stowed with green lumber below decks and on deck is about the same as for the 1-inch kiln-dried lumber.

The Canadian Laboratory concluded that when well-dried lumber was stowed below decks the lumber would arrive at its port of destination at a satisfactory moisture content. The data indicate the advantage of stowing dry lumber separate from green lumber below decks.

No data are available on moisture content changes in present-day ocean shipments of unitized dry lumber.

Recommendations

Softwoods

1. Green lumber is unitized and shipped, sometimes without protection, by truck, railway flatcar, or ocean-going vessels. Extended transit time may result in degrade from mold, stain, and decay fungi, especially during warm weather. Green lumber may need to be treated with a fungicide before shipping during the warmer months (chapter 5).
2. Dry, finished lumber should be shipped in tight boxcars, as wrapped unit packages on flatcars, or below decks in ships. Protection may not be necessary during short truck hauls during dry weather; otherwise, tarpaulin coverage should be used.

Hardwoods

1. Green lumber shipments can be made without protection when the transit periods are short. The lumber should be air dried prior to long periods of rail, truck, and ship transport.
2. Air-dried lumber can generally be shipped by truck, rail, or ocean-going vessel without protection.
3. Kiln-dried lumber requires protection during transit. Use tight boxcars or package wrappers for rail shipments. Use watertight tarpaulins on open truck shipments. Stow below decks on vessels.

Table 7.—*Average gain in lumber*[1] *moisture content during ocean shipment*

Number of shipments	Shipment destinations	Time in transit	Lumber moisture content increase: Stowed with dry lumber below decks	Stowed with green lumber below decks	Stowed on deck with green lumber
		Days	*Pct*	*Pct*	*Pct*
11	England	54	2.9	4.7	---
10	Australia	66	1.7	3.2	---
6	South Africa	85	2.2	1.8	7.6
3	Eastern Canada	47	.7	3.7	6.5
3	Trinidad	37	1.7	3.2	---
Average			1.9	3.3	7.1

[1] 1-in. kiln-dried Douglas-fir.

CHAPTER 8: AT LUMBER DISTRIBUTING YARDS—HANDLING AND STORAGE

Lumber distributing yards may be either wholesale or retail. Handling systems at these yards will depend upon the volume of lumber being stored and the quantity moving in and out of the yard.

At the larger distributing yards, lift trucks, including side loaders and end loaders (fig. 41), are used for unit-package handling. Incoming boxcar shipments of loose dry lumber are usually unitized when unloaded for yarding. The unitized packages are often stored outdoors briefly, without protection (fig. 42); extended storage is often in open or closed sheds (fig. 43). Lumber on incoming railroad chain cars, flatcars, and gondola cars is usually unitized for forklift truck or crane unloading. Shipments to the larger distributing yards in open-top trucks are often strapped packages that can be unloaded by forklift.

Straddle carriers (fig. 44) may be used in the larger yards where haul distances justify the use of these more rapid transport vehicles. Larger distribution yards are usually wholesale operations which ship to woodworking plants, retail lumberyards, or construction sites. Their shipments are usually unitized. Shipping is by truck, both enclosed and open-bed.

At the smaller distributing yards, lumber is unloaded from boxcars onto trucks and moved to open or closed sheds where the lumber is piled in bins. Facilities for unit-package handling are not often available. Shipments out of these smaller yards, usually retail operations, are often on a job-lot basis. Thus the inventory of any one lumber item is relatively small. Hauls to a building site are usually by open truck without protection. If such shipments will be exposed outdoors upon delivery, some sort of temporary protection, as a sheet wrapping, is recommended (chapter 10).

Outdoor Storage

Lumber is often stored outdoors if shed or warehouse space is not available (fig. 45). Unprotected outdoor storage is satisfactory, although not ideal, for such lumber items as timbers and lumber to be used for less exacting requirements. However, kiln-dried lumber should not be stored outdoors unprotected. Such lumber, even if protected from rain by a cover, will dampen excessively for interior uses when stored outdoors for long periods in most parts of the United States. If the storage period is to be brief, piled packages of dry, solid-stacked lumber are often protected by canvas or plastic tarpaulins. Strapped packages of lumber wrapped with waterproof paper are often stored outdoors without additional protection.

Outdoor storage may become an air-drying process if incoming lumber in a green or only partially dried condition is stickered rather than bulk piled. Whether lumber yarded outdoors should be bulk piled or stickered for further drying depends upon the lumber's moisture content and intended use. Lumber at a moisture content of 20 percent or more that is to be held for some time, particularly in warm weather, should be stickered for additional air drying. Piles of stickered packages should be roofed to keep moisture regain during rainy weather to a minimum (chapter 4).

Solid-piled green lumber is likely to deteriorate if held for an extended time. Stain and mold will develop first, followed by decay. Dry lumber in

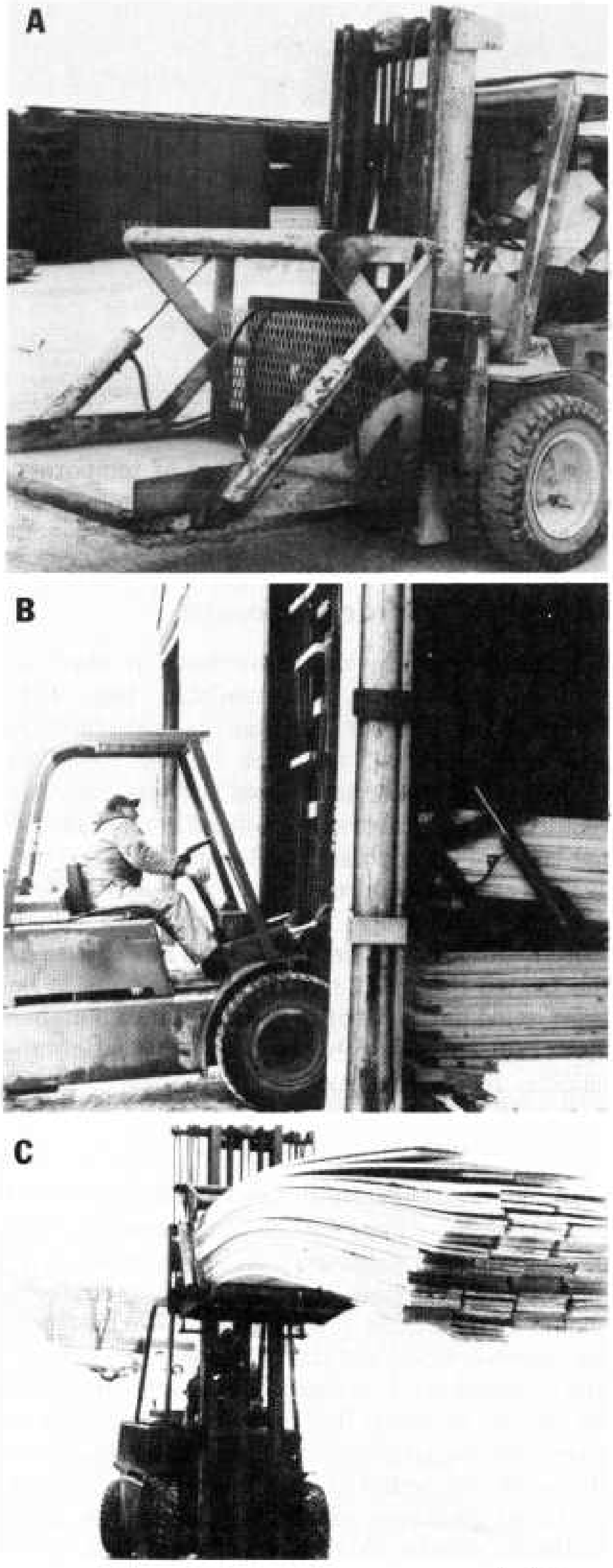


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Figure 41.—The end loader, or end picker, is equipped with a hydraulic clamping device (A) for grasping the ends of lumber parcels (B). The lumber can then be easily transported (C).

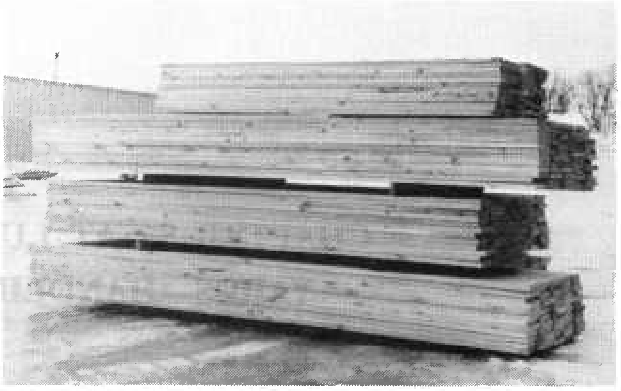

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Figure 42.—Packages of dry, finished softwood lumber are piled in a staggered manner for pick-up by an end loader.

M 142 883

Figure 43.—Strapped unit packages of lumber stored in a closed shed at a wholesale distributing yard.

M 144 221

Figure 44.—Straddle carrier transporting a bulk package of finished lumber. These carriers can move lumber more rapidly than forkloaders or endloaders can.

solid packages, if not protected from wetting by wrappings or pile roofs, will take on excessive moisture with extended storage.

Indoor Storage

All dry lumber items can be protected in the three types of shed detailed in chapter 4: (1) open sheds, (2) closed, unheated sheds, and (3) closed, heated sheds.

Open Sheds

An open shed at a distribution yard provides a permanent roof over the stored lumber (fig. 46). The atmospheric conditions within the open shed are the same as outdoors, and provide equilibrium conditions for air-dried lumber. Stickered packages can be stored in open sheds for further air drying.

The shed may be open on all sides or on one side only. The lumber is piled and unpiled from the open sides. At the larger distributing yards, forklift trucks are used to handle packages of lumber placed in rows of piles across the shed. Certain grades and sizes of lumber are often hand-stacked in bins set up in the bays (fig. 47).

Lumber kiln dried to moisture content levels of 10 percent or less is not often stored in open sheds unless the storage period is expected to be short.

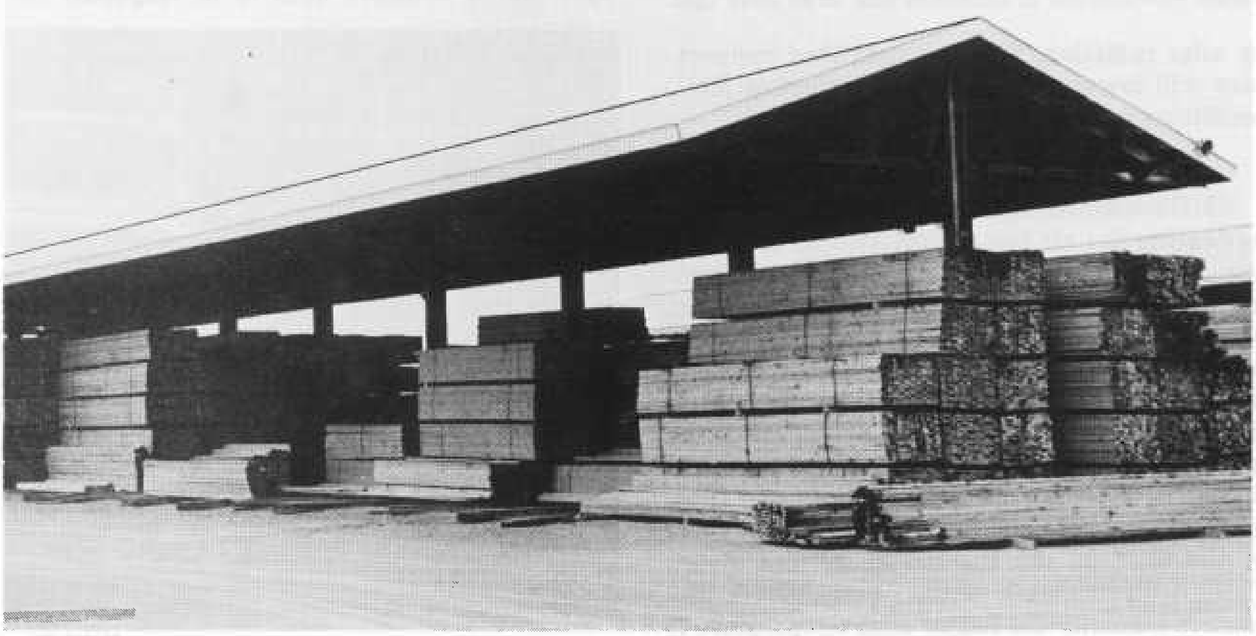
M 142 897

Figure 45.—Outdoor storage of dry, finished softwood lumber. Note the use of pile roofs to provide some protection from rain and sun.

Closed, Unheated Sheds

Closed sheds are used primarily for the storage of well-dried lumber items. The object of this type of indoor storage is to prevent excessive regain of moisture by the dry stock. The lumber is solid piled (fig. 48).

At the larger distributing yards, unit packages are handled with forklift trucks. Blocks of packages of similar lumber items are built up for ready accessibility. The shed is often paved. Patterned and specialty grades of lumber may be hand-stacked in bins from a central aisle or roadway (fig. 49). Moldings of various sizes and



M 136 779-5

Figure 46.—Strapped packages of lumber in an open shed. The lift truck can operate from both sides of the center posts.

patterns which have been bundled and wrapped at the producing mill are often stored upright at the distributing yard (fig. 50).

Kiln-dried lumber stored in an unheated, closed shed will absorb some moisture because the wood's average moisture content is usually lower than the prevailing wood equilibrium moisture content (EMC) in the shed. The lumber tends to come to equilibrium with the higher EMC conditions, with the outer parts of the piles gaining moisture the most rapidly (chapter 2).

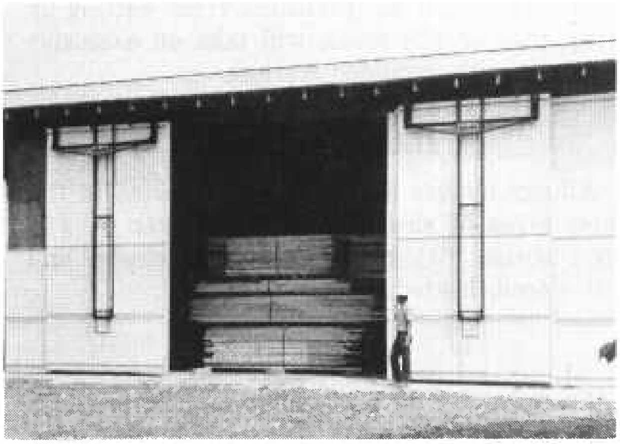
The temperature inside of the closed, unheated shed will be somewhat higher than outdoors because of heat radiating from a roof warmed by solar radiation. The increased shed temperature will lower the average or effective EMC conditions to some extent.

M 138 780-12

Figure 47.—Storage of lumber in bins in an open shed.

Closed, Heated Sheds

EMC conditions in a closed shed can be lowered by heating the air being circulated in the building. A closed shed can be heated with steam-heating coils, steam radiators, steam unit heaters, or gas-fired unit heaters. The heated air should be circulated around the stored lumber continuously. Unit-heater operation is often thermostatically controlled by on-and-off operation of the unit-heater fan. But a better procedure is to attain full-time fan operation by using an automatic valve on the steam or gas line. This valve is controlled by the thermostat or humidistat. Then, with changing outdor temperature and relative humidity the indoor shed temperature is automatically set to maintain the desired EMC condition.



M 144 021

Figure 48.—Packages of dried, finished lumber being stored in a closed, unheated shed.

Recommendations

Softwoods

1. Green lumber can be stored outdoors without protection in cool weather, provided that the storage periods are not extended. In warm weather, the risk of fungal stain, decay, or insect infestation makes prompt stickering, and perhaps chemical treatment, advisable before storage (chapter 5).

2. Dry lumber requires protection from weathering and moisture regain. Wrapped packages stored outdoors need to be inspected for

M 142 882

Figure 49.—Storage of dry lumber in bins in a closed, unheated shed.

Figure 50.—Wrapped bundles of molding stored upright in segregated stalls.

wrapper deterioration; torn wrappers should be repaired or the package quickly moved under roof. Open or closed shed storage offers the best protection.

Hardwoods

1. Green or partially dried rough lumber should be stickered and stacked for air drying. High value lumber should be air dried in an open shed.

2. Air-dried lumber when bulked requires protection from weathering and moisture regain. Outdoor storage requires suitable raintight cover and some elevation off the ground. Storage in open sheds is ideal.

3. Kiln-dried lumber should be bulk piled and stored in a closed shed. Heated storage is advantageous.

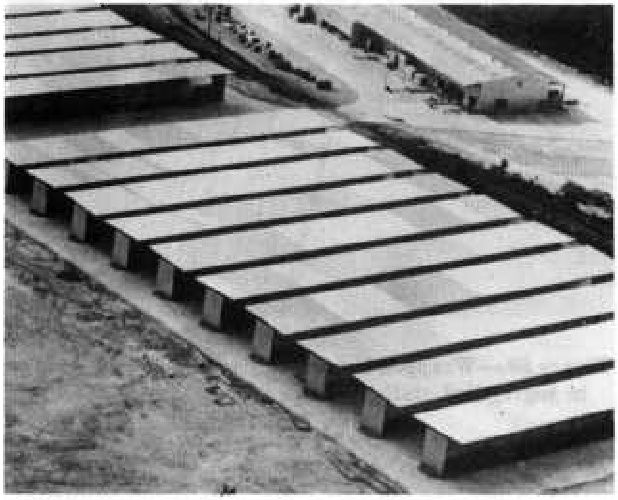
CHAPTER 9: AT WOODWORKING FACTORIES— LUMBER HANDLING AND STORAGE

Woodworking factories buy lumber either directly from sawmills or from wholesale distributing yards. Green, partially air-dried, air-dried, and kiln-dried lumber—all is delivered to such plants. The storage conditions at the plant are adjusted to further dry the lumber if necessary, or to prevent moisture changes. Lumber is stored both outdoors and in sheds. In many instances, the lumber is kiln dried at the factory. If so, cooling sheds and indoor storage rooms are often used to store the lumber before use.

Storage Facilities

Green lumber often arrives at a woodworking factory as solid packages (fig. 51) which are then stickered for drying. Slower drying hardwoods like oak are built into unit packages for drying in a conventional air-drying yard or in specially built open sheds (fig. 52). However, some woodworking plants air dry hardwoods such as oak on kiln trucks prior to kiln drying (fig. 53). The faster drying hardwoods are usually stickered for kiln drying while green, although the thicker sizes may require air drying first. Green softwoods are stickered for immediate kiln drying.

Some woodworking factories do not have dry kiln equipment, but employ the facilities of custom kiln-drying operations. Lumber shipments are kiln dried and often surfaced at the custom kiln-drying plant while enroute from the sawmill to the factory.

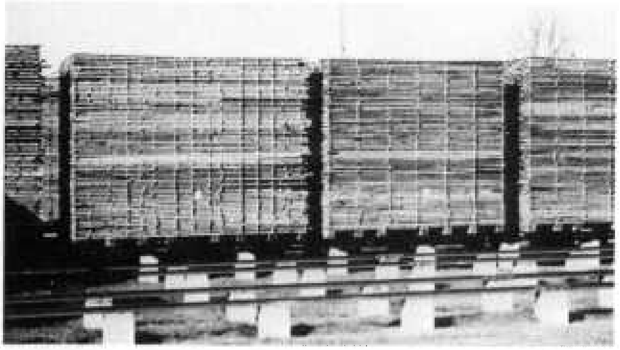


M 142 900

Figure 52.—Air-drying sheds at a furniture factory.

M 136 715-10

Figure 51.—Temporary outdoor storage of green hardwood lumber at a furniture factory.



M 142 913

Figure 53.—Stickered hardwood lumber air drying on kiln trucks prior to kiln drying.

Air-drying yards at woodworking factories should be located at sites favoring good drying. Such yards should be laid out to facilitate lumber handling. The alleys or roadways are often paved and the pile foundations permanent, particularly in line-type yards. Pile covers should be used. Yarding is usually done with forklift trucks because most woodworking factories have converted their air-drying yards from hand-built piles to unit-package handling.

Partially air-dried lumber, either softwood or hardwood, is usually stickered for kiln drying. Stickered unit packages are sometimes stored outdoors without protective cover before loading into a package-loaded dry kiln, or are placed on kiln trucks for drying in a track-type dry kiln. Kiln-truckloads of green, partically air-dried, or well air-dried lumber are sometimes stored in a "green" end storage shed of a dry-kiln installation before loading into the dry kiln. Such storage under roof protects high value lumber.

If kiln-dried lumber must be stored outdoors, it should be bulk piled well off the ground on supporting foundations. Sheet plastic covers on these piles will cut down moisture regain. If the storage period is extended, redrying may be necessary, requiring that the lumber be stickered.

Unit packages of softwood lumber, kiln dried and wrapped, are often stored outdoors at millwork factories (fig. 54). The storage period is usually brief. In extended outdoor storage, the wrappers on kiln-dried packages of lumber should be periodically inspected and repaired (chapter 4). Extended exposure of unit packages with damaged wrappers can increase losses due to stain and decay.

Open Sheds

Lumber stored in an open shed is protected from weathering. The shed roof shields the lumber from exposure to direct sunshine and rain. Green and partially air-dried lumber can be stickered, placed in the open shed, and dried. Well air-dried lumber can be bulk piled and stored in an open shed. The range of moisture content in the package may be reduced with duration of storage if at the time of bulk piling the range was fairly high.

Kiln-dried lumber is sometimes stored in open sheds at woodworking plants with the realization that moisture regain will take place. The storage period must be reasonably short if redrying is not planned. Waterproof paper wrap-

M 144 022

Figure 54.—Wrapped unit packages of kiln-dried finished softwood lumber stored outdoors at a millwork factory.

ping will retard moisture regain during short-term storage of kiln-dried lumber in open sheds.

At many woodworking factories, cooling sheds to relieve stresses in lumber after kiln drying are essentially open sheds. Stickered kiln-charges of lumber should not be left long in such sheds, or moisture regain may become so great that the lumber cannot meet manufacturers' requirements.

Closed, Unheated Sheds

The open shed provides protection from sun and rain, but the closed shed, in addition, protects the lumber from winds. Thus, the closed, unheated shed is not suited to air drying. Well air-dried stock is bulk piled for storage in these sheds. The range in moisture content will be reduced with extended storage. Kiln-dried lumber is stored in closed, unheated sheds with the expectation that some moisture regain will take place, but less rapidly than in an open shed. Reduced air circulation and some heating of the shed by solar radiation help to keep the lumber's moisture regain low.

Many dry-kiln cooling sheds at woodworking factories (fig. 55) can be classified as closed, unheated storage sheds. The access doors, however, must be kept closed most of the time or they are essentially open sheds. Warming by both solar radiation and heat from the dry kilns can reduce the wood EMC conditions in the cooling shed. Stickered lumber can be stored there for some time without excessive moisture regain.

Kiln-dried lumber in closed, unheated sheds requires bulk piling during extended storage to keep moisture regain limited. Redrying may become necessary to reduce the moisture gradient within and between boards of the lot when the duration of storage in the closed, unheated shed is greatly extended.

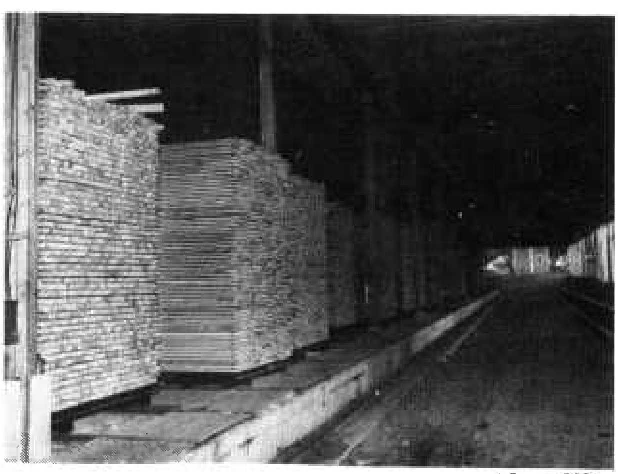
Closed, Heated Sheds

Cooling sheds for kiln-dried lumber at woodworking factories are sometimes heated during cool, damp weather — generally during the winter—to keep the lumber EMC low (fig. 56). However, heating of such sheds is seldom thermostatically controlled, and all heat is turned off during the summer months.

Some woodworking plants include heated storage rooms where lumber is held until needed in the rough mill. Heat in these rooms is often regulated by thermostat, but is turned off during the summer. Such rooms are not used for drying lumber.

Handling Equipment

Factories using track-type dry kilns arrange the plant layout so that the stickered kiln truckloads of lumber can be transferred and moved into the rough mill. Here the loads are usually placed on a lumber lift. As the layers are removed by the cutoff sawyers, stickers are removed by hand and turned to the lumber-stacking area by conveyor. Stickers may also be placed in staked dollies, trucks, or pallets for transfer to the stackers.



M 142 908

Figure 55.—Kiln-dried lumber stored in a cooling shed on kiln trucks. The doors at the two ends of the transfer track are usually closed.

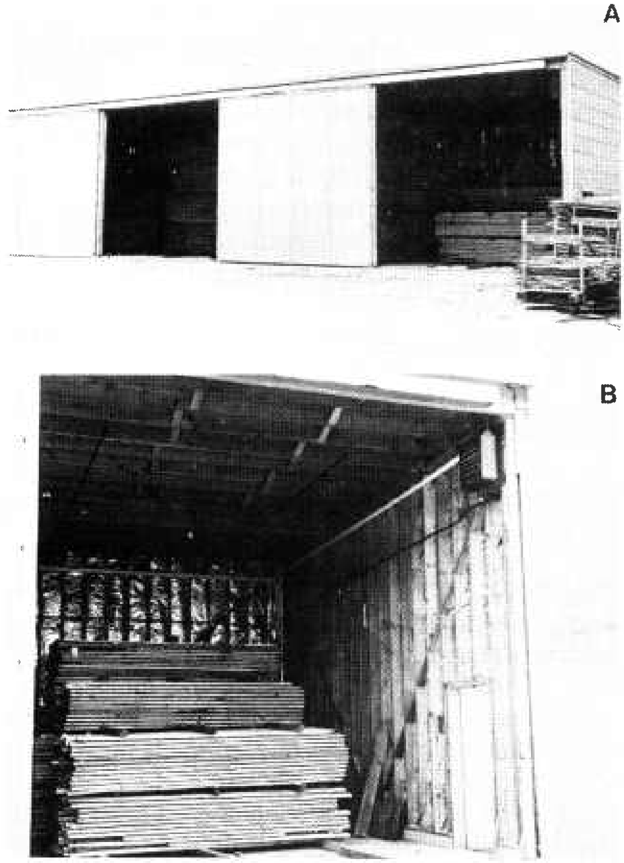
At some factories, forklift trucks serve an air-drying or storage yard (fig. 57), serve package-loaded dry kilns, or load kiln trucks for track-type kilns. At such factories the stickered packages are placed on a roller or chain conveyor feeding a breakdown hoist. The lumber slides off onto a conveyor feeding the sawyers in a rough mill. The stickers are conveyed to the stackers or into a bin pallet. A modification of the system is to unstack the packages at an unstacker station and perhaps do some sorting. Then the bulked packages of dry lumber are moved by conveyor or lift truck to the rough mill or the cutup department of the factory.

Recommendations

Softwoods

1. Green lumber must be stickered for drying if deterioration due to stain and decay is to be avoided.

A



B

M 136 715-9, M 136 715-6

Figure 56.—Kiln-dried lumber stored in a heated shed at a furniture factory. A. Sliding doors provide access for lift trucks with packages of lumber. B. Kiln-dried lumber on stickers stored in an insulated, heated storage shed. Note the unit heater in the shed's upper right-hand corner.

2. Partially dry lumber can be bulked and stored in an open shed if its moisture content is less than 20 percent. If the moisture content is above 20 percent, either sticker for additional drying or plan immediate use, particularly in summer months.

3. Kiln-dried lumber should be bulk piled and stored in a heated shed. Wrapping unit packages with waterproof paper and storing outdoors is satisfactory for temporary storage. Repair torn wrappers.

Hardwoods

1. Green lumber must be stickered for drying. If the stickered units are air dried outdoors, pile covers on high-value lumber are inexpensive. Storage of stickered lumber in an open shed gives better protection than with pile covers.

2. Air-dried lumber can be bulked and stored in an open shed. If the lumber exceeds 20 percent moisture content, stickering and further drying in a conventional air-drying yard or in an open shed is beneficial.

3. Kiln-dried lumber should be stored in a heated cooling shed if the stock is left on sticks pending transport to the rough mill or cutup plant. If the stock is bulked for storage outdoors, protection from weather is essential and the storage period must be limited. Bulked indoor storage should be in an EMC-controlled storage shed.

M 143 998

Figure 57.—Forklift truck removes a wrapped package of lumber to be used at a manufacturing facility.

CHAPTER 10: AT BUILDING SITES—LUMBER HANDLING AND STORAGE

Lumber is not often protected from the weather at construction sites, although in many instances it should be. Lumber is commonly placed on the ground in open areas near the building site as bulked and strapped packages (fig. 58). Supports under such packages are useful to prevent wetting from mud and ground water. At large construction locations, such as apartment buildings, office buildings, and condominiums, the strapped unit packages are delivered to the area on roller bed trucks and rolled off onto the ground (fig. 59). Sometimes these packages are still wrapped with waterproof paper. However, protection is lost if wrappers are torn.

Hazards From Moisture Regain

Prefabricated building parts such as roof trusses are sometimes dumped on the ground at the building site and left lying unprotected (fig. 60). In warm, rainy weather, moisture regain can result in fungal staining. Wetting of the lumber also results in swelling. Subsequent shrinkage of the framing may contribute to structural distortions. Extended storage of lumber over about 20 percent moisture content without drying can allow decay to develop.

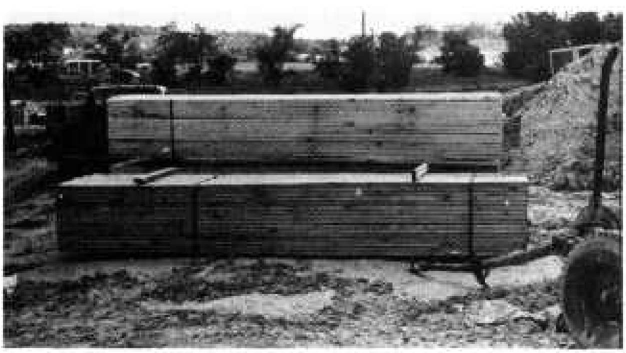


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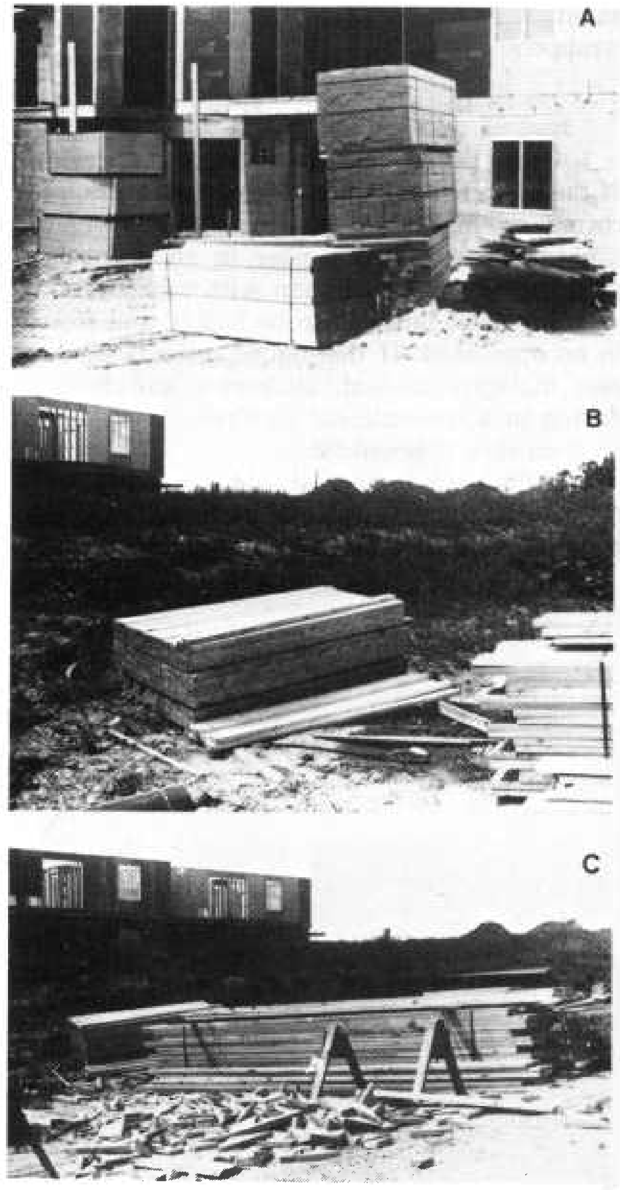
Figure 58.—Strapped packages of lumber at a construction site. Supports under the packages prevent ground contact.



M 142 918, M 142 915, M 142 871

Figure 59.—Construction lumber stored at a building site. A. Strapped unit packages of studs are stored near the building being constructed. No protection is provided against rain, and little protection from ground mud. B. Unit package of studs being broken down and pieces selected for wall framing. C. Joists being cut for installation.

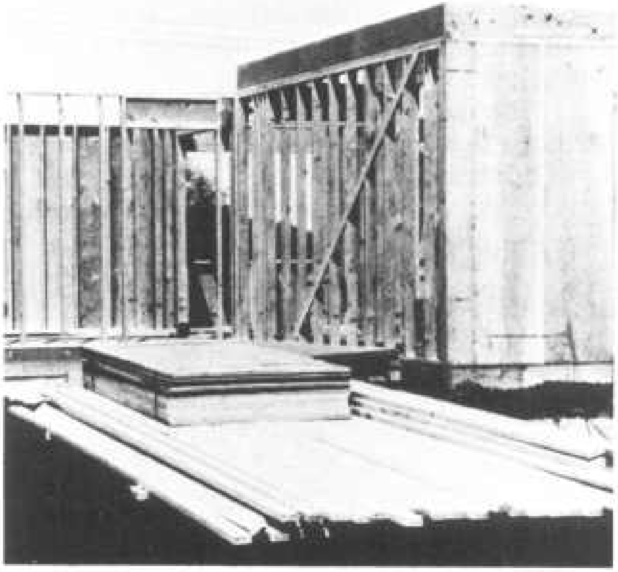
A partially erected building is often exposed to rains that wet the framing and subflooring during the construction period (fig. 61). The effect is not serious because the surface-wetted wood is dried by the sun and warm winds. However, if such wetting is frequent due to construction delays before the building's roof and siding are in place, water-repellent treatment to protect the framing and other exposed wood is beneficial. The water repellent effectively reduces the amount of water absorbed by the wood.

Minimizing The Risks

At small home building sites, the contractor often has most of the building materials delivered after the foundation is completed. These deliveries often include millwork, such as window and door frames, for which swelling or warp can be critical. Such a delivery schedule may be far from ideal in many instances.

M 142 920, M 142 898

Figure 60.—Storage of prefabricated roof trusses at a residential building site. A. Strapped unit of roof trusses placed directly on ground. B. Partially constructed home having ample storage space for roof trusses. Here the problem is the lack of handling equipment to lift and move the heavy packages of roof trusses into the basement area.

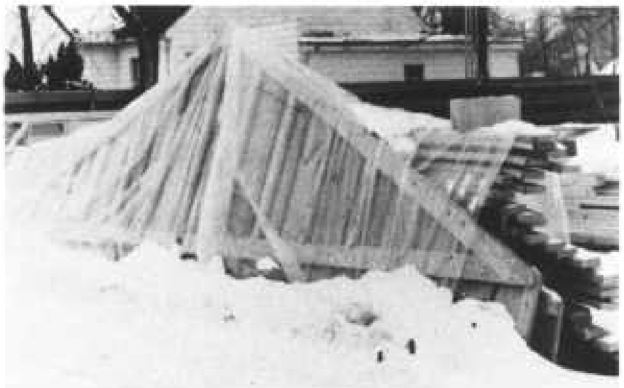


M 142 878

Figure 61.—Partially completed house. Framing and subflooring are exposed to rain. Delivered materials have been placed on supports to keep them from contacting the mud.

So far as possible, deliveries of materials should be arranged to minimize onsite storage time. Delivery of millwork, for instance, might be deferred until the partly completed building offers a source of protection. Once the materials have been delivered construction should proceed rapidly. As soon as the house is completed, exterior surfaces should be primed with paint.

When weather is bad, such as during winter in the northern sections of the country, some protection is afforded by plastic sheeting (fig. 62).



M 142 896

Figure 62.—Prefabricated panels and framing lumber stored at a building site in winter. Plastic tarpaulins are used to provide some protection from snow.

Recommendations

The following recommendations, if followed, should help minimize lumber deterioration at the building site:

(1) Do not unload the lumber in the rain if possible. Delivery by the distributor may need to be delayed.

(2) Try to avoid unloading lumber directly onto the ground. Delivery of unit packages of lumber by roller bed trucks may result in the packages being dumped onto the ground. If the construction project is large enough to warrant use of a lift truck, have stringers laid on the ground to support the packages of lumber.

(3) Protect millwork from the weather and from damage such as glass breakage.

(4) Schedule deliveries to keep exposed-storage times as short as possible.

ADDITIONAL INFORMATION

American Society for Testing and Materials
1965. Standard methods of test for moisture content of wood. ASTM D 2016–65. Philadelphia, Pa.

Brown, N. C., and J. S. Bethel
1958. Lumber—The stages of manufacture from sawmill to consumer. Ed. 2, John Wiley and Sons, N.Y.

Brown, W. H.
1970. Keeping it dry! One of the problems with kiln-dried lumber. Woodwork. Ind. 27(3), p. 27–28.

Canadian Department of Resources and Development
1952. Moisture content changes in seasoned lumber in storage and in transit. Forest Branch Bull. No. 102. Ottawa.

Cech, M. Y.
1966. New treatment to prevent brown stain in white pine. Forest Prod. J. 16(1): 23–27.

Clark, Joe W.
1957. Comparative decay resistance of some common pines, hemlock, spruce, and true fir. Forest Sci. 3(4):314–320.

Comstock, G.L.
1966. Dimensional changes in kiln-dried softwood lumber after surfacing and during storage. U.S. Forest Serv. Res. Note FPL–0144, Forest Prod. Lab., Madison, Wis.

Cuppett, D. G.
1965. How to determine seasoning degrade losses in sawmill lumber yards. U.S. Forest Serv., Res. Note NE–32. Northeast. Forest Exp. Stn., Upper Darby, Pa.

Gill, T. G., D. V. Robertson, and R. J. Miller
1956. Handbook for the preservative treatment of packaged lumber and fabricated wood products for long-term storage. Timber Eng. Co., Washington, D.C.

Glesne, N.
1959. Small sawmill lumber handling. Forest Prod. J. 9(7): 9A–10A.

Hickman, L.
n.d. Protection of lumber for exterior storage. Western Pine Assoc. Res. Note 6.711. Portland, Oreg.

Host, John R.
1969. Economics of producing and handling packaged lumber. U.S. Forest Serv. Res. Pap. INT–66. Forest and Range Exp. Stn., Ogden, Utah.

Hunt, George M. and George A. Garratt
1967. Wood Preservation. Ed. 3. McGraw-Hill, N.Y.

James, William L.
1975. Electric moisture meters for wood. USDA Forest Serv. Gen. Tech. Rep. FPL–6. Forest Prod. Lab., Madison, Wis.

Little, Elbert L., Jr.
1953. Check list of native and naturalized trees of the United States (including Alaska). U.S. Dep. Agric., Agric. Handb. 41, 472 pp. Washington, D.C.

McMillen, John M.
1961. Coatings for the prevention of end checks in logs and lumber. U.S. Forest Prod. Lab. Rep. 1435.

McMillen, John M.
1963. Stresses in wood during drying. U.S. Forest Prod. Lab. Rep. 1652.

Panshin, Alexis J., and Carl DeZeeuw
1970. Textbook of wood technology. Vol. 1, Ed. 3. McGraw-Hill, N.Y.

Rector, Ray M.
1972. Dry storage operations. S. Lumberman 224(2782) p. 21.

Rice, W. W.
1964. Learn profitable lumber stacking. Hitchcock's Woodworking Dig. 66 (2): 44–46.

Rietz, Raymond C., and Rufus H. Page
1971. Air drying of lumber: A guide to industry practices. U.S. Dep. Agric., Agric. Handb. 402. 110 pp.

U.S. Department of Commerce
1970. American softwood lumber standard. National Business Standard. Voluntary Product Stand. PS 20–70. 26 pp. Washington, D.C.

U.S. Department of Defense
1968. Lumber: Unitizing and Loading of. Military Specification MIL–L–14362C.

U.S. Forest Products Laboratory
1967. Factors influencing decay of untreated wood. USDA Forest Serv. Res. Note FPL–0154. Madison, Wis.

U.S. Forest Products Laboratory
1972. Methods of controlling humidity in woodworking plants. USDA Forest Serv. Res. Note FPL-0218. Madison, Wis.

U.S. Forest Products Laboratory
1974. Wood Handbook. U.S. Dep. Agric., Agric Handb. 72, Rev. 528 pp. illus.

GLOSSARY

Airdried.—The dried condition of lumber, usually 12 to 20 percent moisture content, reached by exposing it for a sufficient period to the prevailing atmospheric conditions.

Air drying.—The process of drying green lumber by exposure to prevailing atmospheric conditions.

Board.—1. Yard lumber which is less than 2 inches thick and which is 2 or more inches wide. 2. A term usually applied to 1-inch-thick lumber of all widths and lengths.

Bolster.—A square piece of wood usually 4 by 4 inches in cross section, placed between stickered packages of lumber to provide space for the entry and exit of the forks of a lift truck.

Bound water.—Syn: Adsorbed moisture, hygroscopic moisture, imbibed moisture. Moisture that is intimately associated with the finer wood elements of the cell wall by adsorption and held with sufficient force to reduce the vapor pressure.

Bright.—Syn: Unstained. The term is applied to wood that is free from discolorations. The term "bright sapwood" is sometimes used to describe sapwood of natural color or in which the stain or discoloration can be removed by surfacing to standard thickness.

Bulk pile.—Syn: Solid pile. The stacking of lumber onto dollies or pallets, into unit packages, or into bins without vertical spaces or stickers between the layers for air circulation.

Bunk, carrier.—Specially designed wood beams on which parcels of lumber or other wood items are placed, enabling the straddle truck or carrier to pick the unit up for transport.

Casehardening.—A condition of stress and set in dry wood in which the outer fibers are under compressive stress and the inner fibers under tensile stress, the stresses persisting when the wood is uniformly dry.

Cell.—In wood anatomy, a general term for the minute units of wood structure having distinct cell walls and cell cavities. Includes wood fibers, vessel segments, and other elements of diverse structure and function.

Check.—Syn: Cracks, drying check, checking. A separation of the wood fibers within or on a log, timber, lumber, or other wood product resulting from tension stresses set up during drying, usually the early stages of drying.

Circulation, air.—In drying wood, the movement of air by either natural or mechanical means.

Forced circulation.—The movement of air by mechanical means.

Conditioning.—1. A storage procedure that reduces differences in moisture concentration within lumber, thereby reducing the drying stresses. This usually follows the final stage of drying. 2. Adjustment of the moisture content of wood to that which is expected to prevail under the lumber's condition of use.

Correction, temperature.—An adjustment of the readings of the resistance-type electrical moisture meter to compensate for changes in the temperature of the wood.

Decay.—Syn: Rot, dote. The decomposition of wood substance by fungi.

Advanced (or typical) decay.—The older stage of decay in which the destruction is readily recognized because the wood has become punky, soft and spongy, stringy, ring-shaked, pitted, or crumbly. Decided discoloration or bleaching of the rotted wood is often apparent.

Incipient decay.—The early stage of decay which has not proceeded far enough to soften or otherwise perceptibly impair the hardness of the wood. It is usually accompanied by a slight discoloration or bleaching of the wood.

Defect.—Any irregularity or imperfection in a tree, log, bolt, or lumber which reduces its volume or quality or lowers its durability, strength, or utility value. Defects may result from knots and other growth conditions and abnormalities; from insect or fungus attack; from milling, drying, machining, or other processing procedures.

Degrade.—A loss in adjudged quality which drops lumber to a lower commercial grade.

Density.—The weight of a body per unit volume, usually expressed in pounds per cubic foot or grams per cubic centimeter. In wood, density changes in terms of moisture content.

Dipping.—Process of submerging lumber in a vat containing fungicides or other chemicals to prevent stain or decay, to impart water repellency, or to color the product.

Discoloration.—Syn: Stain. Change in the color of lumber due to fungal and chemical stains, weathering, or heat treatment.

Drying.—Syn: Seasoning, curing. The process of removing moisture from wood to improve its serviceability.

Electrodes.—Devices made of electrically conducting material, usually steel pins, for connecting wood into the electric circuit of an electric moisture meter.

Insulated electrodes.—Special electrodes, used with resistance-type electric moisture meters, that are coated with an insulating material to limit or control the point of contact between the electrode and the wood.

EMC.—see "equilibrium moisture content."

Endloader.—A carrier vehicle for bulked lumber, so named because the lift mechanism grasps lumber packages from the end.

Equilibrium moisture content.—Abbr: EMC. The moisture content at which a material neither gains nor loses moisture when surrounded by air at a given relative humidity and temperature.

Extractives.—Substances in wood, not an integral part of the cellular structure, that can be removed by solution in hot or cold water, ether, benzene, or other solvents which do not react chemically with wood substances.

Fiber saturation point.—Abbr: FSP. The stage in the drying or wetting of wood at which the cell walls are saturated with water (bound water) and the cell cavities are free of water. It is usually considered to be approximately 30 percent moisture content, based on the weight of the wood when ovendry.

Forkloader.—Syn: Forklift truck. A vehicle that handles and transports lumber, so named because of its power-elevated forks.

Foundation, open.—In air drying, structural supports for the pile designed to facilitate air circulation under the pile.

Free water.—Syn: Capillary water. Water that is held in the cell cavity of the wood.

Fungi.—Low forms of plants consisting mostly of microscopic threads that traverse wood in all directions, coverting the wood to materials they use for their own growth. Fungi cause decay and staining of lumber.

Grade.—A classification or designation of the quality of manufactured pieces of wood or of logs and trees.

Gantry.—A framework supported at the ends so that it spans a distance. Used to support a traveling crane, or for other purposes.

Grain.—The direction, size, arrangement, appearance, or quality of the fibers in lumber. When used with qualifying adjectives the term designates the orientation of fibers and/or growth rings in lumber.

Cross grain.—Lumber in which the fibers deviate from a line parallel to the sides of the piece. Cross grain may be either diagonal or spiral grain or a combination of the two.

Diagonal grain.—Lumber in which the annual rings are at an angle with the axis of a piece as a result of sawing at an angle with the bark of the log. A form of cross grain.

Edge grain.—Syn: Comb grain, edge-sawn, quarter grain, quarter-sawed, rift grain, rift sawed, stripe grain, vertical grain. Lumber that has been sawed or split so the wide surfaces extend approximately at right angles to the annual growth rings, exposing the radial surface. Lumber is considered edge-grained when the rings form an angle of 45° to 90° with the wide surface of the piece.

End grain.—The ends of wood pieces that are cut perpendicular to the fiber direction.

Flat grain.—Syn: Flatsawn, plain grain, plain-sawed, slash grain, tangential cut.

Lumber sawed or split in a plane approximately perpendicular to the radius of the log. Lumber is considered flat-grained when the annual growth rings make an angle of less than 45° with the surface of the piece.

Straight grain.—Lumber in which the fibers and other longitudinal elements run parallel to the axis of a piece.

Green chain.—A conveyor for moving green lumber at sawmills, generally from the saw to a sorting or stacking area.

Green lumber.—1. In general, lumber just as cut from freshly felled trees. 2. In accordance with the American Softwood Lumber Standard, lumber above 19 percent moisture content.

Hardwoods.—Generally, one of the botanical groups of trees that have broad leaves—e.g., oak, elm, basswood—in contrast to the conifers or softwoods. Also, the wood produced from such trees. (The term has no reference to the actual hardness of the wood.)

Heartwood.—The inner layers of wood in the growing trees that have ceased to contain living cells and in which the reserve materials, e.g., starch, have been removed or converted into resinous substances. It is generally darker in color than sapwood, though the two are not always clearly differentiated.

High-temperature drying.—In kiln-drying wood, use of dry-bulb temperatures of 212° F or more.

Humidity, absolute.—The weight of water vapor per unit volume of air at a specified temperature and pressure.

Relative humidity.—Ratio of actual to saturation vapor pressure of water in air at a given temperature and pressure. Always expressed as a percentage.

Hygrometer.—Any of several instruments for measuring atmospheric humidity.

Hygroscopicity.—The property of a substance, such as wood, that permits it to absorb and retain moisture readily.

Infection.—The invasion of wood by fungi or other micro-organisms.

Infestation.—The establishment of insects or other animals in wood.

Kiln charge.—Lumber properly packaged and of suitable quantity for insertion in a dry kiln.

Kiln drying.—The process of drying lumber in a closed chamber in which the temperature and relative humidity of the circulated air can be controlled.

Kraft.—A tough brown paper made from sulfite pulp. When faced with a waterproof film, this paper is often used for wrapping lumber packages.

Lumber.—The product of the sawmill and planing mill not further manufactured than by sawing, resawing, passing lengthwise through a standard planing machine, cross cutting to length, and matching.

Lumber storage room.—Usually a room maintained within specified equilibrium moisture content limits so that lumber stored in it will not gain or lose moisture beyond fixed limits.

Meter, electric moisture.—An instrument used for rapid determination of the moisture content in wood by electrical means.

Microwave heating.—Heating a material by using electromagnetic energy alternating at a frequency from 915 megahertz to 22,125 megahertz.

Moisture content of wood.—Weight of the water contained in the wood, expressed as a percentage of the weight of the ovendry wood.

Average moisture content.—1. The percentage moisture content of a single sample of wood which is representative of a larger piece. 2. The average of several moisture content determinations taken of samples from a single piece or lot of wood products.

Core moisture content.—The moisture content of the inner portion of a moisture content section which remains after a shell one-fourth the thickness of the section has been removed.

Determination of moisture content.—The testing of lumber to determine the amount of moisture present. This is usually expressed in terms of percent of the ovendry weight.

Final moisture content.—The average moisture content of the wood at the end of the drying process.

Green moisture content.—The moisture content of wood in the living tree.

Initial moisture content.—The moisture content of the wood at the start of kiln-drying or air-drying.

Shell moisture content.—The moisture content of the outer one-fourth of the thickness of a moisture section.

Moisture distribution.—The variation of moisture content throughout a piece of wood, usually from face to face but sometimes from end to end, or from edge to edge.

Moisture gradient.—A condition existing during drying in which the moisture content uniformly varies from the more moist inside toward the drier surface of a piece of wood. Also a term used specifically to denote the slope of the moisture content distribution curve.

Moisture range.—The difference in moisture content between the driest and wettest boards in a shipment or lot, or between representative samples of the lot.

Mold.—A fungus growth on lumber at or near the surface and, therefore, not typically resulting in deep discolorations.

Ovendry.—A term used to describe wood that has been dried in a ventilated oven at 100° to 105° C until there is no further loss in weight.

Pervious wood.—A wood through which moisture moves readily.

Pile.—Syn: Stack, rack. Stacking lumber layer by layer, separated by stickers or self-stickering, on a supporting foundation (hand stacking) or placing stickered unit packages by lift truck or crane, one above the other on a foundation and separated by bolsters.

Pile roof.—Syn: Pile cover, cover boards, stack cover. A cover on top of the pile to protect the upper layers from exposure to the degrading influences of sun, rain, and snow. The sides and ends of the roof may project beyond the pile top provide added protection.

Psychrometer.—A type of hygrometer which measures relative humidity by subjecting wet-bulb and dry-bulb thermometers to a stream of moving air. The difference in readings, interpreted by means of a chart supplied with the instrument, yields relative humidity.

Rot.—See Decay.

Sap.—The moisture in green wood, containing nutrients and other chemicals in solution.

Sapwood.—The outer layers of the stem that in the living tree contain living cells and reserve materials, e.g. starch. The sapwood is generally lighter in color than the heartwood.

Shrinkage.—The contraction of wood fibers caused by drying below the fiber saturation point. Shrinkage—radial, tangential, and volumetric—is usually expressed as a percentage of the dimension of the wood when green.

Sideloader.—A carrier vehicle similar to a forklift truck.

Softwoods.—Generally, one of the botanical groups of trees that, in most cases, have needlelike to scalelike leaves; the conifers; also, the wood produced by such trees. (The term has no reference to the actual hardness of the wood.)

Specific gravity.—The ratio of the ovendry weight of a piece of wood to the weight of an equal volume of water at 4° C (39° F). Specific gravity of wood is usually based on the green volume and ovendry weight.

Stack.—1. To make a pile on a suitable foundation by hand-placing layers of lumber on stickers, or similar stock (self-stickered). 2. To construct by hand or with mechanical equipment, unit packages of the item to be dried, by separating layers of the stock with stickers.

Stacking rack.—Syn: Stacking jig, stacking stall. In hand building stickered unit packages of lumber, guides are provided to produce good sticker alinement and square sides.

Stain.—A discoloration in wood that may be caused by micro-organisms, metal, or chemicals. The term also applies to materials used to impart color to wood.

Sticker.—Syn: Crosser, strip, piling strip, stick. A wood strip placed between courses of lumber in a pile or unit package and at right angles to the long axis of the stock, to permit air to circulate between the layers.

Sticker alinement.—The placing of stickers in a pile, package, or truckload of lumber so that they form vertical tiers.

Sticker spacing.—The distance between stickers measured from center to center.

Straddle carrier.—A transport vehicle for lumber, so named because its arched frame straddles the lumber package being transported.

Stress, drying.—An internal force, exerted by either of two adjacent parts of a piece of wood upon the other during drying, caused by uneven drying and shrinking, and influenced by set.

Compressive stress.—The stress that develops in the interior region of wood during the early stages of drying, caused by the shrinking of the outer shell; also the stress in the outer layer at a later point in drying caused by the shrinking of the interior.

Tensile stress.—The stress that develops in the outer layers of wood during the early stages of drying when these layers are trying to shrink but are restrained by the still-wet interior region; also the stress later in drying as the interior layers try to shrink and are restrained by the outer shell.

Stresses, relief of.—The elimination of normal drying stresses as a final step in drying by applying the appropriate conditioning treatment.

Swelling.—Increase in the dimensions of wood due to increased moisture content. Swelling occurs tangentially, radially, and, to a lesser extent, longitudinally.

Temperature, dry-bulb.—Temperature of air as indicated by a standard thermometer or comparable temperature-sensing device.

Temperature, wet-bulb.—The temperature indicated by any temperature-measuring device, the sensitive element of which is covered by a smooth, clean, soft, water-saturated cloth (wet-bulb wick).

Temperature, wet-bulb depression.—The difference in the readings of the wet- and dry-bulb thermometers.

Tier.—In air drying or kiln drying, lumber or other wood products stacked in vertical alinement. Usually refers to sticker alinement from layer to layer.

Thermostat.—A device for automatically regulating temperature.

Thermostat, differential.—A device which keeps the temperature of a building a fixed number of degrees above outdoors temperature.

Unitized packages. — Syn: Unit packages. Bundles of lumber bound as units with steel strapping or by other means. Lumber is usually packaged in this way to facilitate mechanical handling.

Warp.—Distortion in lumber causing departure from its original plane, usually developed during drying. Warp includes cup, bow, crook, twist, and kinks, or any combination thereof.

Water, bound (adsorbed, hygroscopic).— Moisture that is bound by adsorption forces within the cell wall; that is, the water in wood below the fiber saturation point.

Free water.—Moisture that is held in the cell cavities of the wood, not bound in the cell wall.

Weathering.—The mechanical or chemical disintegration and discoloration of the surface of lumber which is caused by exposure to light, the action of dust and sand carried by winds, and the alternate shrinking and swelling of the surface fibers with continual variation in moisture content brought by changes in the atmosphere. Weathering does not include decay.

Wood.—Syn: Xylem. The tissues of the stem, branches, and roots of a woody plant lying between the pith and cambium, serving for water conduction, mechanical strength, and food storage, and characterized by the presence of tracheids or vessels.

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