Chapter 10
Log and Lumber Storage

Kiln drying is only one step in the harvesting, handling, and processing of wood products. The best results can be obtained in kiln drying, therefore, when adequate attention is paid to related phases of wood processing. Although a dry kiln operator may have no responsibility for these related phases, knowledge of them is required to understand how they interact with drying. Problems that occur in drying, or that are erroneously blamed on drying, are sometimes related to the methods used to store logs and lumber before drying and those used to store kiln-dried lumber and finished products.

Logs and lumber go through various storage and transport periods while moving through the processing sequence. Log storage and transit really begin when the tree is felled and continue until the log is sawed into lumber. Similarly, lumber storage and transit include the time between sawing and drying and the time between drying and end use. The moisture content of lumber should be controlled in storage and transit. Large increases in moisture content during storage may make lumber unsuitable or out of specifications for many uses, cause lumber to warp, or cause the development of stain or decay. Large decreases in moisture content may cause checks and warp to occur or make machining and fastening difficult.

Chapter 10 was revised by William T. Simpson, Supervisory Research Forest Products Technologist, and James C. Ward, Research Forest Products Technologist.

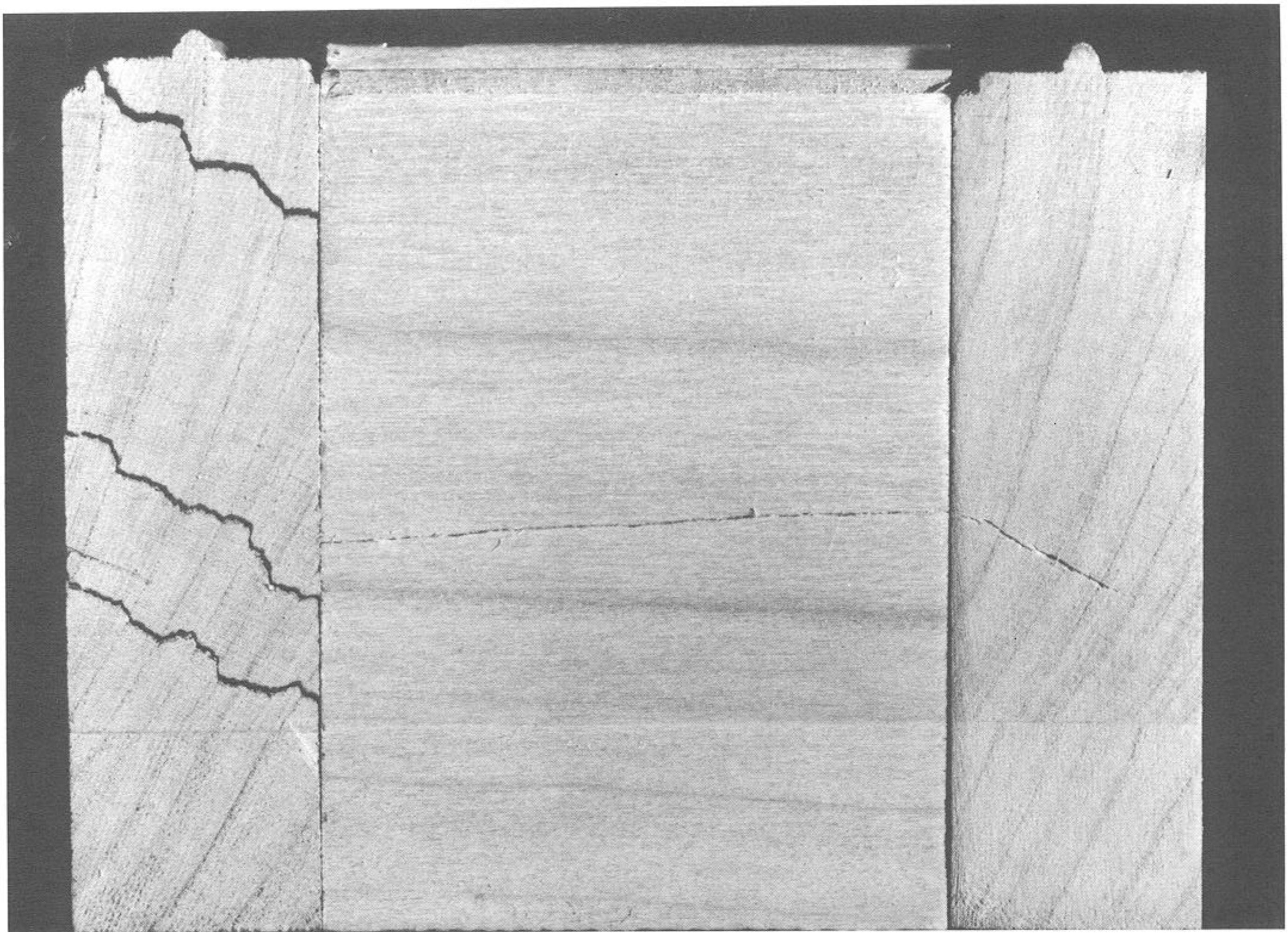
Figure 10-1—Splits in black cherry millwork from lumber that was sawn from a wind-damaged tree. (M88 0170)

Log Storage

The source of some lumber drying problems can be traced to changes in the wood that began in the tree just before or during the timber harvesting operation. Logs that have been salvaged from forests that were damaged by hurricanes or tornadoes may yield lumber that is likely to split during drying and subsequent machining (fig. 10-1). Felling the tree with a clipping or shearing machine can initiate radial splits and ring failures in the end of the log, which may lengthen considerably with lumber drying.

After felling, the main stem of the tree is detached from the crown, except when transpiration drying is desired. At most commercial logging operations in North America, the main stem of the felled tree is either left full length (tree-length log) or cut (bucked) into shorter logs with lengths that correspond to lengths of the intended lumber. Tree-length and standard-length logs should be sawed into lumber as soon as possible after felling, especially during warm weather. However, prompt sawing of logs is not always possible because of log transportation difficulties or the economic need to stockpile logs at the sawmill. This section suggests methods for reducing drying defects that result from prolonged storage of logs.

Logs need to be stored under conditions that will minimize defects associated with shrinkage, mainly end checking, and attacks by fungi, bacteria, and insects. Defects associated with shrinkage are minimal during periods of cloudy, wet weather and low temperatures. Fungi and insects are inactive at temperatures below 32 °F or under conditions of wet storage with low levels of oxygen. On the other hand, many types of bacteria can grow in wood under wet, anaerobic conditions, but not at subfreezing temperatures. There are two general methods for storing logs: dry storage and wet storage. Precautions must be taken with each storage method to ensure defect-free lumber.

Dry Storage

Most sawlogs in North America are stored under dry conditions with the bark intact. Occasionally, kiln

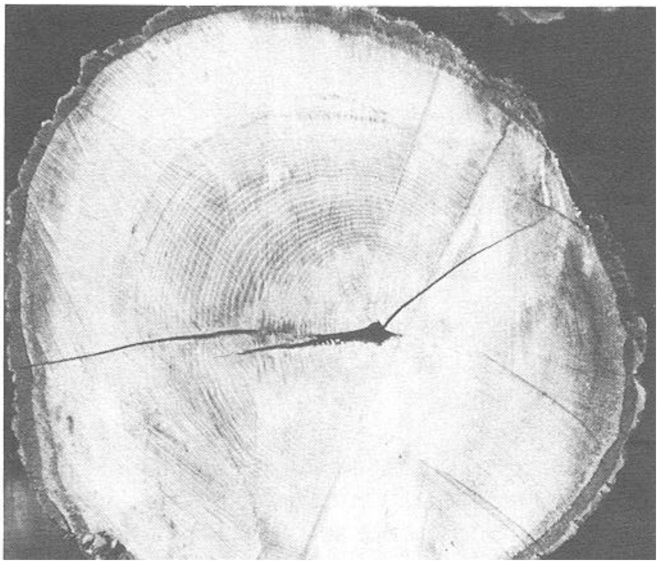

Figure 10-2—Splits in the end of a red oak log resulting from ruptures caused by an imbalance in tree growth stresses after felling. (M88 0169)

operators may encounter logs from diseased or insect-damaged trees where most or all of the bark has fallen off.

Because lumber from logs subjected to transpiration drying may show up in the drying operation, this subject will be discussed as a part of dry storage.

Logs With Bark

Most lumber that needs to be kiln dried will be sawed from logs that were stored on land with the bark intact. If the logs do not contain wetwood, then any lumber drying problems will usually be associated with serious end checking of the logs, insect attack, and sapwood stains.

End checks can occur in all species of logs and are more pronounced in the denser hardwoods. Deep end splits can sometimes occur in the log ends, but these are the result of residual tree growth stresses that become unbalanced after the log is bucked, and they **can**not be prevented by measures for reducing end checking (fig. 10-2). End checks are minimized by keeping the log ends in cool, moist, and shaded locations. If the logs are valuable and cannot be sawed into lumber within a short time, then the ends should be coated with a suitable end-sealing compound (fig. 10-3). The end coating should be thick enough to cover all wood pores, cracks, and irregularities on the surface, yet viscous enough so that it neither cracks nor "sags" excessively. It is good practice to treat the log ends with chemical fungicide before end coating to prevent sapwood staining.

Figure 10-3—Oak logs 8 months after they were cut and the ends treated with preservatives. All but two logs were also end sealed; no end checking developed in these logs. The preservative treatment of the unsealed logs (topmost and lower left) was of little value once the barrier of the surface-treated wood was ruptured by seasoning checks. (M 81288).

Figure 10-4—Sweetgum logs with heavy sapwood stain at the ends. Under conditions favorable for staining, end stain may appear within 2 weeks and the discoloration may penetrate into the log as rapidly as 1 ft per month. (M 38236)

Fungal blue stain will develop in the sapwood of exposed log ends and debarked surfaces during warm weather within 2 weeks after the tree is felled (fig. 10-4). Applying or spraying chemical fungicides on all exposed log surfaces will provide adequate protection if the wood does not check or split. These chemically treated areas should then be coated with a log end-sealing compound to prevent checking and the opening of untreated inner wood to fungal attack. Since wood-boring insects can carry spores and hyphae of sapwood-staining fungi into the logs, even through areas with attached bark, logs may need to be sprayed with a mixture of chemicals that control both insects and fungi.

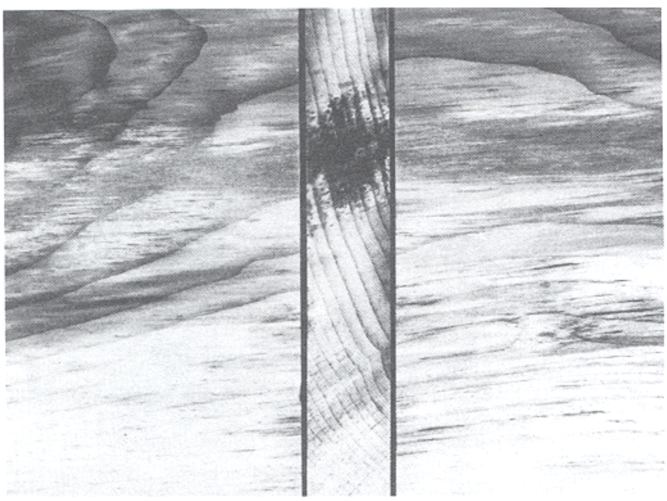

Figure 10-5—Fungal blue stain and chemical brown stain in sapwood and wetwood of a kiln-dried eastern white pine board sawed from a log stored during early spring on a log deck in the forest. (M88 0168)

Chemical changes will occur in moist sapwood during log storage that may cause chemical discolorations during subsequent drying. These discolorations can vary from gray, yellow, and pinkish to deep brown. Chemical stains are likely to occur in lumber from logs that were stored under moist, shaded conditions for the purpose of preventing end checking. Brown stain and blue stain will develop together in lumber from logs that were stored in the forest or similarly shaded locations (fig. 10-5). Prompt sawing of freshly cut logs is the easiest way to control chemical sapwood stains because treating the logs with fungicides that prevent blue stain will not be effective.

The most effective method for controlling chemical stains is to freeze freshly cut sapwood. This can be done economically only by sawing winter-cut logs in northern climates during cold weather and using proper kiln-drying conditions. At some northern mills, short logs of birch, maple, and pine that are to be sawed into specialty products are frozen to ensure white color. The short logs from winter-cut timber are placed in ground depressions and sprayed with water to form a coating of ice. The frozen log decks are covered with sawdust, wood shavings, or other available insulating material so that the wood remains frozen well into the summer months.

Debarked Logs

Most logs intended for lumber are debarked on the day of sawing; the problems associated with the storing of debarked logs are thus not carried over into the drying operation. Logs intended for poles and pulpwood are debarked soon after felling to reduce losses from insect borers and decay and to lower sapwood moisture content. The disadvantages of early debarking are extensive surface checking and end splitting. Sapwood staining can also be quite substantial.

Transpiration Drying

After a tree is cut or girdled, the main stem will lose more moisture if the crown is left attached than if the stem is bucked into logs. This method of drying is called transpiration drying. Teak trees in the forests of southeast Asia are girdled and left standing for at least a year before felling so that the logs will be light enough to float to the sawmills via the river systems. In North America, there is some interest in transpiration drying because of its potential application to wood energy production. If tree-length logs are stored in the woods for a short time, leaving the crown attached also seems to provide some protection from ambrosia beetle attack.

The amount of moisture lost depends upon viable foliage in the crown and the amount of sapwood in the stem. Softwoods will undergo transpiration drying throughout the year if winter temperatures are not below freezing, but deciduous hardwoods can only be dried during the summer when the leaves are present. During transpiration drying, oak logs with narrow rings of sapwood will not lose much more than 10 percent moisture content whereas sweetgum and yellow-poplar, species with wide bands of sapwood, can lose over 30 percent moisture content. The maximum moisture loss from hardwoods will occur in 1 to 2 weeks, but this period will usually be longer for conifers. On the west coast of Washington, Douglas-fir will undergo a maximum moisture loss of 30 to 50 percent in about 90 days.

In South Africa and Holland, Visser and Vermaas (1986) found that transpiration drying of both hardwood and softwood trees resulted in total energy savings because of easier handling of green lumber and reduced kiln-drying times. A mass loss of 30 percent after 1 month of transpirational drying resulted in an energy saving of approximately 55 percent in the kiln, while a maas loss of 10 percent after 1 week of drying resulted in an energy saving of approximately 25 percent. These authors also noted that the sudden drop in moisture content with transpirational drying helps to suppress the development of blue stain in South African timber.

Wet Storage

When logs must be stored for a long time at temperatures above freezing, it is desirable (when possible) to keep them soaking wet. This prevents drying and checking and inhibits attacks by insects and sapwood-stain fungi. However, some types of bacteria are not inhibited, and the wood may become predisposed to developing chemical stains.

Pond Storage

Pond storage includes logs that are stored in lakes, rivers, and salt water estuaries as well as mill ponds. Although pond storage was once a regular practice, it is now rare in North American mills. Nevertheless, a dry kiln operator may receive lumber from logs that have been submerged in water. Considerable volumes of logs are rafted from woods to mills along the coast of the Pacific Northwest. Foreign lumber is frequently sawed from pond-stored logs, and some lumber is salvaged from old submerged logs and timber.

Pond-stored logs are usually banded together to increase the log-holding capacity of the pond and to prevent wetwood (sinker) logs from sinking to the bottom (fig. 10-6). Some logs in the bundle will be above water and are subject to insect attack, stain, and decay. Until recent Environmental Protection Agency (EPA)

Figure 10-6—Logs banded together in a log pond in northern California. Some logs are completely submerged while others are entirely out of the water. (M88 0167)

Figure 10-7—Water sprinkling of decked hardwood logs. A fine mist effectively covers log surfaces and ends. (M 144876).

prohibitions, these types of damage were controlled for several weeks by spraying the exposed parts of the log bundles with insecticides and fungicides. Logs rafted and stored in ocean water are also subject to attack by marine borers and salt water micro-organisms.

Most damage to submerged logs can be traced to growth of bacteria in the sapwood. In softwoods, pit membranes in the sapwood are destroyed so that the wood becomes more permeable, and the wood will dry somewhat faster. However, the lumber will also overabsorb chemicals used to stabilize and preserve the wood, and finishing can be a problem. Honeycomb, ring failure, and collapse are likely to develop in lumber from logs and timber that have been submerged for over a year. Chemical brown stain has been a frequent problem with the drying of ponderosa pine and sugar pine lumber from pond-stored logs. In rare situations, the iron content of the water is unusually high, and woods gradually acquire a grayish color because of an iron-tannate reaction.

Water Sprinkling

Where log decking is a preferred manner of storage, sprinkling the decks with water provides an effective method for reducing checking, sapwood stains, and decay when temperatures are above freezing (fig. 10-7). Sprinkling will not provide certain protection from insect attack although it tends to be more effective than dry log storage in some localities. Nevertheless, the beneficial effects of using water sprays during warm weather have been reported for western softwoods and eastern hardwoods, especially in the South.

For sprinkling to be effective, the log ends and exposed, debarked wood surfaces must be kept continuously wet during the entire period of storage. This prevents shrinkage and checking of the exposed wood. Water sprays reduce temperatures in and around the log decks, but the reduction of oxygen from continuous soaking of the wood is the major deterrent to sapwood-staining and decay fungi.

Bacteria and slime molds, less common in dry-stored logs, may develop extensively in sprayed logs. Bacteria can be responsible for chemical stains and increased porosity in lumber from wet-stored logs, but these problems are greater in pond-stored logs than in logs stored on sprinkled decks. Bacterial problems with sprinkling can be prevented by not drawing the water from stagnant reservoirs where drainage from the wetted logs is returned and recycled. Under water sprays, bacteria from wetwood zones in the log may extend their growth into the sapwood, which will then develop brown stains during drying.

Water sprinkling requires constant maintenance to guard against clogging of hoses and spray nozzles from debris and slime in the water. Adequate drainage must be provided in the log yard to prevent handling problems with forklift vehicles.

Effects of Climate On Lumber Storage

Relative humidity, air temperature, and rainfall of the storage region are the main factors that determine the rate and amount of moisture content change in the lumber and the procedures necessary to protect lumber stored outdoors or in unheated sheds.

Relative Humidity

Relative humidity has a much greater effect on wood equilibrium moisture content (EMC) than does temperature (table 1-6). The more humid a region, the more moisture the lumber will absorb and the more rapid the rate of absorption. Seasonal estimates of the average wood EMC for a region can be helpful when trying to control moisture change in lumber stored outdoors.

Storage methods to retain low moisture content in kiln-dried lumber will differ between humid regions like the gulf coast and dry regions like the Southwest. Likewise, storage requirements may differ from month to month in regions where average relative humidity varies considerably with the season, such as inland California.

Temperature

Air temperature has a minor effect on EMC (table 1-6), but its main effect is on the rate of moisture content change. Moisture content changes occur faster at warm temperatures than at cool temperatures. Therefore, if lumber has to be stored at EMC conditions different than the moisture content of the lumber, the temperature should be taken into consideration. Some moisture equalization can be effected in storage; the warmer the temperature, the faster the rate of equalization.

Warm temperatures also increase the hazard of fungal infection in stored lumber. All lumber is practically immune to fungal infection below 30 °F. When green lumber is solid piled, mold, stain, and decay fungi will grow at temperatures from 40°F to 100 °F with the rate of attack increasing rapidly at higher temperatures in this range. Dipping or spraying freshly sawed lumber with an approved fungicide reduces the chance of fungal growth.

Rainfall

When lumber is protected while stored outdoors, rainfall does not greatly affect its moisture content. Solid-piled green lumber is often unprotected while temporarily stored outdoors before stacking for air 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 to prevent leaching of the chemicals.

Solid-piled dry lumber should be protected from rain, preferably in storage sheds. Redrying solid-piled lumber that has been wetted by rain is difficult. Solid-piled lumber that has been thoroughly soaked requires stickering before it is redried, and redrying may result in drying losses. Also, if rain increases the moisture content of the lumber to 20 percent or more, fungi may grow and cause stain and decay.

Average Equilibrium Moisture Content Conditions by Region and Season

Estimated monthly wood EMC conditions at various locations throughout the United States are given in table 10-1. They represent average values from climatological data and thus may vary from year to year. Also, EMC conditions are often influenced by microclimates within regions, so more localized values can be determined from local weather stations.

The Southwestern States are generally the driest regions, and the coastal regions, the wettest. During summer months, the states west of the Mississippi River are much drier than during the spring months. East of the Mississippi, the summer months are slightly more humid than the spring. Fall is usually more humid than spring or summer in most of the United States, and winter is generally even more humid.

Lumber Storage

Lumber storage can be classified into five major types: outdoors, open shed, closed and unheated ‘shed, closed and heated shed, and conditioned shed. The desirable type of storage depends on the moisture content of the lumber and the weather conditions during storage.

Outdoor Storage

Lumber is often stored outdoors because shed or warehouse facilities are not available. Unprotected outdoor storage is satisfactory for small timbers and lumber for less exacting end uses, although precautions to prevent stain, decay, and insect infestation may be necessary.

Kiln-dried lumber stored outdoors without protection will have a rapid increase in moisture content.

Protection against rain is more important for solid-piled lumber than for stickered lumber because rainwater cannot evaporate readily from solid piles. Furthermore, rain that penetrates solid-piled lumber may in time increase the moisture content enough that stain and decay can grow. Storage areas should be open, well drained, and kept free of weeds and debris that restrict air movement along the surface of the ground, harbor fungi and insects, and create a hazard when dry. The ground, particularly along runways for lumber-handling equipment, should be surfaced with gravel, crushed rock, asphalt, or concrete. Surfacing or paving permits vehicles to operate efficiently in all weather and restricts weed growth. The method of piling for outdoor storage depends on the species involved, its moisture content, and the degree of drying desired during the storage period.

Green Lumber

Green lumber dries during storage. To reduce drying defects and kiln-drying time as much as possible, the principles of good air-drying practice should be followed (Reitz and Page 1971). Briefly, these include (1) stacking the lumber properly with dry stickers spaced correctly so as to minimize warp, (2) providing good pile foundations, (3) laying out the yard with adequate spacing between piles and rows of piles, and (4) providing good pile roofs.

If green lumber must be stored in solid piles for more than 24 h in warm weather, it should be dipped in an approved antistain solution. Green lumber properly stacked and protected on a good site will lose moisture rapidly with a minimum of defects and can remain outdoors indefinitely without excessive deterioration.

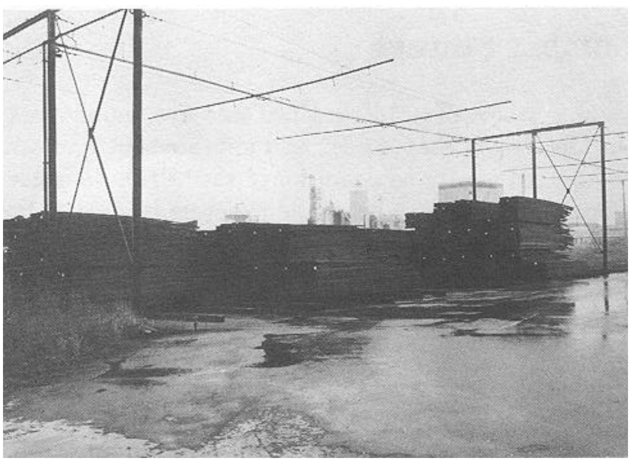

Figure 10-8—High-grade Douglas-fir stored temporarily under water spray while the mill accumulates enough for a full kiln load. (M88 0165)

Sometimes high-quality green lumber is stored temporarily under water spray (fig. 10-8), while lumber is being accumulated for a kiln load.

Partly Dried Lumber

If the moisture content of lumber is above 20 percent or if further drying is desired, the lumber can be stored like green lumber. Lumber that is below 20 percent moisture content can be solid piled if no additional drying is desired. The piles should be fully protected against infiltration of rainwater. Water that penetrates a solid lumber pile is not readily evaporated and is likely to cause stain or decay. Lumber surfaces that are alternately wetted and dried are likely to check.

Kiln-Dried Lumber

Lumber kiln dried to a moisture content of 12 percent or less can be stored outdoors in dry weather in stickered or solid piles for a short time. Extended storage will result in excessive moisture regain. Figure 10-9 shows the change in moisture content of southern pine during yard and shed storage in solid piles in inland Louisiana. If the lumber had been piled on stickers, its moisture content would have risen to the maximum of about 13-1/2 percent in a much shorter time. During the warm, dry season in areas such as the arid Southwest and in parts of Idaho, Montana, Nevada, Oregon, and Washington, the outside storage period can be extended considerably without serious effects if pile covers are used.

Kiln-dried lumber can and often is afforded temporary protection, particularly in transit, by wrapping in various types of coated paper. Such wrap for unit packages of lumber (fig. 10-10) will adequately protect kiln-dried softwood lumber under short-term storage conditions such as long-haul transport on flatcars, interim storage at distribution centers, and short-term outdoor storage at construction sites. However, coated paper wrappings should not be considered a substitute for storage sheds when long-term storage of dried lumber is involved. The lumber could deteriorate during storage and is susceptible to tearing during handling. If such storage is unavoidable, the protective wrap should be inspected periodically for tears or other deterioration. Water that enters packages through tears in the protective wrapping can collect and cause more regain of moisture than if no wrap were used. To avoid trapping water in torn packages, the bottom is often left open. However, moisture from ground water can enter packages if not enough ground clearance is provided by the pile foundations.

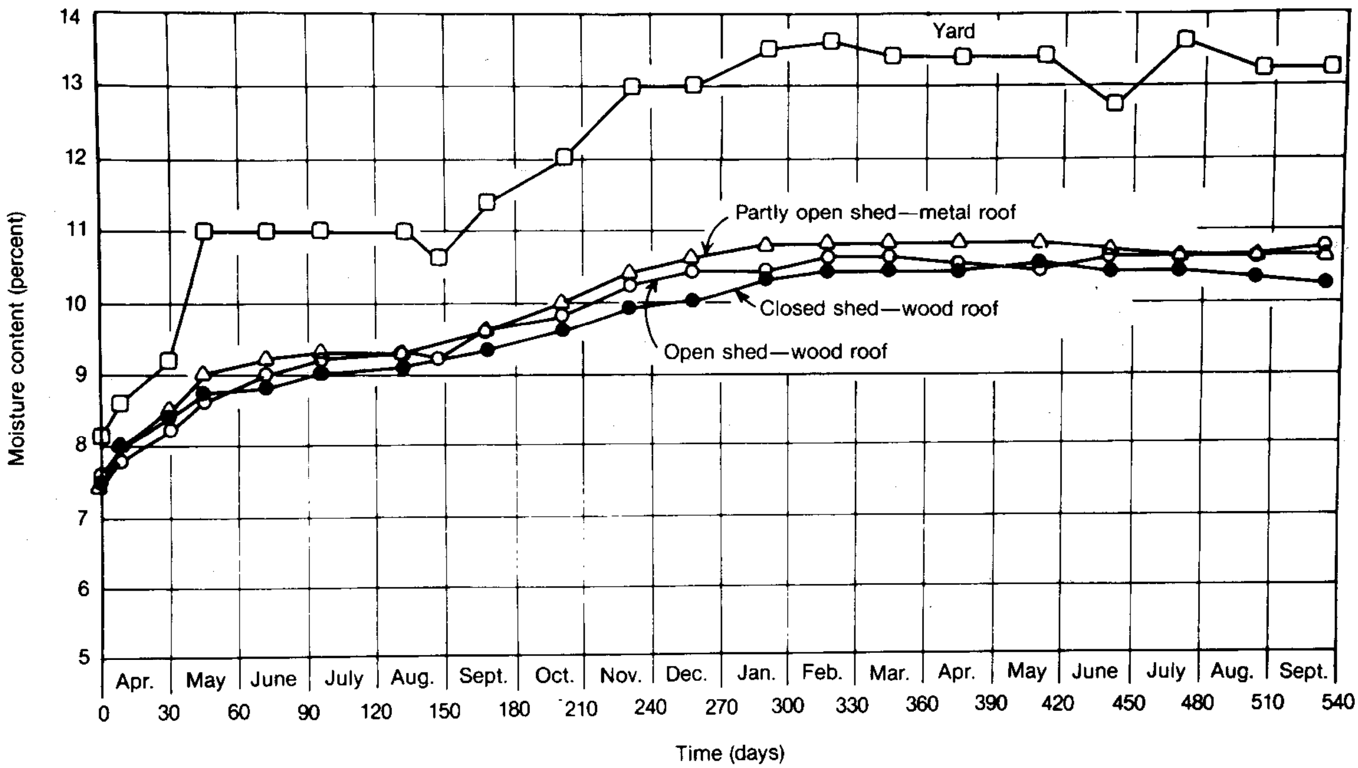

Figure 10-9—Change in average moisture content of kiln-dried southern pine 1- by 4-in flooring and 1- by 8-in boards during storage in solid piles within sheds and in a yard with a protective roof over each pile. (ML88 5557)

Figure10-10—Covering packages of lumber with waterproof kraft paper wrap. The wrap does not cover the package bottom, and thus will not be damaged by forklift handling nor will it trap rainwater. (M 120954)

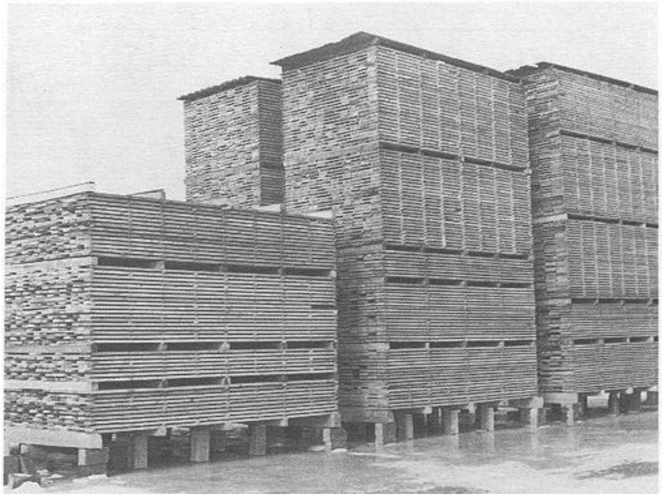

Figure 10-11—Stickered lumber yarded for air drying. The well-braced pile foundations of stringers and cross-beams prevent tipping. Most piles are covered with a prefabricated board and batten roof (M 134963)

Pile Covers

High-grade lumber stored in a yard, whether solid piled or stickered, green or dried, should be protected from the weather. Lumber surfaces exposed to alternate wetting and drying will check, warp, and discolor. Stacks of lumber in storage yards can be provided with pile covers the same as are used in air-drying yards **(fig. 10-11).**

Open Shed Storage

Open sheds provide excellent protection for green and partially dried lumber. Lumber that has been kiln dried to a low moisture content can also be stored in open sheds for varying periods, depending on weather conditions.

An open shed is a roofed lumber storage yard. Lumber dried to moisture contents as low as 12 to 14 percent can be stored in open sheds without significant regain of moisture. The atmospheric conditions within an open shed are the same as those outdoors except that lumber is protected from direct contact with rain and sun. A shed may be open on all sides or on one side only (fig. 10-12). Often the side facing the prevailing winds can be closed to keep out driving rain.

The shed should be located on an open, well-drained area. It should be large enough to permit rapid handling of the lumber and have a floor of gravel, crushed rock, blacktop, or concrete firm enough to support the piles of lumber and the weight of lumber-handling equipment. The roof should overhang far enough beyond the piles of lumber to protect them from driving rain and snow.

Figure 16-12—Open storage for packages of dry, surfaced lumber. (M88 0164)

Green Lumber

Green lumber can be stored for long times in open sheds without danger of serious deterioration, provided it is stickered. Such sheds protect the lumber from the sun, rain, and snow, thereby keeping end and surface checks and splits to a minimum. To obtain good air drying in open sheds, adequate spaces should be provided between the sides and ends of the stacks. By allowing this free circulation of outdoor air, lumber will dry to as low a moisture content as it does in the open air. The drying time in an open shed is usually shorter and the lumber brighter than if stored outdoors because rewetting is avoided.

Partly Dried Lumber

Open sheds afford excellent protection to partly dried lumber. If the moisture content is above 20 percent, the lumber should be stacked on dry stickers. If it is below 20 percent, it can be solid piled unless further drying is desired, in which case it should be stickered.

Kiln-Dried Lumber

Kiln-dried lumber can be well protected from sun, rain, and melting snow when stored in open sheds. An open shed will not, however, prevent regain of moisture during periods of high humidity, especially if temperatures are also high. Therefore, storage time should be limited during warm, humid weather. Lumber piles can be either solid or stickered. Solid-piled lumber will regain moisture more slowly than stickered lumber. Increase in moisture content will be greatest at the ends and in the outer tiers of a solid pile, as illustrated in figure 10-13. The effect of long-term storage in an open shed on moisture content of solid-piled, kiln-dried lumber is also shown in figure 10-9.

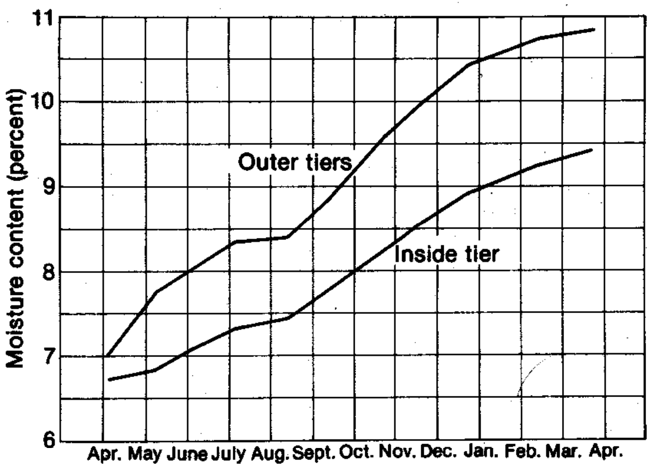

Figure 10-13—Change in average moisture content of solid-piled, surfaced 1- by 8-in Doughs-fir boards stored in an open shed. (ML88 5556)

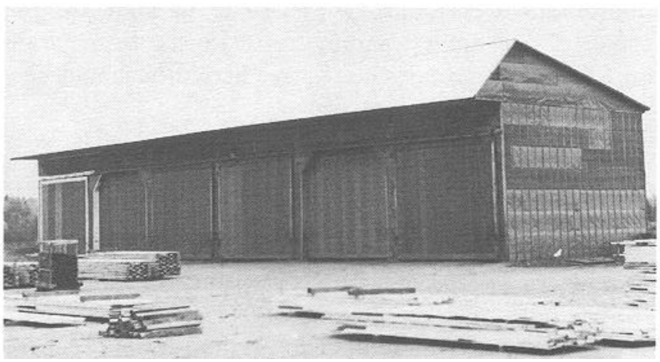

Figure 10-14—Closed, unheated storage shed at a distributing yard. (M88 0166)

Closed, Unheated Shed Storage

Closed, unheated sheds (fig. 10-14) are generally used for storing kiln-dried lumber, although they also can be used for storing green or partly dried lumber. This type of shed should be provided with reasonably tight-fitting doors. Ventilators are sometimes provided, and their need depends on the moisture content of the stored lumber and the tightness of the building.

Green Lumber

Green lumber is sometimes stored in closed sheds, although this type of storage will retard drying. The drying can be retarded enough that the growth of mold becomes a problem. Some drying capability can be added to closed-shed storage by exhaust vents and circulation fans. The solar heat that is absorbed through the roof and walls of a shed will provide some energy for drying. Care should be exercised for species that are susceptible to surface checking. If air circulation is inadequate, the temperature near the roof will rise and could cause surface checking.

Partly Dried Lumber

Partly dried lumber that is properly piled can be stored in a closed shed without developing drying defects. Lumber should be stickered if it has a moisture content greater than 20 percent. If below 20 percent and no further drying is desired, lumber can be solid piled. If further drying is desired, the lumber should be stickered, and it may be advantageous to add fans to circulate air through the lumber. High shed temperatures from solar energy generally will not cause checking or splitting in partly dried lumber because these defects usually occur when moisture contents are higher.

Kiln-Dried Lumber

The object of storing kiln-dried lumber in closed sheds is to minimize pickup of moisture. Thus, lumber should be solid piled. Although kiln-dried lumber will regain some moisture during periods of high relative humidity, the percentage regained will be less than if the lumber were stored outdoors. In dry regions, kiln-dried lumber can be stored indefinitely during hot, dry weather.

The ultimate moisture content lumber will reach in a closed shed depends on the local weather. If sunny weather prevails, the roof and walls of the shed will absorb solar radiation and heat the air inside. This lowers the relative humidity in the shed and thus the EMC conditions. Prolonged periods of sunshine can thus result in low moisture contents. Conversely, if cloudy weather prevails, moisture contents will not be much lower than in an open shed.

Lumber dried to a moisture content of 10 percent or less, and items manufactured from it, will regain moisture if stored for extended periods under conditions of high relative humidity. Excessive regain of moisture frequently results in (1) swelling of whole pieces or of certain parts, such as the ends of the pieces, (2) warping of items such as glued panels, and (3) wood or glueline failures in solid-piled items where the moisture regain is confined to the ends.

During fabrication and use, lumber and items that have adsorbed excessive moisture during storage may (1) end check and split when the high-moisture-content surfaces are exposed to low relative humidities in heated buildings, (2) shrink excessively, (3) warp, (4) suffer extension of end splits, and (5) open at glue joints.

Closed, Heated Shed Storage

If air in a shed is heated, the relative humidity and EMC are lowered as long as no additional moisture is added to the air. Thus, storage in closed, heated sheds provides excellent protection in preventing kiln-dried lumber from regaining moisture. Lumber for use in final products such as furniture and millwork that will be used in a heated environment should be stored in heated sheds. A heated shed should be reasonably tight and can be insulated or uninsulated. Heat can be supplied by any convenient means as long as the system can maintain up to 30 °F above outside temperatures. Circulation is desirable to maintain uniform temperature. Ventilators are generally not necessary but should be provided if any drying is anticipated. Temperature can be controlled by a simple thermostat that regulates the heating system.

The shed should be located on a well-drained site. Its floor should be of gravel, crushed rock, asphalt, or concrete, and it should be sufficiently firm to support piles of lumber.

Green Lumber

Green lumber is not ordinarily stored in heated sheds because the higher temperatures within the shed may cause end and surface checks or splits. If drying in a heated shed is considered, predryers should be used, as described in chapter 2.

Partly Dried Lumber

Partly dried lumber can be stored in heated sheds for further drying. Stickering and ventilating are necessary. If further drying is not desired, lumber should be stored in open or unheated sheds because it will dry further in a heated shed.

Kiln-Dried Lumber

Closed, heated sheds are ideal for storing lumber kiln dried to 12 percent moisture content or less. The desired EMC of the lumber can be regulated simply by increasing the temperature in the shed by a certain amount over the outside temperature. This can be done with thermostats that measure temperature differentials. When outside air is heated without adding moisture, even though the absolute humidity remains the same, the relative humidity decreases and thus the EMC decreases. The outside temperature and relative humidity must be known to determine the amount by which the temperature in the shed must be increased to attain a certain EMC. For example, if the outside air is at a temperature of 50 °F and is at 80 percent relative humidity, how much must the temperature in the shed be raised to attain an EMC of 6 percent? The answer can be determined by using figure 10-15. Enter the graph along the arrows that lead from 50 °F and 80 percent relative humidity to the point where they intersect. Note that this is at an EMC of about 16.5 percent and an absolute humidity of about 0.0625 pound of water per pound of dry air (at a barometric pressure of 29.92 in Hg). Since no moisture is being added to the air in the shed, the absolute humidity will remain the same as we raise the temperature. Therefore, follow the arrowed line down parallel to the absolute humidity lines to the point where it intersects the 6 percent EMC line. From this point drop straight down to the temperature axis and read the required temperature in the shed as 80 °F or a 30 °F temperature rise.

An alternative way to control conditions in a heated shed is to control the heater with a humidistat. When the relative humidity is above the set point of the humidistat, the heater will be on until the relative humidity falls to set point. For example, we know from table 1-6 of chapter 1 and figure 10-15 that to maintain an EMC of 6 percent, the relative humidity should be controlled at about 30 percent.

Conditioned Storage Sheds

Kiln-dried lumber and finished products can also be held at any desired moisture content in storage by controlling both relative humidity and temperature. This is the most costly method of controlling EMC because of the equipment involved. However, when it is desirable or necessary to maintain temperature within certain limits, then it may not be possible to maintain relative humidity simply by manipulating temperature. For example, to attain 6 percent EMC when the outside air is at a temperature of 85 °F and a relative humidity of 80 percent, the temperature must be raised to 114 °F. This temperature is unreasonable in a work area where people must spend any length of time. In this case, refrigeration equipment is required to attain 6 percent EMC at a comfortable temperature.

Treating Stored Lumber

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 l-in southern pine lumber. Insect infestation also causes serious losses in stored lumber, particularly in the warmer parts of the United States. 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.

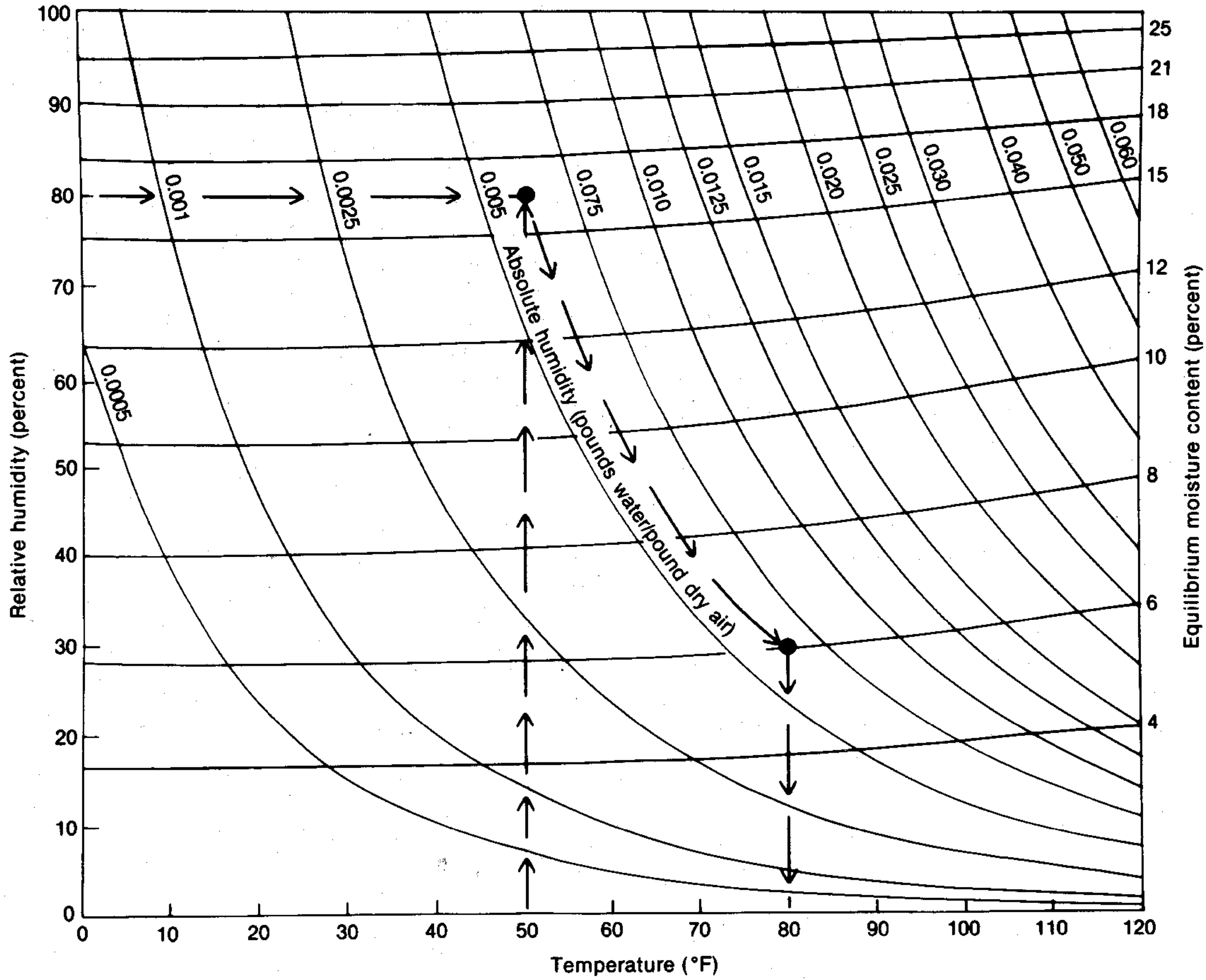

Figure 10-15—Psychrometric chart showing the relationship between temperature, relative humidity, absolute humidity, and equilibrium moisture content (EMC) of wood at a barometric pressure of 29.92 in Hg. The chart and arrowed lines illustrate the temperature rise required to attain 6 percent EMC by heating outside air originally at 50 °F and 80 percent relative humidity. (ML88 5558)

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 lumber uniformly below 20 percent moisture content is immune to attack by fungi. With protective storage it will keep that immunity. However, dried lumber that 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 that 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, grow no more than one-fifth as rapidly at 50 to 60 °F, and cease growth at about 32 °F. 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, similar deterioration requires five or more times as long. At 32 °F 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 or below but increase their activity rapidly as the temperature rises above this level. Insects will approximately double their activity with each increase of 10 ° above 50 °F, reaching maximum activity levels at about 80 °F.

When and Where to Apply Treatment

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 follows: 1 day at 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.

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. 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 bundles 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.

How to Apply Treatment

Lumber to be dipped at the storage installation will probably be in unit packages. Thus, the dipping procedures explained here are 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 ensure 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 is about 1-1/2 times the height and width of the largest package to be dipped and about 3 ft 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 shall hold extra treating solution, which can be prepared without interrupting treating operations. Steam or electrical heating coils are a desirable supplement to the mixing tank to ensure that chemicals dissolve rapidly and completely.

Dipping Operation

Packages of lumber should be submerged in the protective solution for at least 5 min and for up to 15 min 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 oilborne 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

All insects that cause damage to sound (nondecayed) lumber during storage will be either beetles or termites. Wood-destroying beetles cause annual damage amounting to $50 million in hardwood lumber and secondary manufactured products such as flooring, furniture, and millwork. Losses from termites can be much higher, although most of this loss occurs in wood in buildings; nevertheless, termites can damage lumber stored for some time in contact with the soil. Treatment may be needed to control insect damage in both dry and green wood, regardless of the wetness or dryness of the storage location.

The principal beetles that attack stored wood vary in their need for moisture. Ambrosia or pinhole beetles invade green or partially dried wood but usually are only a minor hazard in lumber stored away from forested areas or sawmills. The destructive golden buprestid beetle lays its eggs in western softwood trees, preferably Douglas-fir, but viable eggs and wood-boring larvae can persist for as long as 15 to 20 years in air-dried lumber that was not kiln dried.

Among the most troublesome and damaging insects to stored lumber are those belonging to the true powder-post beetle group because they infest wood after it is dry. 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 other principal insect that might attack stored lumber is the termite. There are two general types of termites: subterranean and drywood. 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 insects that primarily attack dry wood.

Properly applied treatments that are commercially available generally provide protection to stored lumber against powder-post beetles and termites. Environmentally safe boron compounds such as boric acid and borax are toxic to many wood-destroying insects and have been successfully used in the wood industries of Australia and New Zealand for over 40 years. Lumber is immersed for 1 min in a borate solution and stored under cover for 7 days. Storage permits the borate to thoroughly diffuse through and penetrate the wood and ensures excellent protection from damage by powder-post beetles. There is also considerable protection from damage by termites and brown-rot decay fungi.

It is important to realize that the dip treatments described here apply only to the protection of lumber 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 the danger of subterranean termites, a more efficient method of protecting the lumber is to treat the ground under the storage piles or sheds.

Precautions for Handling Chemicals

All treating solutions should be so handled that none, or as little as possible, gets on the skin and clothing of workers. 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 dipping or spraying results in only a small increase in moisture content. Residual oil should be cleaned from any dry hardwood lumber to be painted.

Lumber Handling and Storage in Transit

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.

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 may take place in transit. 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 into trucks. Ocean-going vessels are loaded by ship gear.

Generally, when l-in dry softwood lumber is shipped in tightly closed boxcars, 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.)

Precautions are also necessary in shipping green lumber by truck or open flatcar. Air flowing over unprotected green lumber as it moves along a highway or rail causes uncontrolled surface drying that may result in severe surface checks. This is especially likely to occur with oak, maple, or beech. Green lumber of these species should be covered with a tarp or reinforced paper to prevent this uncontrolled surface drying.

Truck Transport

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, seldom exceeding a week even on longer hauls, so little change in the lumber's moisture content would be expected from atmospheric humidity. Many lumber-hauling trucks have flatbeds that are fully enclosed with canvas coverings over skeleton frameworks. When kiln-dried lumber is transported in these covered trucks during cold, moist weather, the outer boards will gain 3 to 7 percent moisture content in their outer shell. This moisture uptake can develop within a week, and such boards will give a casehardened reaction even though they were properly conditioned during kiln drying. Trucked lumber can also be wet by rain or splashed road water.

High-value, air-dried lumber is often protected by covering the load with canvas tarpaulins (fig. 10-16). 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 will cross several climate or elevation zones.

Figure 10-16—Packages of kiln-dried hardwood lumber on a truck trailer are covered with a tarpaulin. (M 142893)

Rail Transport

Some years ago, the Forest Products Laboratory studied the changes in moisture content of softwood lumber shipped in tight railroad boxcars from West Coast sawmills to midwestern U.S. markets. These studies involved five boxcar loads of l-in clear Douglas-fir shipped from a West Coast sawmill to the Chicago, IL, area during late winter and spring. The time in rail transit averaged 18.5 days; the shortest period was 14 days and the longest, 22 days. Average moisture content of the five carloads of kiln-dried boards at the time of loading was 8 percent, and the average gain in moisture content was 0.2 percent. These values were baaed on an average of 18 teat boards distributed throughout the boxcar load in each shipment. In another 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.

A study of moisture changes in rail shipments of kiln-dried hardwood lumber was conducted by the Forest Products Laboratory. These shipments were of kiln-dried pecan lumber, transported in wide-door boxcars from midsouth Mississippi to a furniture company in North Carolina, a distance of about 900 mi. Each load of unitized lumber packages contained four test boards for moisture analysis. Test shipments were made from June through November, and the increase in moisture content was less than 0.5 percent moisture content. Conventional flatcars have become widely used for the transport of dried lumber because they can (1) save handling time and shipping cost, (2) hold twice the load of conventional boxcars, and (3) be loaded by lift trucks to save handling time. Improvements in unitized package wrapping have made it possible to obtain these advantages without much increase in moisture content, even on long hauls.

Unitized packages on flatcars are usually protected, either partially by tarpaulins or entirely by flexible, waterproof packaging that completely “tailor-wraps” each package. One common type of waterproof packaging uses composite kraft paper that is reinforced with glass fiber coated with polymer. 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-dried lumber with little change in moisture content and a good retention of brightness.

Wrapping for unitized packages of lumber should be free from rips to be effective. Rain that enters through 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.

Ship Transport

Lumber is often transported overseas in ships while it is either green, partly dried, or kiln dried. A study conducted in Canada, which involved 33 shipments of l-in lumber from the Canadian west coast to five different ports, concluded that seasoned lumber stored below decks, either by itself or together with green lumber, will not undergo moisture regain of serious proportions (table 10-2). This study also indicates that well-dried lumber may undergo significant moisture regain if stored on deck, although it is not commonly stored in this way.

Similar tests were made with 2-in Douglas-fir lumber. The kiln-dried lumber had a moisture content of 9 to 10 percent when stowed. The overall average moisture gains for the seasoned 2-in lumber were as follows:

Lumber stowed below decks with dry lumber	1.3 percent
Lumber stowed below decks with green lumber	2.4 percent
Lumber stowed on deck with green lumber	4.2 percent

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Table 10-1—Equilibrium moisture content of wood, exposed to outdoor atmosphere, in the United States

Location	Equilibrium moisture content in different months (percent)[1]											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Portland, ME	16.9	15.5	15.8	14.8	15.0	13.4	13.9	15.5	17.2	15.4	16.3	14.9
Concord, NH	14.9	14.0	14.3	13.0	13.0	11.7	12.6	14.1	14.2	14.2	15.4	14.6
Boston, MA	13.0	12.3	12.3	12.0	12.3	10.9	11.7	12.6	12.9	12.7	13.0	11.9
Providence, RI	13.7	12.4	13.1	12.4	12.9	12.1	12.6	14.5	14.6	14.2	13.6	11.8
Bridgeport, CT	14.8	12.3	13.4	12.9	13.0	12.6	13.2	14.1	14.3	13.6	14.5	13.2
New York, NY	13.7	11.7	12.7	11.7	12.6	11.2	11.3	12.2	12.0	11.9	12.6	12.5
Newark, NJ	14.0	11.9	13.2	12.0	12.4	11.4	11.5	12.9	13.0	12.3	13.3	13.4
Wilmington, DE	15.1	12.1	13.4	12.3	13.4	12.7	12.6	12.9	14.5	13.9	14.6	13.7
Philadelphia, PA	14.3	11.3	12.4	11.9	12.7	12.0	11.7	13.5	13.3	12.3	13.0	12.9
Baltimore, MD	13.7	10.8	12.5	11.7	12.9	12.2	11.8	13.3	13.3	12.3	13.6	13.0
Norfolk, VA	13.9	12.7	13.0	12.4	13.0	13.2	13.4	14.9	14.5	14.7	14.5	14.0
Wilmington, NC	15.7	15.4	15.0	13.7	13.5	13.5	15.4	16.7	16.8	15.8	15.9	16.3
Charleston, SC	14.8	15.1	13.2	13.4	14.1	15.5	16.2	16.8	17.3	16.1	15.6	16.0
Savannah, GA	14.3	14.7	12.5	12.9	12.9	13.9	14.5	15.4	15.6	14.3	14.6	15.4
Key West, FL	14.7	14.7	14.3	12.9	13.7	14.0	14.0	13.0	14.5	16.3	15.9	14.8
Burlington, VT	14.9	14.3	14.9	13.1	13.0	11.7	11.8	13.1	14.7	14.5	14.6	14.9
Cleveland, OH	16.9	14.9	15.0	13.6	13.0	11.8	11.6	12.6	12.2	10.0	13.3	15.2
South Bend, IN	18.9	15.4	15.2	13.3	14.1	13.0	12.9	14.5	13.7	13.3	14.3	17.4
Charleston, WV	14.3	12.1	12.0	11.9	12.7	13.8	14.1	13.8	12.6	11.7	12.2	13.4
Louisville, KY	15.4	12.8	12.9	12.3	12.8	12.2	12.0	11.8	11.3	11.5	11.9	14.3
Nashville, TN	15.4	14.0	12.9	12.1	12.3	11.4	11.8	11.9	11.8	11.7	12.0	14.8
Mobile, AL	15.8	16.2	14.6	13.3	15.0	14.2	15.4	16.7	14.3	12.0	13.0	14.9
Jackson, MS	14.7	14.5	12.6	12.7	13.5	11.9	12.7	12.5	11.4	10.3	11.5	13.9
Detroit, MI	17.5	14.3	15.2	12.2	12.2	11.4	11.5	12.4	12.5	11.9	14.0	15.8
Milwaukee, WI	15.8	14.6	14.9	12.4	13.0	13.7	13.2	14.2	13.0	11.8	13.2	15.8
Chicago, IL	16.1	13.7	14.2	11.8	12.4	11.9	11.9	12.5	11.6	10.9	10.3	15.2
Des Moines, IA	16.9	16.0	14.9	12.4	12.8	13.6	13.5	13.3	11.6	10.1	12.4	16.4
Kansas City, MO	14.3	13.1	13.4	12.0	12.5	10.3	10.9	11.1	9.5	9.3	11.2	13.7
Little Rock, AK	15.7	13.6	12.7	12.5	13.6	11.7	12.0	12.5	11.2	10.6	11.8	13.7
New Orleans, LA	16.2	15.6	14.0	13.4	14.6	14.5	15.7	17.1	16.8	13.1	14.5	15.3
Duluth, MN	15.5	15.2	16.0	12.8	12.7	14.9	14.8	16.1	16.5	13.9	15.9	16.9
Bismark, ND	17.2	17.6	17.0	12.4	11.9	12.9	11.6	11.6	11.2	11.0	14.3	16.1
Huron, SD	17.0	18.0	16.0	12.7	12.1	13.0	11.8	12.2	10.1	10.2	13.4	17.6
Omaha, NE	18.0	15.5	15.2	12.2	12.6	11.3	12.1	12.9	11.3	10.4	12.4	15.7
Wichita, KS	13.7	12.4	13.0	12.0	11.9	9.9	11.0	10.5	8.3	8.5	11.9	15.5
Tulsa, OK	14.0	12.2	12.2	12.6	12.6	11.0	12.4	11.2	9.7	9.7	12.0	12.7
Galveston, TX	18.2	18.2	18.1	15.8	16.9	15.7	15.4	15.7	15.5	14.2	16.6	15.9
Missoula, MT	16.1	15.1	12.5	10.2	11.6	11.5	8.2	8.7	9.3	10.5	14.6	16.4
Casper, WY	11.0	12.3	11.5	10.3	11.2	8.4	8.6	8.1	7.0	8.2	11.0	12.8
Denver, CO	8.4	8.3	9.3	10.3	9.8	7.6	8.2	8.9	6.9	7.2	9.9	10.4
Salt Lake City, UT	14.3	12.5	12.4	10.8	9.3	7.8	7.8	7.4	7.5	9.1	12.1	15.8
Albuquerque, NM	9.2	8.1	8.0	6.9	6.3	5.7	7.9	7.7	7.1	6.9	10.5	11.1
Tuscon, AZ	8.8	7.0	7.9	6.8	5.3	4.6	8.1	8.0	5.2	5.2	7.7	8.0
Boise, ID	15.8	14.3	12.1	10.3	10.9	10.5	7.3	7.3	7.6	8.6	10.3	18.0
Reno, NV	13.2	11.3	11.0	9.4	9.0	8.6	8.0	7.8	8.9	9.6	11.3	13.4
Seattle-Tacoma, WA	21.0	18.9	16.8	14.8	14.2	15.3	13.7	14.6	14.7	17.2	18.9	18.9
Portland, OR	19.6	16.8	14.7	13.0	14.1	14.5	12.1	13.4	13.1	15.9	18.5	20.0
San Francisco, CA	18.5	14.8	14.7	16.0	14.7	15.6	15.8	16.6	15.5	15.9	16.0	16.3
Juneau, AK	19.8	20.2	17.9	15.8	16.3	14.8	16.2	18.2	21.4	—	22.0	18.6
San Juan, PR	14.7	15.3	14.4	15.2	14.6	15.7	16.2	15.7	15.7	15.7	15.5	14.7
Honolulu, HI	13.8	13.5	13.2	12.6	12.0	12.1	12.3	12.6	11.9	12.8	12.9	13.5

[1]The values were calculated by means of average monthly temperatures and relative humidities given in Climatological Data monthly reports of the Weather Bureau and the wood equilibrium moisture content to relative humidity relationship.

Table 10-2—Average gain in lumber moisture content during ocean shipment[1]

Number of shipments	Shipment destination	Time in transit (days)	Lumber moisture content increase (percent)		
			Stowed with dry lumber below decks	Stowed with green lumber below decks	Stowed on deck with green lumber
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]Lumber used was 1-in kiln-dried Douglas-fir.