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AIR DRYING OF LUMBER

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AIR DRYING OF LUMBER

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Introduction

Although the number of dry kilns in this country is increasing, the drying of lumber by exposure to the outdoor air, called air drying, remains an important process. Since air-dried lumber has satisfactory dimensional stability for most exterior uses, low-grade softwood lumber is often air dried exclusively. Although most hardwood lumber for furniture and interior uses is eventually dried in a kiln, it is generally air dried first to reduce kiln costs. Generally, high-grade softwood lumber for interior uses goes to the kiln fresh from the saw.

The objective in air drying is to reduce the moisture content of the green lumber to the minimum value consistent with the weather conditions in the shortest time, with avoidance of drying defects that lower the grade.

Air drying has been studied and the results reported in several publications.[2,3] As a result of this work, principles of good air-drying practice were established. The studies were conducted on hand-stacked piles.

During the past several years, the practice of handling and transporting lumber in packages by straddle and fork-lift trucks and of piling the packages by means of fork-lift trucks has become more widespread throughout the lumber-producing and wood-using industries. These practices have

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Fullaway, S. V., and Hill, C. L. The Air Seasoning of Western Softwood Lumber. U. S. Dept. of Agr. Bul. 1425. 1928.

[3] Mathewson, J. S. The Air Seasoning of Wood. U. S. Dept. of Agr. Tech. Bul. 174. 1930.

brought about changes in yard layout and in piling methods. In the change-over to machine piling, some of the principles of good air-drying practice have been ignored. It is necessary to make some changes in the features of the present piling practices to meet acceptable standards.

Considerable material and financial loss can and sometimes does occur during air drying. The losses are caused principally by staining, warping, and checking. These losses are not inevitable but can be avoided largely by the practice of good air-drying technique.

General Principles of Air Drying

The air drying of lumber is dependent upon the temperature and relative humidity of the outdoor air, precipitation, and the air circulation within the pile. The climatic conditions vary with the region and season. Climatic conditions are also affected by local factors, such as elevation, topography, drainage, and water bodies. Air at any condition below 100 percent relative humidity or saturation possesses the ability to take up moisture from green lumber. Air that enters a pile cools as it takes up moisture from the lumber, and as its temperature decreases and its relative humidity increases, it loses its ability to dry the lumber. As a consequence, if drying is to continue, the air within the pile must be removed and fresh, drier air admitted. This is accomplished by natural horizontal and vertical air movements. Vertical movement, which is generally downward, is caused by the increase in density of the air within the piles as it is cooled. Horizontal air movement within the piles is induced by this vertical movement and by a difference in pressure between the two sides of the pile caused by winds.

The active drying season in the U. S. spans the spring, summer, and early fall, when the temperatures are higher and relative humidity lower than during the late fall and winter. Seasonal variations and regional climatic conditions affect not only the rate of drying but the final moisture content of the lumber. Figures 1 through 10 show mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying periods for various regions throughout the country. The temperature and relative humidity data were obtained from United States Meterological Yearbooks for 1939 and 1941, issued by the Weather Bureau. The equilibrium moisture content values were obtained by use of the Weather Bureau data and charts showing the equilibrium moisture content values for wood at different temperatures and relative humidities. The 6-month active drying periods were based on the temperature and relative humidity. The active drying period is ideally the time of high temperature and low relative humidity, but the phases of high temperature and low relative humidity do not always correspond. In three regions of the western part of the country, the hot season and the dry season coincide. In the South, the periods of high temperature and high relative humidity coincide.

In the redwood region, however, no active drying period was selected because of the slight temperature variations throughout the year and of the continuously high relative humidity. In the central and southern regions, the relative humidity reaches a low point during the spring months and increases with temperature increases during the summer months. The effect of rain and snow on drying is difficult to evaluate. Rain is accompanied by high relative humidity, and rain and snow often penetrate the piles and wet the lumber. The amount of wetting depends on the intensity and duration of the storm, the wind velocity, and the extent to which the pile is protected by a roof. Maximum protection from wetting is obtained when piles are placed in open sheds. Temperature affects drying not only through its influence on the water-vapor capacity of the atmosphere, but by its effect on moisture diffusion through the wood. When the temperature drops below freezing and much of the water within the wood becomes frozen, there is an additional retarding effect. Since in most regions winter is an unfavorable season for drying, the aim in air drying is to take advantage of conditions during the favorable drying seasons. Air-dry lumber that remains in the yard during a cold wet season may take on moisture. Some mills take down lumber piles that have become dry during the favorable drying season and store the lumber in solid piles to retard pick-up of moisture during the damp season.

Table 1 gives equilibrium moisture content values for lumber exposed to the outdoor air at a city in each State and in several territories. These values are based on monthly mean temperatures and relative humidities taken from Climatological Data Monthly Reports of the Weather Bureau for 1952 and 1953.

Because of the seasonal variations in climate and the variations in local conditions, the time required to air-dry lumber of any species and thickness can be stated only on an approximate basis.[4] Lumber that might become thoroughly air dry in 30 to 60 days during the active drying period of the year may have to remain in the yard for an additional 6 months if the air-dry condition is not reached during the active drying period. The final moisture content of thoroughly air-dried lumber can likewise be stated only within general limits. The moisture content of thoroughly air-dried lumber reduced during the spring, summer, or early fall is 12 to 15 percent in most parts of this country, but it is lower in arid regions and higher in humid regions.

The Air-Drying Yard

Site

The air-drying yard is preferably located close to the plant producing or using lumber to reduce the hauling distance between the plant and the yard. It is preferable that the yard be located on high ground that is level,

[4] See Forest Products Laboratory Technical Note No. 233. 1949.

well drained, and not adjacent to water bodies or wind-obstructing objects such as tall trees or buildings. A yard located on low ground is likely to be sheltered from the full sweep of the winds, and the ground surface is likely to be damp. Such conditions retard drying and promote stain and decay in lumber.

Surface

The ground surface should be kept free from debris and vegetation. Debris harbors stain and decay organisms and obstructs the movement of air over the ground surface and beneath the lumber piles. Vegetation restricts the movement of air in the same manner as debris but to a greater extent if the growth is luxuriant (fig. 11). Vegetation can be controlled by cutting or by applying crude oil, salt, or weed killers. Covering the ground with cinders, gravel, shells, or crushed stone hinders the growth of vegetation. The surface of the yard should be firm and smooth for the operation of lumber-hauling and piling machines. Where hand-stacking is employed, only the main and cross alleys need be paved, but where lumber is piled in the form of packages by fork-lift trucks, additional areas of the surface should be paved. Rough driveways cause wear and tear on the machines and injure operators. Such driveways are also likely to cause displacement of stickers and boards in packages being transported and to impede the accurate placement of the packages in piling.

Layout

There are three types of alleys in an air-drying yard: main, cross, and rear. The main and cross alleys serve as transportation routes. Sometimes the main alleys are used for working areas for stacking lumber. The rear alleys serve as passageways for the movement of air through the yard, and they often contain drainage ditches. All alleys retard the spreading of fire and provide fire fighting areas.

A hand-stacked yard has main, cross, and rear alleys, as well as spaces between the sides of the piles (figs. 12, 13, 14, and 15). These spaces between the piles may also form long, straight passages through the yard, but these are considerably narrower than the alleys (fig. 14). Where hand-stacking is used, main alleys are generally 16 to 20 feet wide. Cross alleys for transportation and protection against the spread of fire are spaced every 200 to 300 feet and may be 60 or more feet in width. Rear alleys should be 6 feet or more in width (fig. 15). The distance between the sides of the piles should be 2 to 6 feet.

Where the piles consist of packages piled by fork-lift trucks, the main alleys must be wider than 20 feet (fig. 16). Twenty-four feet is about the minimum width that is feasible for the operation of the larger sizes of fork-lift trucks, and alleys for the operation of fork-lift trucks are often 30 feet wide. Yards consisting of package piles usually do not have rear alleys. The piles are in rows extending from one main alley to the next (figs. 17 and 18). The number of piles in a row varies from a minimum of 2 to a maximum of 100. The width and spacing of the cross alleys in a yard with package piles can be the same as in a hand-stacked yard.

There has been considerable discussion about the orientation of the lumber piles in a yard. Claims are made that piles should be placed perpendicular to the direction of the prevailing winds so that the stickers will be parallel to the direction of the winds. While this would probably accelerate drying in the piles on the windward edge of the yard, it could have no important influence on the drying of lumber within the yard. The important thing is to arrange the yard so that the air can move through it regardless of wind direction. Alleys and spaces must be provided between piles and rows of piles for unobstructed wind movement. In a machine-piled yard, placing the piles of the various rows in alinement facilitates wind movement. In both types of yards, it is advantageous to have the main alleys run north and south. With this arrangement, the sunshine has better access to the alley surface and is able to melt snow or dry up the alleys quicker.

Pile Foundations

The foundations for yard piles, or "pile bottoms" as they are sometimes called, should be well designed and well built. They represent a considerable investment, and the use of poor design or material can result in excessive maintenance costs. Inadequate foundations result in settlement, failure through decay, and damage through machine collisions. Lumber pile foundations should be high enough off the ground to allow the escape of air that has circulated through the lumber pile and to promote the general movement of air through the yard (fig. 19). Foundation piers are made of concrete, masonry, preservative-treated blocks or posts of any species, or untreated heartwood of such decay-resistant species as baldcypress, redwood, or the cedars. If wood posts are used, they should be about 6 inches square. Posts or piers used to support stringers should be placed about 5 feet apart along the length of the pile and not over 6 feet apart across the pile. When crossbeams are supported directly on posts or piers, the lengthwise spacing will of necessity be the same as the spacing of the crossbeams, usually 4 feet, and the lateral spacing will be about 6 feet. Concrete or masonry piers should extend into the ground below the frost line. Wood piers or posts may also be set into the ground, or they may rest on the yard pavement or on mud sills or sleepers laid on or slightly below the ground surface. Timbers in contact with the ground should be treated with a preservative unless they are cut from the heartwood of a decay-resistant species. The tops of the piers or posts of a pile foundation should all be in a horizontal or sloped plane. If the foundation is sloped, the slope should be about 1 inch per foot of length from front to rear, and the rear piers should be of sufficient height to keep the underside of the boards in the first course at least 18 inches above the ground. Unless the posts are set into the ground, they should be braced to prevent lateral tipping (fig. 20). It is preferable to support the pile foundations on piers or posts rather than on solid cribbing, because the piers or posts permit more air movement beneath the pile.

The piers or posts support stringers or crossbeams. Stringers, extending in the direction of the length of the pile, are made from steel I-beams, railroad rails, or timbers. The timbers should be about 6 by 8 inches in dimension, set on edge, and treated with a preservative. The stringers are evenly spaced across the width of the pile. Stringers carry the crossbeams, which should be spaced so as to support tiers of stickers. Stringers are often omitted, and crossbeams are placed directly on top of the piers or posts. Sometimes the crossbeams are in long lengths to accommodate a whole row of piles (fig. 21).

Crossbeams may consist of steel I-beams or railroad rails, but they are generally 4- by 4- to 6-inch timbers. Usually crossbeams are not given a preservative treatment. Where they rest on posts or piers, however, they should be treated like stringers. If stringers are used, the crossbeams can be shifted to accommodate different lengths of lumber and different sticker spacing. When the crossbeams are carried directly by the posts or piers, no adjustment is possible. The stringers and crossbeams of foundations for hand-stacked piles are generally arranged so that the length of the piles is perpendicular to the alley.

The pile foundations for package piles differ from those of hand-stacked piles. The foundations for package piles are placed so that the rows of piles are perpendicular to the main alleys. The lumber piles themselves are parallel to the main alleys. The top of the foundations are usually level, but they may be sloped. Since some fork-lift trucks have forks that can be tilted 5 degrees laterally, sloping package piles is feasible. A sloped pile should also be pitched to prevent the entrance of rain or snow at the high end of the pile. To build a pitched package pile, each package must be pitched at an angle greater than that of the pile. For example: if the pile has a 1 to 12 slope, and a 1 to 12 pitch is desired, the unit package must be constructed with a 1 to 6 pitch. When the lumber is to be kiln dried after air drying, sloping and pitching becomes impractical because satisfactory kiln truckloads cannot be built with pitched packages.

Where the rows consist of more than two piles, the timbers of the pile foundation must be arranged to provide for the entrance and exit of the fork-lift truck. If the foundations are not over 6 inches in height, the machine can pass over them, and the only requirement is that the timbers do not fall in the wheel tracks. Some package piles are placed on 4- by 4-inch bolsters or 6- by 6-inch timbers resting on the ground surface (fig. 22). This is obviously poor practice because there is insufficient ground clearance for proper ventilation beneath the piles. Air movement in the yard as a whole is also restricted. Where the ground surface is uneven, various combinations of timbers are employed to obtain an approximately level foundation. In cases like this, the ground clearance is increased, but it is still insufficient to provide good ventilation beneath the piles (fig. 23).

When the pile foundations are more than 6 inches in height, and the foundation members are to be fixed or permanent, the central support cannot be fixed. An operating space of 8 to 9 feet must be provided for the fork-lift truck, since the clearance of most fork-lift trucks is 6 to 8 inches. The only alternative is to provide elevated runways for the wheels of the fork-lift truck. Increasing the elevation of such runways (fig. 24) by several inches would permit the installation of a fixed central beam. The simplest fixed-beam pile foundation consists of 2 timbers set on the ground or on sleepers with a space of 8 feet or more between them. An advanced type of foundation is made of 4 timbers instead of 2. The 4 timbers are generally placed in pairs, 3 to 4 feet apart, with an 8- to 9-foot center space. The addition of a fifth timber in the center between the pairs provides support for the middle of the pile. If the foundation is more than about 6 inches high, the center timber must be arranged so that it can be removed for the passage of the fork-lift truck. These various arrangements of timbers resting on sleepers or directly on the ground may not provide enough clearance between the bottom course of lumber and the ground.

Good pile foundations that provide sufficient ground clearance for package piles have been devised. These consist of 4 to 6 fixed elevated beams, with a central space of 8 to 9 feet (figs. 25 and 26). The fixed beams may be made of concrete, timbers, or railroad rails. They may be continuous throughout the length of the row or in lengths to accommodate a number of piles or a single pile. They may be made of solid or crib construction or of beams supported by posts, piers, or timber framework (fig. 27). The solid or crib type is undesirable because the circulation of air beneath the piles is limited to one direction only. One or more removable supports are provided over the central span.

The removable supports are of several types. They may consist of several short timbers piled up or of a timber carried on a framework. In hand-stacked piles, it is practical to place a crossbeam directly beneath each tier of stickers, but this is impractical with package piles. With packages, a crossbeam approximately every 4 feet with 16-foot stock and a few crossbeams at 2-foot intervals with shorter stock appears to be the only practical arrangement. Two timbers or stringers may be placed upon the foundation beams for package piles, with bolsters directly beneath each tier of stickers irrespective of the spacing.

Whenever a package of lumber is picked up or set down with a fork-lift truck, space for the insertion or removal of the forks must be provided. This space is usually about 4 inches wide, but it may be narrower. Bolsters, 4 by 4 inches in dimension, are used. The bolsters may be placed directly on the ground in place of foundation timbers, on stringers in place of crossbeams, or between each pair of packages in the pile. When building a pile of packages, the bolsters are placed on top of each package in alinement with the tiers of stickers or on top of the upper package when handling two at a time. The bolsters are inserted before the packages are piled. Of course, this need not be done with the lower package of the pile since the top is readily reached from the ground. When the pile is completed, the spaces between the bolsters form channels for air passage from side to side of the pile. If the boards in the package were piled with spaces between their edges, the space provided by the bolsters might further contribute to drying by exhausting the air as it comes to the bottom of the package.

Piling

Sorting Lumber

Because of the marked difference in the drying characteristics and in the seasoning degrade of stock of various species, grades, and thicknesses, lumber should usually be sorted on the basis of those three factors. For instance, 1-inch sap gum requires rapid drying conditions to prevent blue stain unless dipped in an antistain solution, while 1-inch southern lowland red and white oak, which are susceptible to checking, should be subjected to more moderate drying conditions. If a species yields an appreciable amount of both sapwood and heartwood lumber, it is advisable to separate heartwood and sapwood. In addition to sorting on the basis of species, grade, and thickness, sorting by width and length facilitates piling. When the lumber is piled by hand, it is usually not feasible to sort the lumber with respect to all of these categories because lumber in some categories is not produced rapidly enough to complete a hand-stacked pile within a reasonable length of time. It is easier to accomplish this sorting when the lumber is made into packages containing one to two thousand board-feet, because a package pile generally contains less footage than a hand-stacked yard pile. Lumber is sometimes grouped according to length; for example, 6, 10, and 12 feet, and 8, 14, and 16 feet. Since the shortest boards are half as long as longest boards, the scheme aids in stacking.

The Stacking Operation

Hand-stacked piles in a yard are built from the main alleys. The lumber is transported and delivered to the spot in the main alley in front of the pile that is being built. Packages are built at or near the mill in a stacking rack or jig. They are sometimes built beside a green chain or a sorting and grading chain. Packages also are built in semiautomatic stackers. Stacking packages has advantages over hand stacking lumber in yard piles, because the stacking can be done under shelter at a central point near the mill. Since the crew can be easily supervised and the work is generally lighter, the crews can stack lumber faster. After the packages are completed, they are transported to the yard by straddle or by fork-lift trucks.

Types of Piles

Yard piles may be classified in various ways. Under one system, piles are either box piled or not box piled. A box pile is characterized by the square appearance of both pile ends, the support of all outer board ends and most inner board ends by stickers, and the support of the outer ends of stickers by boards (fig. 28). The type that is not box piled is characterized by projecting and unsupported outer board ends, unsupported board ends within the pile, and poorly supported stickers (fig. 29). With random-length lumber, care and skill are required in order that the pile will conform to the specifications of a box pile. In a box pile of random-length lumber, the longest boards or planks should be placed in the two outer tiers. If there are sufficient long boards, additional tiers of them should be uniformly distributed across the width of the pile. If there are not enough of the longest boards to form two tiers, then the outer tiers may include a number of the next longest boards. In this case, the pile will not be truly box piled, because the ends of the longest boards will project beyond the ends of the pile.

Sometimes the package is built on the length of the second longest boards, and the ends of the longest boards project equally at both ends (fig. 30). Tiers of shorter boards are placed between the tiers of long boards, and all the boards of a tier should be of the same length if possible. The ends of the short boards may all be placed flush with the front of the pile, or they may alternate between the front and rear in adjacent tiers. With these two schemes, the boards within a tier are piled directly above each other.

In some cases, the boards of the inner tiers are not piled directly above each other but are placed with their ends flush with first one end and then the other end of the pile. This accomplishes a better distribution of the openings within the pile, but it places a strain on the stickers. Sometimes, placing the ends of all the shorter boards flush with the front end of the pile may save a tier of stickers, but it may result in excessive air space at the rear of the pile if there are only a few tiers of long boards.

Packages of lumber should be built in the same way as hand-stacked piles. Since packages contain a smaller quantity of lumber than a yard pile, it is easier to segregate the boards by length and thus make the packages from single-length boards. When random lengths are included in a package, box-piling should be used. Usually, the ends of all boards are piled flush with one end of the package.

Pile Spacings

Where lumber is hand stacked in long rows of piles fronting on the main alleys, it is necessary to provide spaces between the sides of the piles (fig. 14). These spaces aid air movement through the yard and within the piles. In lumber yards, these spaces vary from a few inches to 6 feet. It is not always possible to recommend the proper lateral spacing, but a space of 2 to 6 feet generally is considered satisfactory. The optimum spacing will vary with the species and thickness of the lumber, the width and height of the piles, the manner of piling with respect to chimneys or flues, the chief seasoning defect to be avoided, and the climate. Yards are generally laid out with the piles of the various rows in alinement. Sometimes a checkerboard scheme with alternate piles left out of the rows is used, so that the piles are opposite the open spaces (fig. 31). This amounts to increasing the space between any two piles by the width of a pile.

Since piles of packages are usually considerably narrower than hand-stacked piles, the lateral spacing presumably can be less (fig. 17). In actual practice, the spacing between piles of packages in a row varies from 0 to 8 feet (fig. 32). As with hand-stacked piles, the selection of an optimum spacing is not feasible because this would vary for different operations, but a space of 3 to 4 feet should generally be sufficient. With hand stacking, spaces between the ends of piles are provided by the main and rear alleys. Since the ends of package piles do not face the alleys, spaces between the ends of the piles are provided by spacing the rows (figs. 27 and 33). Spaces between rows of package piles in air-drying yards vary from 2 to 12 feet. Again, it is not feasible to recommend an optimum spacing, but a spacing of 3 to 4 feet should be sufficient.

Pile Widths

Mainly because of the effect on horizontal air movement, the width of the pile and its relation to pile spacing and chimney and flue areas affect the drying rate. For example, a wide pile with ample space around it and a large area of flues or chimneys would probably dry faster than a narrow, crowded pile with inadequate chimneys or flues. In softwood regions where hand-stacked lumber is often self stickered, the width and length of the pile are generally the same, commonly 16 feet (fig. 34). For hardwood lumber, the width varies from 6 to 16 feet, but the narrower widths are more prevalent. When special stickers are used for softwood lumber, there is a tendency to make the piles narrower than 16 feet (fig. 35). Lumber that is susceptible to staining should be stacked in piles as narrow as 6 feet, while lumber that is likely to check may be placed in wider piles. Where a lumber item accumulates slowly, narrow piles will build up more rapidly than wider ones. This reduces the deterioration that may be caused by exposure to the elements when there is delay in completing and roofing the pile. A temporary protective roof would eliminate this difficulty.

When lumber is piled for air drying in the form of packages, the width of the package may be determined by the seasoning process and the capacity of the fork-lift truck. Packages for yard drying only are likely to vary between 3 and 4-1/2 feet, with 4 feet the most common width (fig. 16). When the lumber is to go from the yard to the dry kiln, the packages vary from 3-1/2 to 8 feet in width, depending on the width of the kiln truckloads and whether the loads are to be 1 or 2 packages wide. Narrow packages are also used with kilns that have no trucks or tracks. Fork-lift trucks can handle packages up to 8 feet wide, but large piles decrease the safe loading capacity of the machine. Yard piles of packages are generally considerably narrower than hand-stacked piles. This feature would tend to increase the drying rate of lumber piled in the form of packages.

Pile Heights

The effect of pile height on drying rate is similar to that of pile width. Increasing the pile height tends to retard drying in the lower parts of the pile. The air traveling downward in a pile cools and approaches saturation at a point higher up in a tall pile than in a short one, unless the air is replenished by horizontal movement. Piles stacked solely by hand range from 9 to 16 feet in height. If mechanical aids or tramways are used, they may range from 20 to 30 feet in height (fig. 36). Lumber piled in packages may range from about 4 to 30 feet in height (fig. 32). Single packages from 4 to 5 feet high are sometimes placed in the yard. These are generally handled by straddle truck and not by fork-lift truck. One concern with specially built straddle trucks handles lumber in packages 6 feet wide and 12 feet high, both in the yard and in the kiln. The dimensions of the package were determined by the size of the kiln truckload. Piles made with fork-lift trucks may be six packages high. In this case, the two top packages are generally handled together.

Not only do tall piles result in retarded drying in the lower portions, but the excessive height of such piles places increased weight on foundations, stickers, bolsters, and boards in the lower parts of the pile. Sagging, breaking, and crushing of boards and stickers increase with increased loading. Additional height also increases the danger of tipping and falling because of the great height compared to the width. This is particularly true when there are poorly piled or displaced boards and stickers in the lower packages. Tipping of the piles may partially close the spaces between piles and retard air movement (fig. 37).

If the packages of lumber are to be kiln dried after air drying, the height of the packages will be determined by the height of the kiln truckloads and the number of packages making up this height.

Board Spacings--Flues and Chimneys

Since drying is brought about by the downward movement of air within a lumber pile, it is highly important to provide channels for this movement. Vertical movement in itself accomplishes little drying, except in the case of squares or edge-piled stock, but vertical movement through interior spaces induces horizontal air movement across the faces of the boards.

Spaces for the downward movement of air are obtained by leaving spaces between the edges of the boards. The wider these spaces with respect to the total width of the pile and the smoother the sides of the spaces, the greater will be the passage of air through them. These spaces are called flues, chimneys, or vents. Flues are less than 6 inches wide, while chimneys or vents are wider (figs. 35, 38, and 39). The sides of chimneys or vents may be straight or tapered so as to be wider at the bottom and narrower at the top. Flues, vents, or chimneys decrease the effective width of a pile. In other words, if a 2-foot chimney were built in the center of a 16-foot-wide pile, it would approximately change the 16-foot pile to two 7-foot piles. When lumber is sorted for width, it is easy to build a straight-sided flue between adjacent tiers of boards or between pairs of tiers with narrow boards. In the latter case, 2 tiers are placed edge to edge, and a space is left between them and the next 2 tiers of boards that are placed edge to edge.

With random-width stock, it is more practical to build fewer but wider chimneys or vents. The boards between these spaces are combined so that the total of their widths will be approximately the same from course to course and thus provide straight chimneys. It is necessary to separate some of the boards at the edges to accomplish this, but the majority are placed edge to edge. When very wide random-width stock is piled, it is more practical to build a wide, tapered central chimney than several narrow ones. A rough rule concerning the amount of flue or chimney space necessary in hand-stacked piles is that their widths should equal at least 20 percent of the width of the pile.

Boards piled in packages are often placed edge to edge, but this is impossible if very wide boards are made into narrow packages. One reason for edge-to-edge piling is that the packages are often placed in a cross-circulation kiln after air drying. Another justification for edge-to-edge piling is the narrowness of many of the packages. Boards piled edge to edge in packages 3-1/2 to 4-1/2 feet wide with good pile spacing in the rows have a drying rate comparable to boards in a wide hand-stacked pile with chimneys. In edge-to-edge piled packages, 6- to 8-feet wide, there is probably some retardation of drying.

When wide packages are destined to be dried in a cross-circulation kiln, it is better to design the package for the kiln than for the yard. One company built a central 1-foot chimney in a 7-foot package destined to be dried in a cross-circulation kiln (fig. 32). This chimney would increase the air-drying rate and would not interfere with the air movement through the lumber while in the kiln. The only disadvantage would be a slight loss of capacity. Lumber in packages destined to be air dried only is often piled with one inch to several inches between the edges of the boards. Also, lumber in packages that is to be kiln dried in natural-circulation kilns is piled with edge spacing. The openings between the edges of the boards are advantageous both for air drying and kiln drying.

Stickers

The strips or boards separating the layers or courses of lumber in a pile are called stickers or crossers. They may be separated into two classes, stock stickers and special stickers. Stock stickers are boards of the same kind of lumber that makes up the pile, but they are generally of the narrow widths. When stock stickers are used, the lumber is said to be self stickered (figs. 34 and 40).

Special stickers may be made from any species, but they preferably should be of heartwood material. Edgings are sometimes used for stickers. Many of these are of sapwood with a bark edge. The use of such material is not recommended because the sapwood may develop and harbor stain organisms and the waney edge causes variations in the widths of the bearing surfaces. Special stickers for hand-piled softwoods are often of lumber, nominally 1 inch thick by 4 inches wide. For hardwoods, they are nominally 1 inch thick by 1-1/4 inches wide. No matter what type of sticker is used, they should be of uniform thickness. Dressed stickers 25/32 inch thick are commonly used for hardwood lumber.

When stock stickers are used, the length of the boards used for stickers determines the width of the pile. Special stickers are generally cut several inches longer than the width of the pile. If the prevention of checking and staining is important, special stickers should be used. With low-grade stock, the use of stock stickers is justified not only because the loss from depreciation is small, but also because they permit faster and more economical piling. The use of stock stickers reduces the investment in special stickers and the cost of replacement, and it eliminates the handling and storing of stickers because the stock stickers are sold with the lumber when the pile is taken down. Special stickers should be at least thoroughly air dry in order to minimize blue stain, decay, and checking in the lumber they support. If green stickers are used, the portions of the boards in contact with them dry out more slowly and thus increase the danger of stain and decay-fungus development and, at the same time, of setting up shrinkage stresses that may result in checking.

The number and the position of stickers may have an important bearing on the development of drying defects. The number of stickers needed varies with the species, thickness, type, and grade of lumber. Lumber cut from a species that is prone to warp needs more stickers than lumber cut from other species. Thin lumber needs more stickers than thick lumber to reduce warping. Lumber that is susceptible to staining should be piled with a minimum number of dry and narrow stickers. High-grade lumber should be piled with more stickers than low-grade lumber of the same species. Basically, the function of the stickers is to provide columns for the support of the pile, to separate the courses of lumber, and to restrain warping by holding the boards in a flat position. The support of the pile should be accomplished by perfect alinement of the stickers with the crossbeams of the foundation, without crushing of the boards or stickers.

The presence of stickers is disadvantageous because it retards drying at the points of contact with the boards and interferes with horizontal air movement. As a consequence, the minimum number of stickers that will satisfy the requirements represents the optimum. Fewer stickers are used with softwoods than with hardwoods because softwoods generally do not warp so severely as hardwoods. Also, softwoods are often cut in greater thicknesses. Since fewer stickers are used with softwoods, they should be wider to provide bearing surfaces sufficient to avoid crushing. From 2 to 9 stickers are used with 16-foot softwoods. When 2 are used, they are spaced 8 to 9 feet apart, and the board ends are allowed to overhang at both ends of the pile. Although the limits are 2 to 9 stickers, 3 or 5 tiers of stickers are most commonly used for 16-foot lumber. The limits for 16-foot hardwood lumber are 5 to 17 stickers. A spacing of 16 inches to 2 feet is common for hardwood lumber.

Stickers should be in good vertical or nearly vertical alinement. The alinement should follow the pitch of the pile in pitched hand-stacked piles (fig. 41). If the stickers are not in good alinement, the weight will not be transmitted from one to another by direct compression but will act on the span of the boards to cause sagging. Sagging results in warped boards. Since sticker guides (fig. 42) are only infrequently used in hand stacking yard piles, the alinement of the stickers depends on the care and skill of the workmen.

Thicker or doubled-up stickers are sometimes used in the lower part of a hand-stacked pile (fig. 43). The wider spaces between lumber courses promote horizontal air movement in this slowly drying part of the pile.

In packages, special stickers are used almost exclusively. Generally, the narrowness of the package prohibits the use of stock stickers. Special stickers for packages are generally made from nominal 1-inch stock dressed to about 25/32 inch. The width ranges from 1-1/4 to 4 inches. The sticker should be several inches longer than the width of the package. The number of stickers used in packages is about the same as that used in hand-stacked piles. Stacking racks or jigs are generally used in building packages (fig. 44). The jigs are equipped with sticker guides on one side and occasionally on both sides. Jigs equipped with guides on both sides are constructed so that one side can be opened readily to permit the insertion of the forks for removal of the package when it is completed.

Sticker guides are more essential for making packages of lumber than hand-stacked piles. Guides not only assure good sticker alinement within a package, but they also regulate the sticker spacing so that it will be uniform from package to package. Uniform sticker spacing is necessary if good alinement of stickers, bolsters, and crossbeams is to be obtained in a pile consisting of several packages. Although most packages are stacked by hand, semiautomatic or mechanical stackers are sometimes used. These stackers carry sticker guides that assure good sticker alinement and uniform spacing. Good alinement of stickers is needed to prevent sagging and breaking of boards (fig. 45).

Stickers will also reduce end checking and splitting of boards in air-yard piles. Stickers placed close to ends eliminate or reduce the overhang of the boards. Overhanging or projecting boards are susceptible to end checking and splitting and also to surface checking and warping (fig. 46). Placing stickers flush with the ends and allowing them to project slightly reduces the amount of end checking and splitting. Projecting stickers retard the drying from the board ends and shelter the ends from sunshine and rain. Rapid end drying along with alternate drying and wetting invite end checking.

In building a pitch into a hand-stacked pile, it is natural to place the first sticker with its front edge projecting slightly beyond the ends of the boards of the course on which the stickers rest (fig. 43). This is one way of obtaining the proper pitch of the pile. It is better, however, if the first tier of stickers is made to project somewhat more than is necessary to obtain the required pitch. To accomplish this, it is necessary to use extra-wide stickers for the first tier. When the boards are trimmed before piling, the stickers can be placed so that they project beyond the ends of the boards at the rear of the pile also. When the boards in a pile are not trimmed to exact lengths, the rear stickers should be placed as close as possible to the rear ends of the boards.

Pile Roofs and Sheds

A good pile roof has always been considered an essential feature of good air-drying practice, unless very low-grade lumber is involved. A roof shields the upper lumber courses and, to a lesser extent, the lower part of the pile from direct sunshine and precipitation. Without a roof, the upper courses, and particularly the top course of lumber become warped and checked, and rain is permitted to penetrate the pile from the top or to drive in from the ends and sides. Rain penetrating the pile may retard drying, contribute to the development of blue and sticker stain, and have an adverse effect on surface checks that may be present in the lumber. A leaky roof will afford protection against direct sunshine, but it will permit water to wet the upper lumber courses and penetrate the pile.

To afford maximum protection, a roof should project beyond the ends and sides of the pile. For a hand-stacked, sloped pile, the roof should project about 1 foot at the front, 2-1/2 feet at the rear, and 6 inches at the sides (fig. 47). For a level pile of packages, the roof should project about 2 feet at both front and rear ends and about 6 inches on one side. It is generally not feasible to have the roof of the top package project on the side towards the machine because it will come in contact with the vertical members of the forks.

A roof should be pitched so that the water will run from front to rear and drip off the rear edge. The extension of the roof 2 to 2-1/2 feet over the rear end of the lumber pile allows the drip to fall free. With hand-stacked piles, the pitch of the roof should follow the slope of the pile if the roof is reasonably tight. If the roof is not tight, the pitch should be increased to about 1 in 9 rather than 1 in 12.

Various methods are used in constructing and placing pile roofs. Roofs are commonly made from low-grade lumber. The boards may be placed in single layer, single length; double layer, single length; or double layer, double length. To lay a double-layer, double-length roof, 2 crosspieces about 4 by 6 inches or the equivalent are placed on the top course of lumber directly over the rear and center tiers of stickers. For a 16-foot pile, a layer of boards which are at least 11 feet long is laid on the crosspieces with narrow spaces between the board edges. The ends of these boards should project about 2-1/2 feet beyond the rear crosspiece and about 6 inches beyond the center crosspiece. A second layer of similar boards is laid to cover the spaces in the first layer. The front portion of the roof is made up of boards at least 9-1/2 feet long laid in like manner. The rear end of the boards of the front part of the roof rests upon the front end of the rear portion, which it overlaps by about 1 foot. If the front portion of the roof is composed of boards longer than 9-1/2 feet, the projection at the front of the pile, usually about 1 foot, or the amount of overlap at the center may be increased.

To obtain the proper roof pitch, the crosspiece at the front of the pile above the first tier of stickers should raise the roof about 8 inches from the top course of lumber. It is advisable to fasten down the roof as a precaution against its being blown off by wind. Tie pieces of 2 by 4 or 4 by 4 inches can be laid crosswise at the front, middle, and rear and fastened by wires or springs to the pile about 10 courses below the top.

Package piles may also be supplied with roofs consisting of a double layer of boards. Since package piles are generally horizontal, the matter of providing sufficient pitch to the roof is more difficult than with a sloped hand-stacked pile. To obtain a roof pitch of 1 to 12 on a 16-foot pile, a roof of a double layer of boards would have to be elevated 18 inches at the front end for a single-section roof and 20 inches for a double-section roof, if the rear end was elevated 2 inches. Since this does not appear to be practical, a flatter pitch will have to suffice for loose board roofs on horizontal or level package piles. Because of the difficulty in obtaining sufficient pitch in roofs on horizontal piles, roofing package piles with double layers of boards is not as satisfactory as roofing sloped hand-stacked piles, unless the package piles are also sloped. The roofs on horizontal package piles should project 18 to 24 inches at both ends. For a sloped and pitched package pile, the roof projection at the ends should be the same as for a hand-stacked pile. A roof on a package pile can project only on the side that is furthest from the vertical members of the lift of the truck when the package is lifted. A roof for a package pile can be placed on the top package while it is still at ground level.

Building paper or roll roofing may be laid directly on the top course of a package pile, or it may be combined with boards to form a pile roof. The paper or roofing provides watertightness, while the boards support the paper or roofing in a flat sheet and permit the roof to be anchored to the pile. The boards in this type of roof should be laid roughly edge to edge in a single layer. The building paper or roll roofing can be held down by boards laid upon it or by the tie pieces. Since this type of roof is tight, the pitch can be flatter than in one composed of a double layer of overlapping boards. A combination of building paper or roll roofing and boards is probably more feasible with piles of packages than with hand-stacked piles.

The paper or roll roofing can be laid in strips running either the width or the length of the pile. When laid crosswise, they should be lapped like shingles and held down by three or more tie pieces running the length of the pile. When the strips are laid lengthwise, a tie board should be placed over each lap. This last method approaches a scheme that would consist of a double layer of boards with paper or roofing between the layers. The boards of each layer would be laid with several inches between the edges. With a roof of this type there would be no need for the front part to overlap the rear part.

There is a wide variety of papers and roofing on the market, and the choice of a suitable material should be based on the life of the material with reference to the length of time the pile is to stand in the yard. The most economical scheme probably would be to discard the paper or roofing when the pile is taken down.

Panel-type roofs are best for package piles. The panels may be made full length or in pairs (fig. 48). The panel may be designed to slope from one end to the other or from the center towards both ends. Boards may be nailed to a light wooden framework of 2 by 4's or 2 by 6's and covered with tightly fastened roll roofing or building paper. When a pair of panels is used, they overlap at the center and slope toward both ends. Sheets of corrugated galvanized steel or aluminum may be fastened to a wood framework to form panels. The panel roofs are placed on the top package while it is still on the ground. Fork-lift trucks are used to place full-length panels, but the single panels of pairs can be handled manually.

Marine or exterior-grade plywood and other types of composition building boards may offer possibilities in the construction of pile roofs. The material could be made into segments or units capable of being handled by two men. The units could be placed like shingles and anchored by tie pieces. These materials would make a good pile roof, but the service life is not known. Long life would probably be required to justify the initial high cost.

Corrugated galvanized iron or steel is used for pile roofs. The sheets may be fastened to a wooden framework and placed in position by mechanical means, or the individual sheets may be placed manually. The sheets are laid like shingles and anchored by tie pieces.

All roofs for air-drying piles are only substitutes for a shed roof (fig. 49). Lumber piles in a shed are afforded the maximum protection from sunshine and precipitation. An open-sided shed resembles an air-drying yard, except that the shed roof takes the place of all of the pile roofs. All lumber may be piled horizontally in a shed, since nothing is gained by sloping or pitching. In sheds that are wholly or partially closed, the lumber may dry somewhat more rapidly than in a yard because the mean temperature within the shed is generally a few degrees higher than the mean temperature out of doors. If enough ventilation is provided to get rid of the moisture coming from the lumber, the relative humidity within the shed will be a trifle lower than the relative humidity outside. Foundations for shed piles should be similar to those for yard piles, but no slope is required.

Drip Boards and Sun Shields

Drip boards and sun shields on hand-stacked piles may be considered as adjuncts to roofs. Drip boards (fig. 50) are used to replace 3 to 4 stickers at the rear end of a sloped and pitched pile. They can be used only where the board ends are flush with the rear of the pile. The drip boards project several inches beyond the back face of the pile to catch rain that may elude the overhanging roof. The rain falling on the drip boards generally drops to the ground or onto lower drip boards instead of entering the rear end of the pile. Drip boards are not in common use.

Since a pile roof projecting 1 to 2-1/2 feet at the end of a pile does not protect the ends of all of the boards from direct sunshine, sun shields (fig. 51), made of boards arranged like louvers, are used to protect the ends of all boards except those near the top. The boards of the shield may be attached to the end of the pile or to a special portable framework. Shielding the board ends reduces the tendency to end-check under the heat of the sun. Shielding from the sun should not be confused with boarding up the pile to retard drying.

End Coatings

Although end checking and splitting are reduced by projecting stickers and sun shields, the application of a moisture-resistant coating to the ends of the boards is a better preventive measure. End coatings retard the drying of the ends and thus reduce the tendency to check. End coatings should be applied to fresh lumber before the ends have started to check. There are two general types of end coatings, hot and cold. Hot, melted coatings can be applied best by dipping. If the pieces are too large to dip, a cold coating may be applied by brush or spray. With both types of coatings, it is essential to put on enough to form a layer of adequate thickness. There are numerous coatings on the market. It is seldom feasible to end-coat 1-inch boards, but with thicker lumber, the material saved through the reduction of end checking and splitting may more than pay for the coating and its application.

Other Piling Methods

The methods of hand stacking already described may be called flat piling. Other methods of piling that have more or less limited use are end piling and end racking. End piling (fig. 52) is approximately the equivalent of tilting a flat pile until the boards are in an almost vertical position. In end racking (fig. 53) the boards are placed upright and cross each other to form an "X" or an inverted "V." The row of crossed boards is supported by a framework. With both end piling and end racking, it is important to support the lower ends of the boards above the ground surface. The lower ends of end-piled boards commonly rest on a wooden platform made of edge-spaced boards. In end racking, the lower ends of the boards usually rest on timbers or planks placed on the surface of the ground. Both of these piling methods have disadvantages and advantages over flat piling. End piling and end racking can be done by 1 man while the flat piling generally requires at least a 2-man crew. Occasionally, unit packages are built at the side of the green chain by one man. End piling and end racking promote rapid surface drying and consequently reduce the likelihood of staining.

With end piling, most of the weight is carried by the lower end of each board instead of the stickers, so the stickers do not act to reduce warping. For this reason, end piling reduces warping caused by sagging, but promotes warping caused by natural shrinkage. End-piled lumber is not generally roofed. Both end-piled and end-racked lumber is more susceptible to checking and warping than flat-piled lumber, particularly in the exposed upper ends. End-racked lumber is often placed in flat piles after a short period of drying.

Although package piles are generally built by using fork-lift trucks, packages are also handled and piled with several types of cranes. No matter how the packages are piled, a piling technique that conforms to the features of good air-drying practice should be adopted.

Air-Drying Defects and Their Control

The object in air drying is to dry the lumber rapidly to a minimum moisture content consistent with climatological conditions with a minimum of drying defects. The amount of drying defects and consequent degrade and loss in value is one measure of the success of the air-drying operation. Air-drying defects may be divided into those caused by shrinkage and its variations and into those caused by stain, mold, and decay. Under the first category are surface, end, and honeycomb checking, splitting, and warping, while under the second are fungus stain (blue or sap), chemical stain, decay, and mold.

Checking

Checking can be reduced somewhat by retarding drying. Placing piles closer together, placing the boards closer together, reducing the size of flues or chimneys in hand-stacked piles, building wider piles, reducing the thickness of the stickers, placing the stickers so that they project over the board ends, using end coatings, avoiding projecting board ends, and shielding the pile against wind, rain, and sun will all reduce checking. Roofing is the most effective shield against rain and sun, but shields at the pile sides or ends may be used also.

Warping

Warping is caused by differential shrinkage, poor piling technique, or exposure to sunshine and rain. A mechanically strong pile foundation with crossbeams beneath the tiers of stickers tends to reduce warping. Box piling, sufficient and well-alined stickers of uniform thickness, and good pile roofs help to reduce warping. Weighting the tops of piles tends to hold the boards in the top courses flat. Good piling tends to overcome the natural tendency of boards to warp by compelling the boards to remain flat. Poor piling not only allows the boards to acquire their natural warp but causes additional warp by subjecting them to loads. Unsupported boards sag under their own weight and under loads imposed on them due to lack of alinement of foundation crossbeams, bolsters (in package piles), and stickers. When the boards are dry, the sag is retained as warp.

Staining

Rapid drying tends to reduce both types of staining. The fungi that causes blue or sap stain primarily in sapwood cannot grow in wood whose moisture content is less than 20 percent. Retarded drying favors the growth of bluestain fungi and mold. Mold stains the surfaces of boards but does not penetrate like blue stain. Chemical stain, which usually takes the form of sticker stain, results from the oxidation of the constituents of the sap. It is a grey to black discoloration that interferes with the use of the lumber for flooring or furniture where natural or light finishes are desired. Under retarded drying and with certain patterns of moisture distribution and flow, the constituents or extractives of the sap become concentrated and this creates a favorable condition for the development of the stain. The lack of protective pile roofs encourages both types of staining because precipitation retards drying and creates particularly wet spots by collecting at the points where the stickers cross the boards. Both blue stain and chemical stain develop more rapidly during warm than during cold weather.

Since rapid drying reduces staining, one of the means of combatting stain is to encourage rapid drying. Decreasing the widths and heights of the piles in a hand-stacked yard, increasing the size of the spaces between piles and between the rows in a machine-piled yard, keeping the yard free of vegetation and debris, using pile foundations of open construction and proper height, building more vertical flue space, and using thicker stickers are ways of encouraging rapid drying. Piling lumber within an open shed or providing good pile roofs protects the lumber from wetting and thereby encourages rapid drying. Blue or sap stain can be prevented largely by dipping the green lumber in a solution of an antistain chemical.[5] Boards are often dipped as they pass along the green chain by submerging them in a trough containing the solution (fig. 54). Even dipped lumber may stain, however, if drying is retarded greatly or if the lumber is subjected to repeated wettings. Dipped lumber may show a bright surface but a stained interior.

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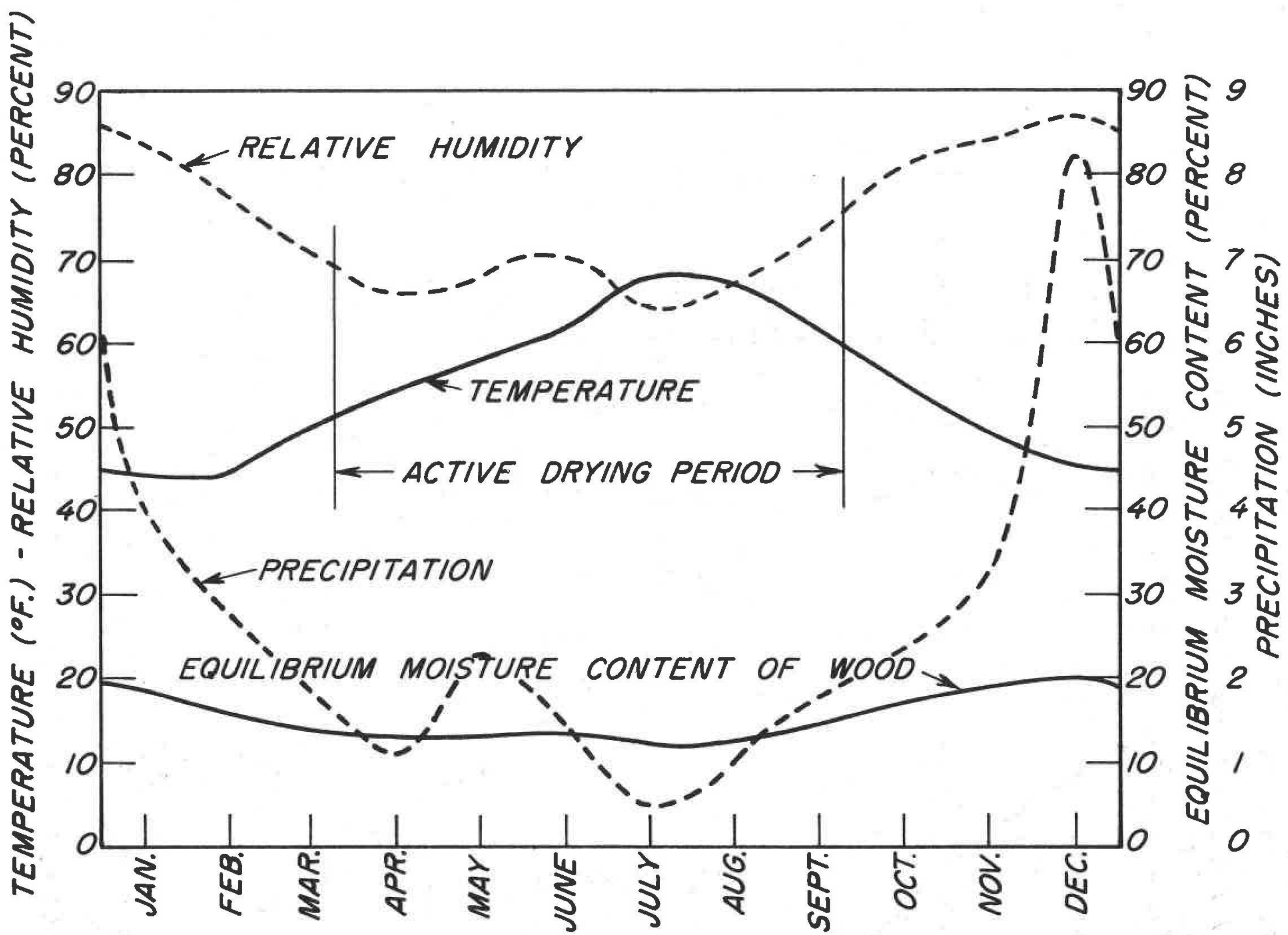
[5] Scheffer, Theodore C. and Lindgren, Ralph M. Stains of Sapwood and Sapwood Products and Their Control. U. S. D. A. Technical Bulletin No. 714. 1940.

Table 1.--Equilibrium moisture content of wood exposed to outdoor atmosphere in the United States and Territories

Location	Equilibrium moisture content[1]											
	January	February	March	April	May	June	July	August	September	October	November	December
	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Portland, Maine	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, N. H.	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, Mass.	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, R. I.	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, Conn.	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, N. Y.	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, N. J.	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, Del.	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, N. C.	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, S. C.	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, Fla.	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, Ohio	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, Ind.	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, W. Va.	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, Tenn.	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, Ala.	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, Miss.	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, Mich.	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, Wis.	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, Ill.	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, Iowa	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, Ark.	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, Minn.	15.5	15.2	16.0	12.8	12.7	14.9	14.8	16.1	16.5	13.9	15.9	16.9
Bismarck, N. Dak.	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, S. Dak.	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, Nebr.	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, Kans.	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, Okla.	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, Tex.	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, Mont.	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, Wyo.	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, Colo.	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, Utah	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, N. Mex.	9.2	8.1	8.0	6.9	6.3	5.7	7.9	7.7	7.1	6.9	10.5	11.1
Tucson, Ariz.	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, Idaho	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, Nev.	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, Wash.	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, Oreg.	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, Calif.	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, Alaska	19.8	20.2	17.9	15.8	16.3	14.8	16.2	18.2	21.4	....	22.0	18.6
San Juan, P. R.	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, T. H.	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 the average monthly temperatures and relative humidities given in Climatological Data monthly reports for 1952 and 1953 of the Weather Bureau, and wood equilibrium moisture content diagrams.



Z M 85747 F

Figure 1. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in the Douglas-fir region of western Washington and western Oregon.

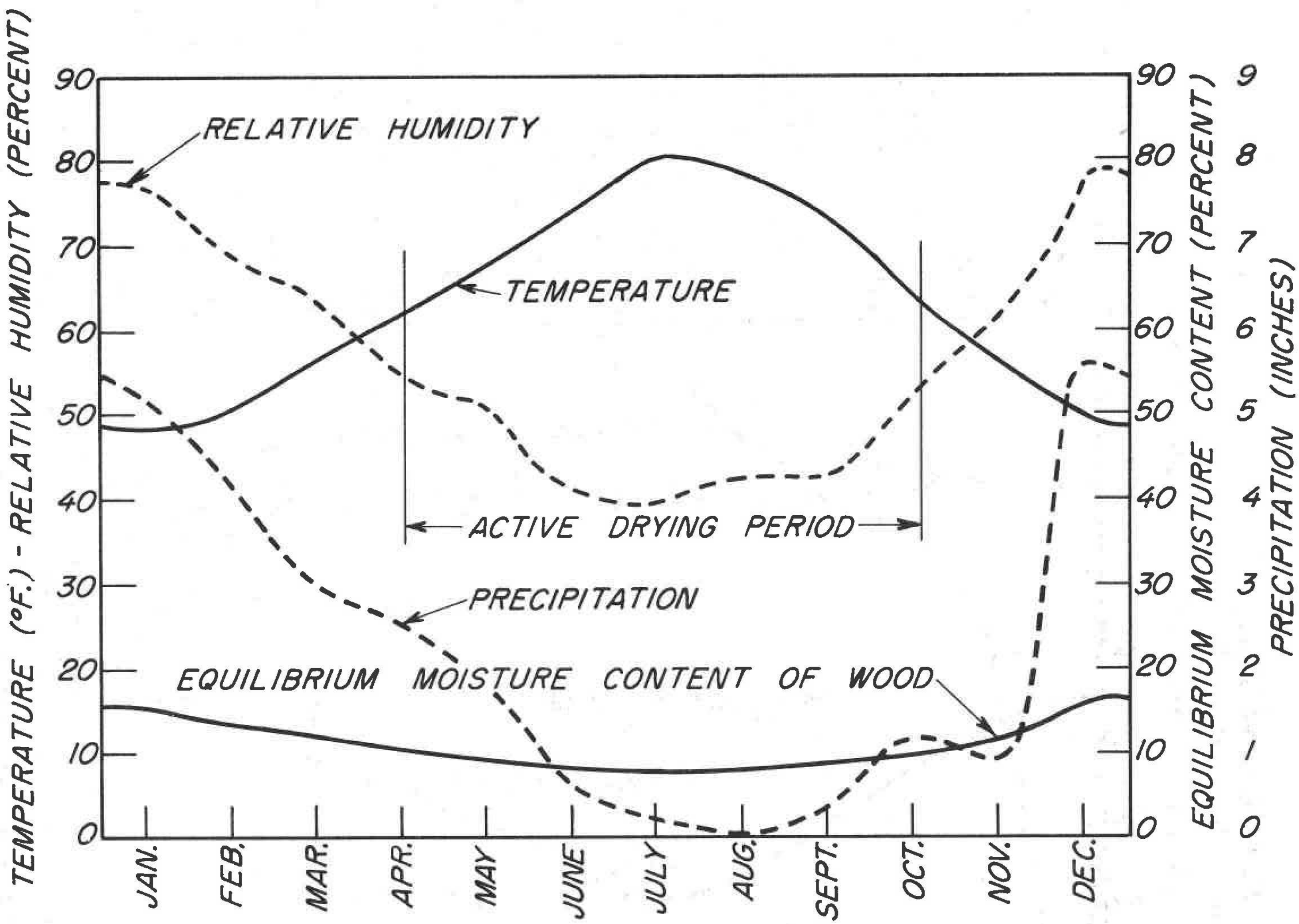


Figure 2. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in California pine region.

Z M 85748 F

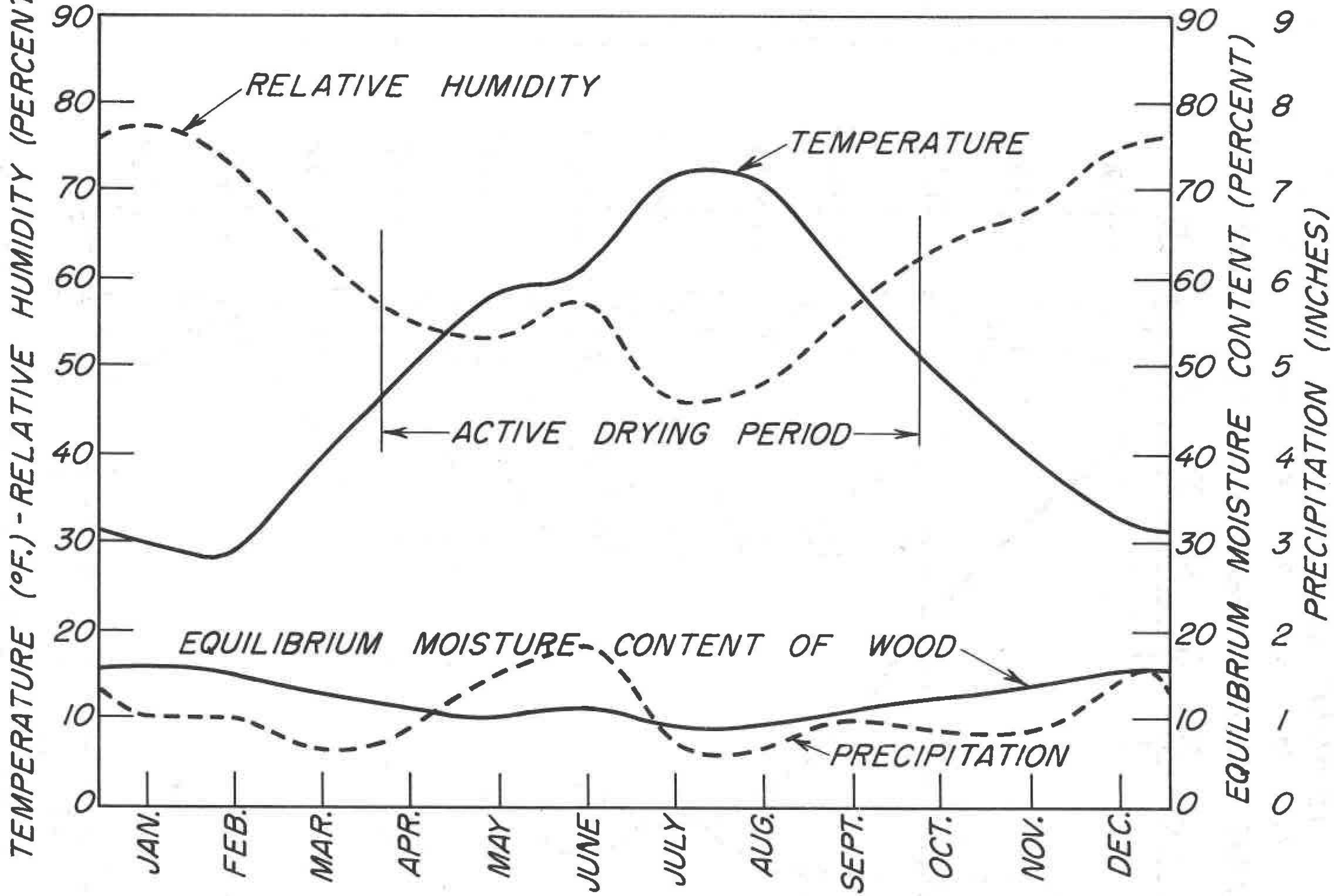


Figure 3. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons of eastern Washington, eastern Oregon, Idaho, and Montana.

Z M 85749 F

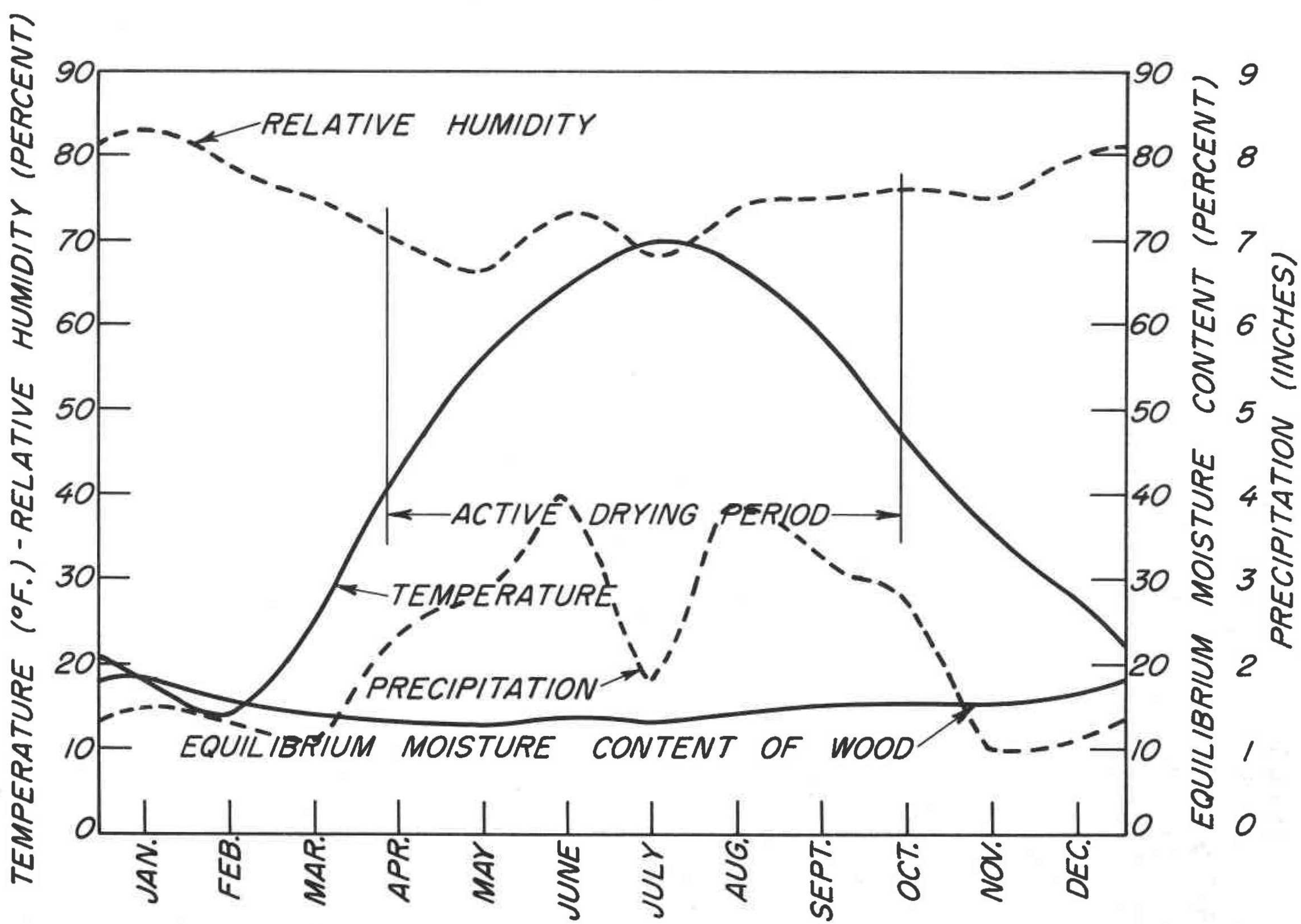


Figure 4. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in northern Michigan, northern Wisconsin, and Minnesota.

Z M 85750 F

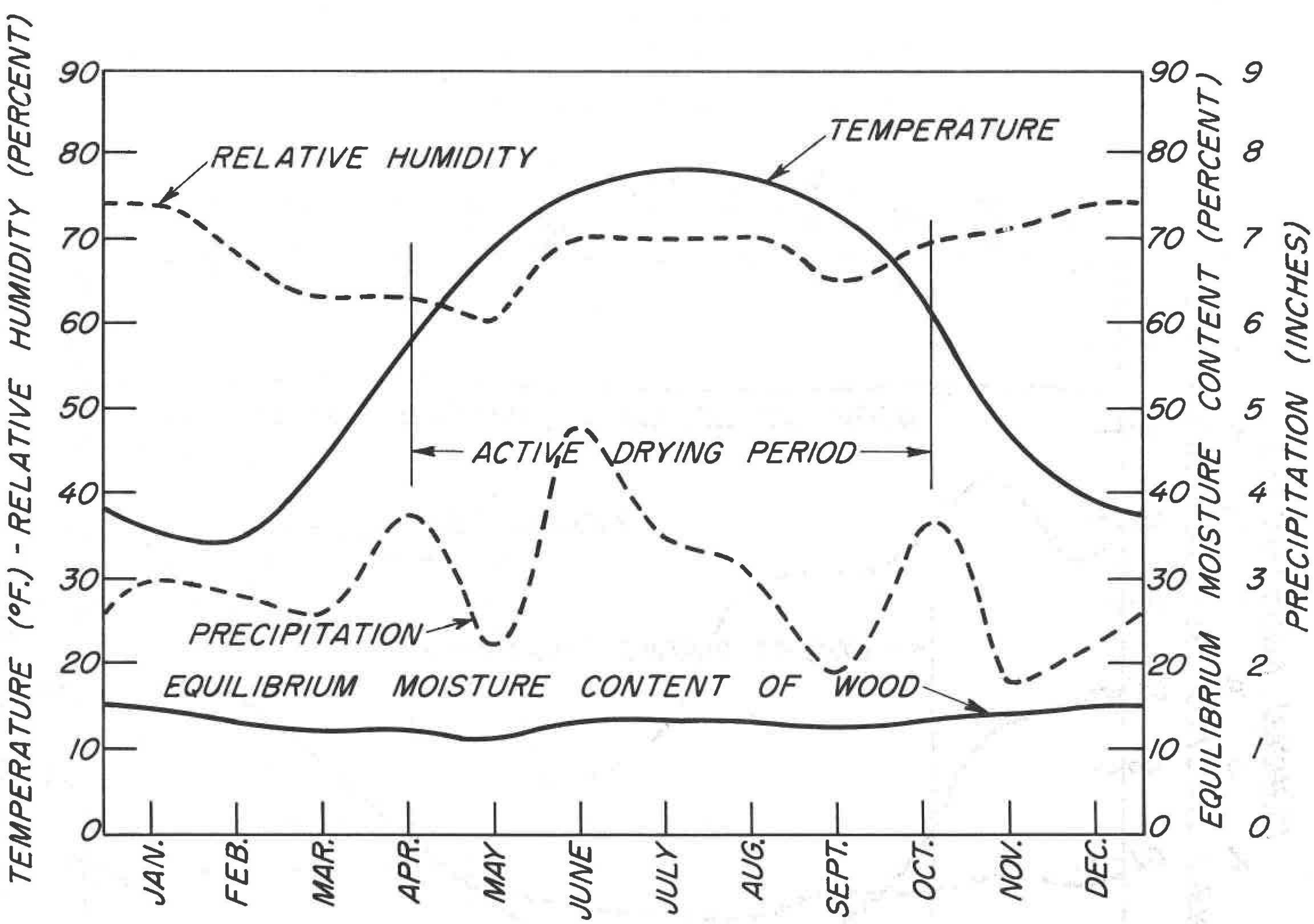


Figure 5. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in Missouri, Kentucky, Ohio, Indiana, Tennessee, and Pennsylvania.

Z M 85751 F

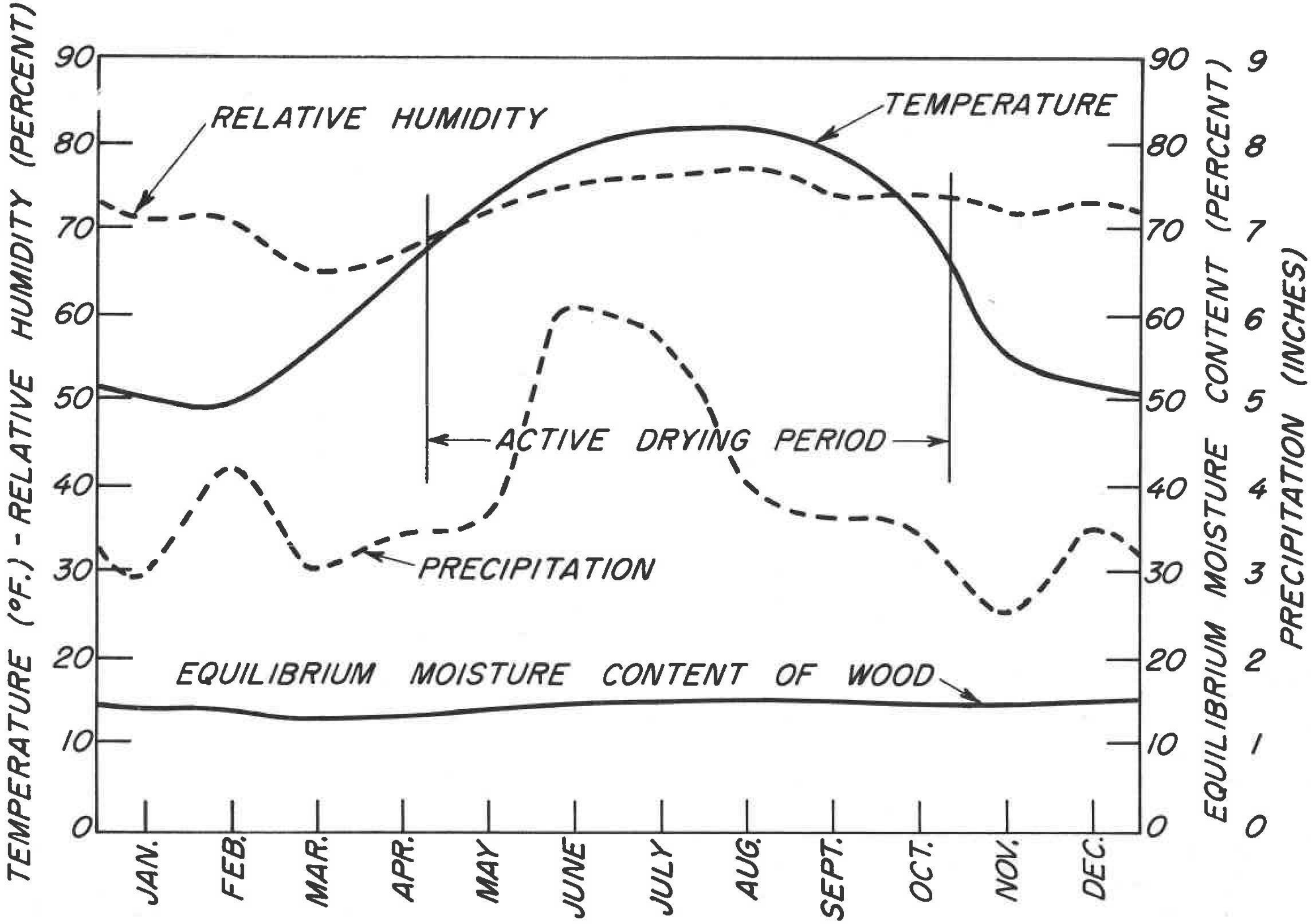


Figure 6. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in eastern Texas, Louisiana, Mississippi, Georgia, northern Florida, and Arkansas.

Z M 85752 F

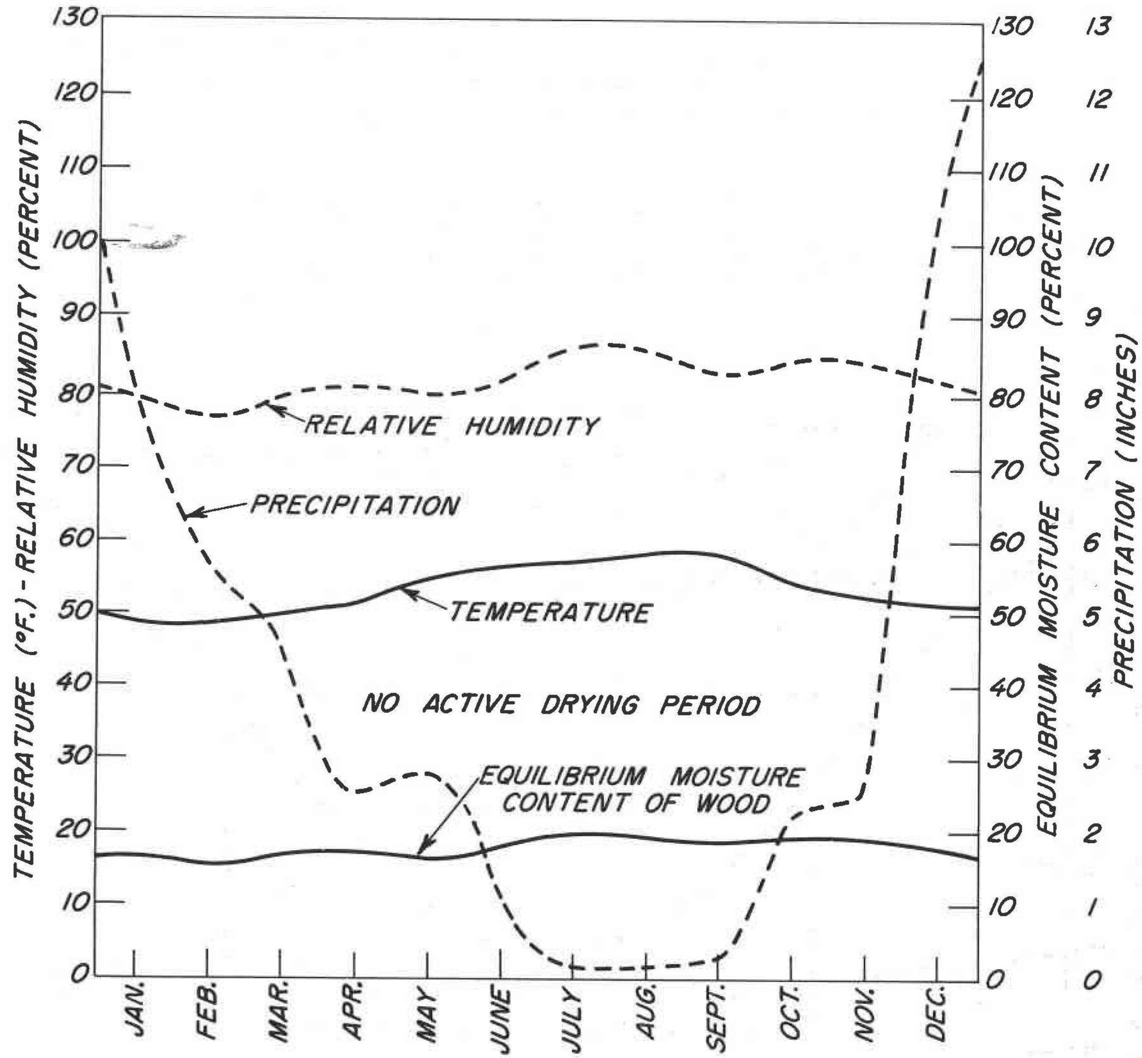


Figure 7. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in the redwood region.

Z M 85753 F

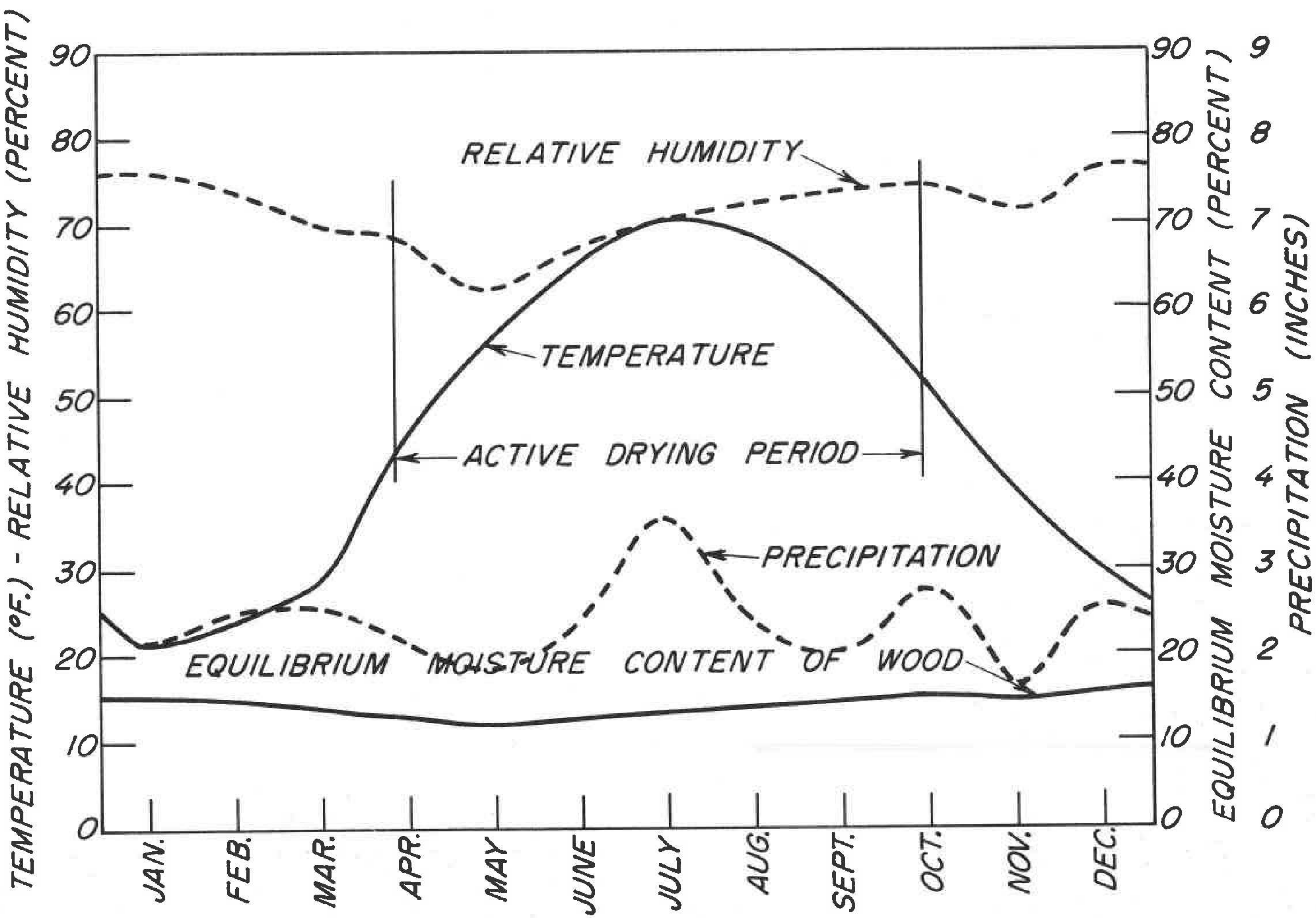


Figure 8. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in northern New York, Vermont, New Hampshire, and Maine.

Z M 85754 F

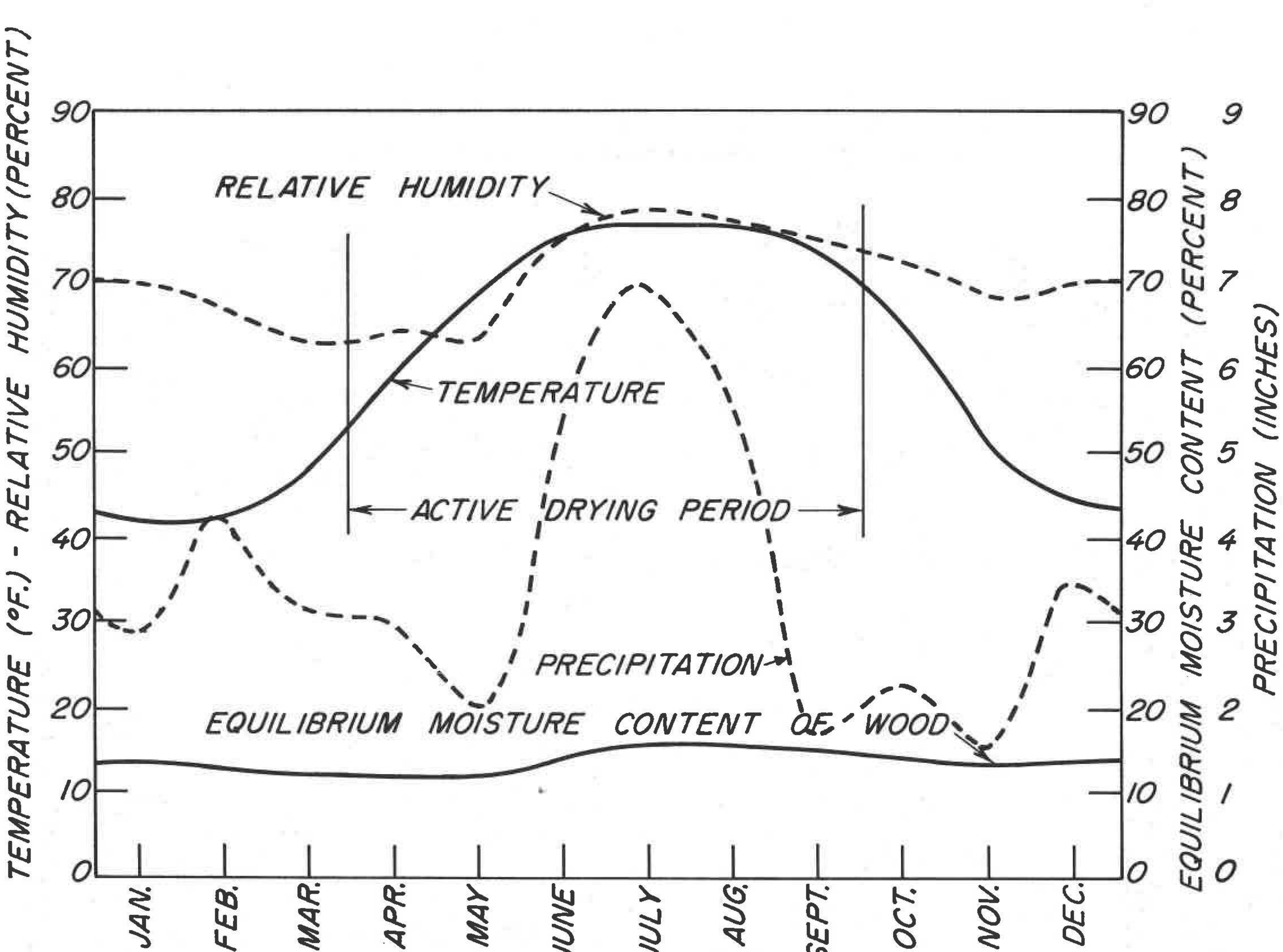


Figure 9. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in North Carolina, South Carolina, Virginia, and West Virginia.

Z M 85755 F

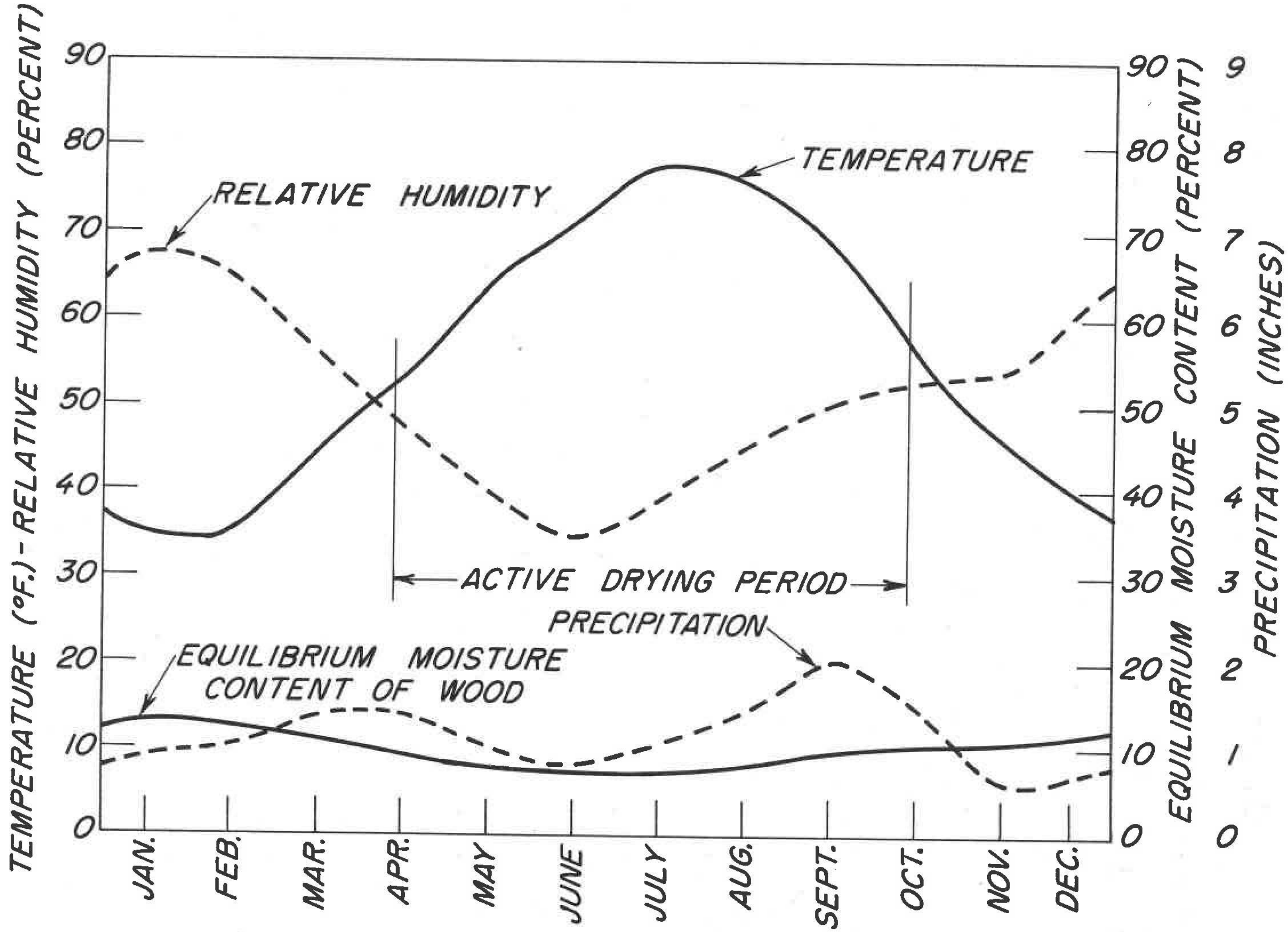


Figure 10. --Mean monthly temperatures and relative humidities, precipitation, equilibrium moisture content of wood, and the active drying seasons in Colorado, Utah, Arizona, and New Mexico.

Z M 107 774

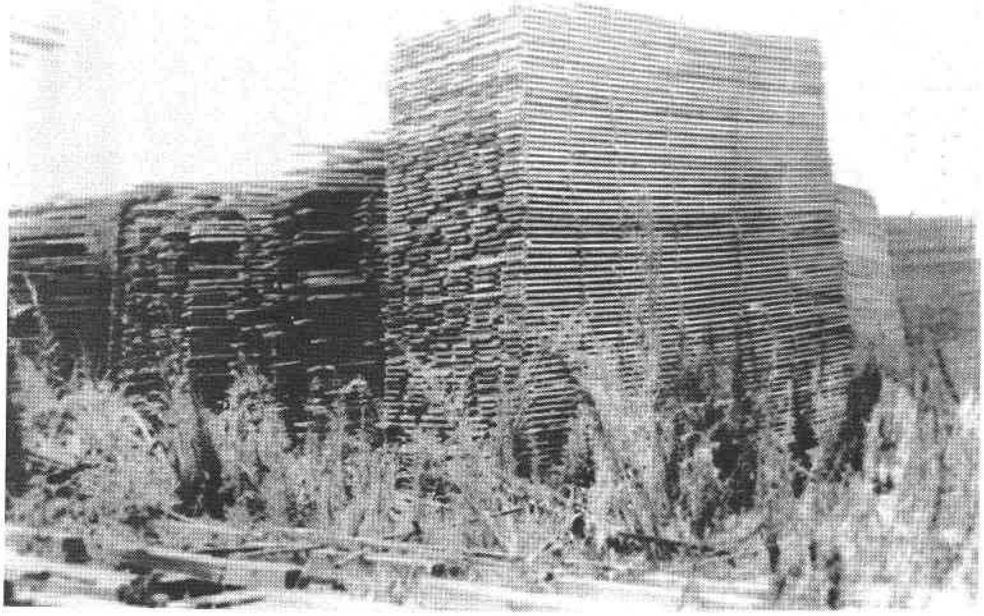


Figure 11. --Poor sanitation is apparent in this air-drying yard. The retarded drying and loss from stain and decay due to the choking off of circulation by the weeds would more than pay the cost of maintaining the yard in good condition.

Z M 107 775

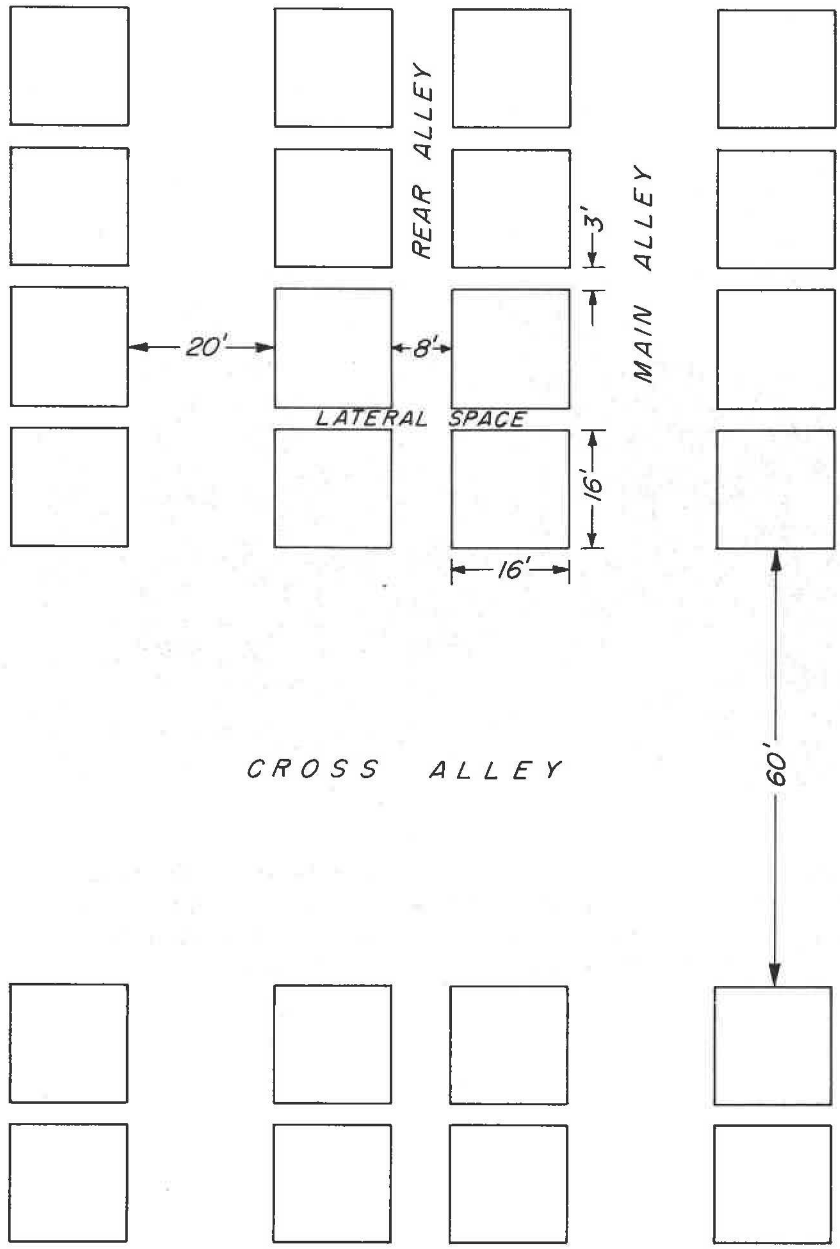


Figure 12. --This diagram shows a small portion of yard with hand-stacked piles.

Z M 84592 F

Figure 13. --A main alley in a yard of hand-stacked piles. The freedom from vegetation permits the maximum movement of air over the yard surface and beneath the piles.

Z M 107 776

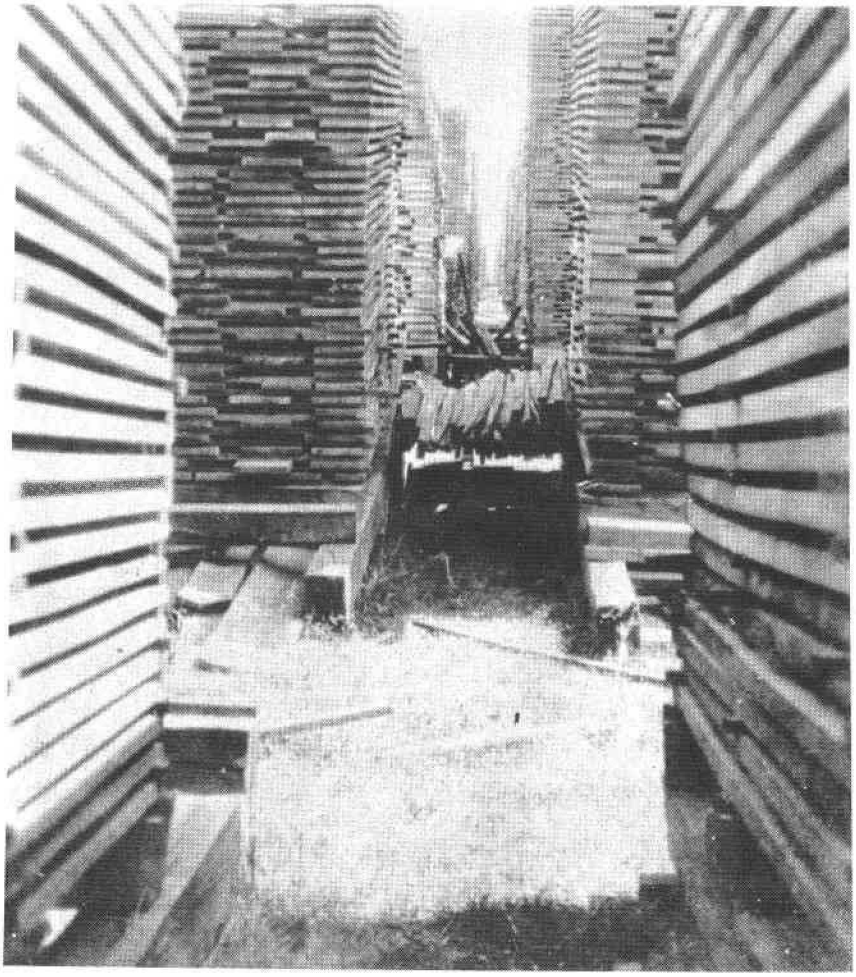


Figure 14. --Lateral spaces between hand-stacked piles allow straight passage for the movement of air through the yard.

Z M 107 777

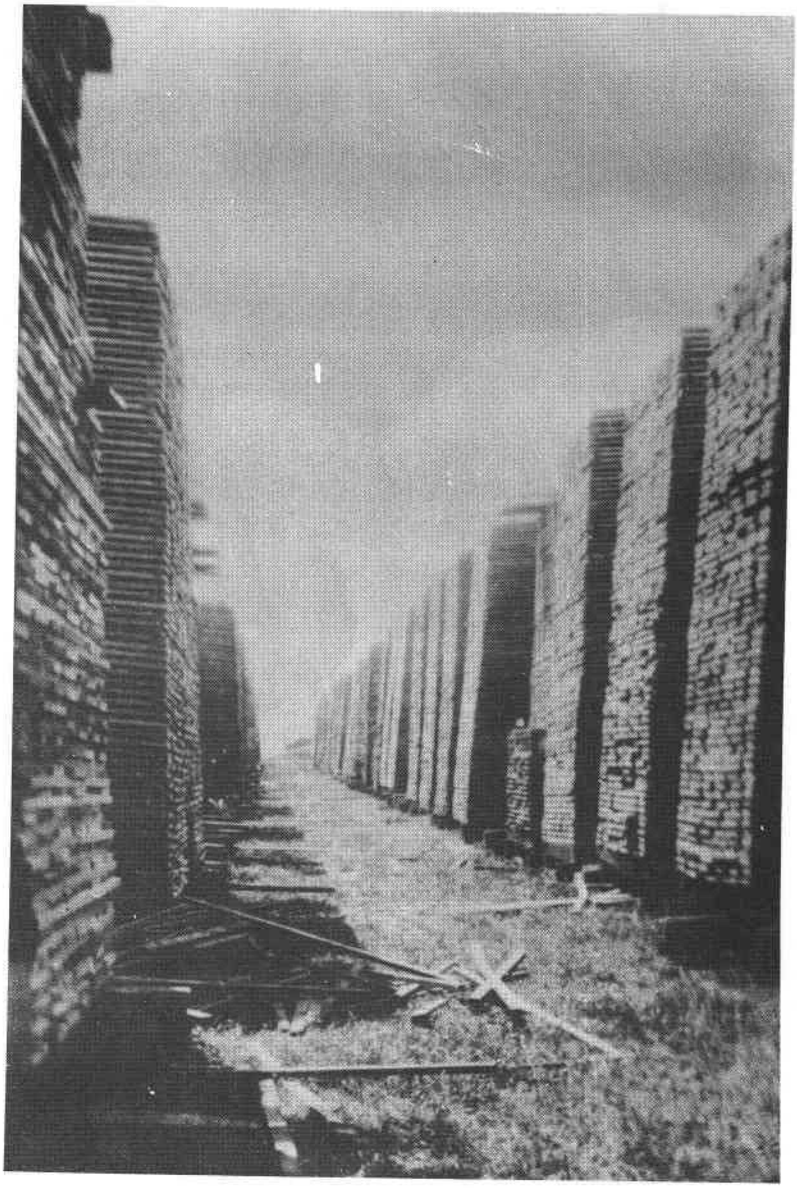


Figure 15. --A rear alley was provided in this yard of hand-stacked piles.

Z M 107 778

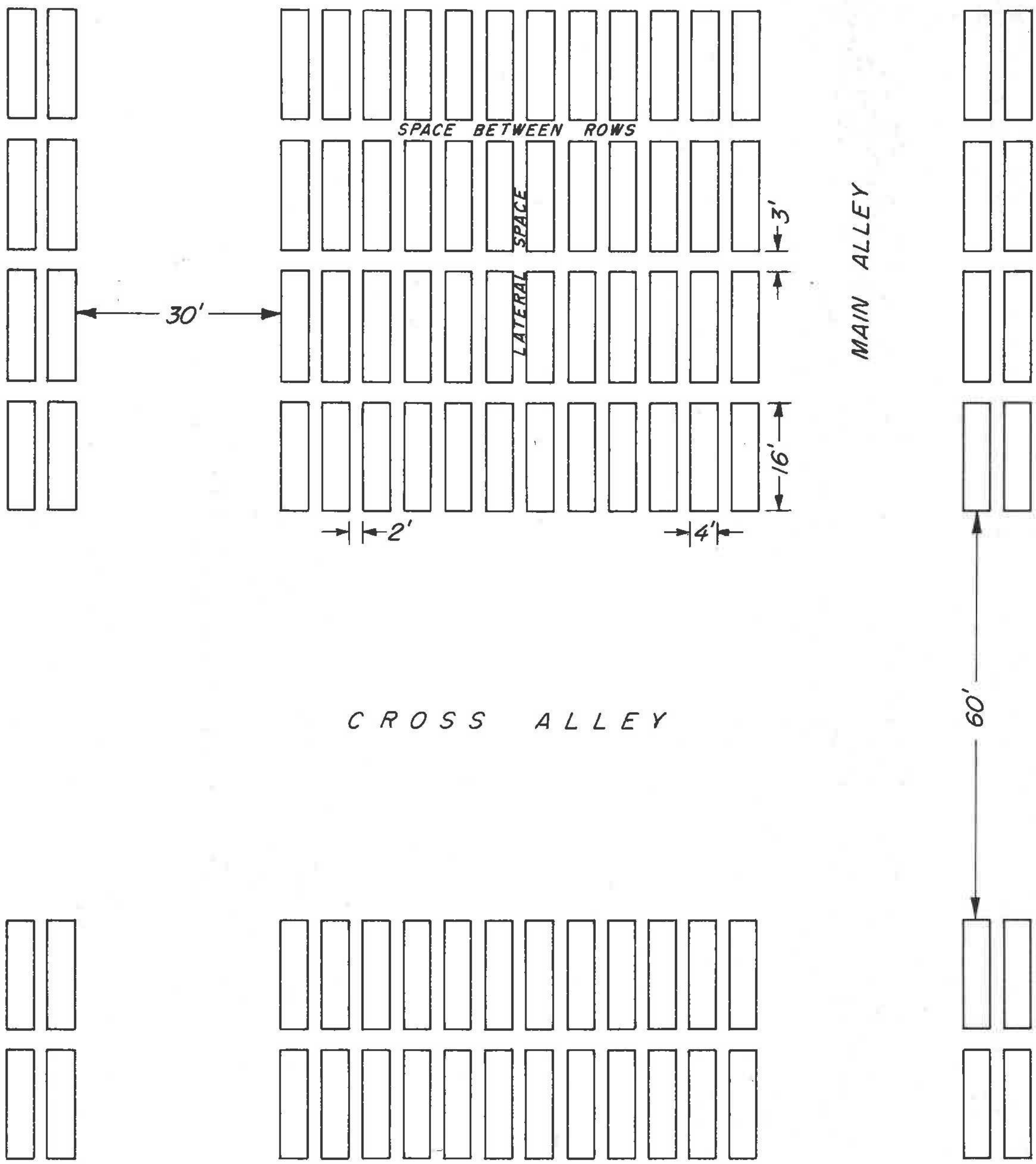


Figure 16. --Diagram showing a section of a yard with package piles.

Z M 107 779

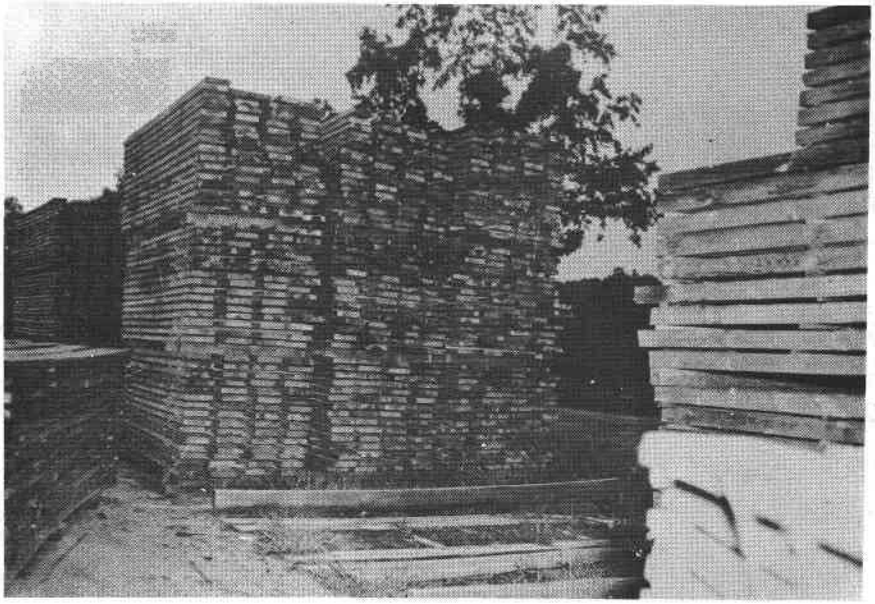


Figure 17. --The ground clearance in this row of package piles is inadequate, because the foundation consists merely of two timbers resting directly on the ground.

ZM 83674 F

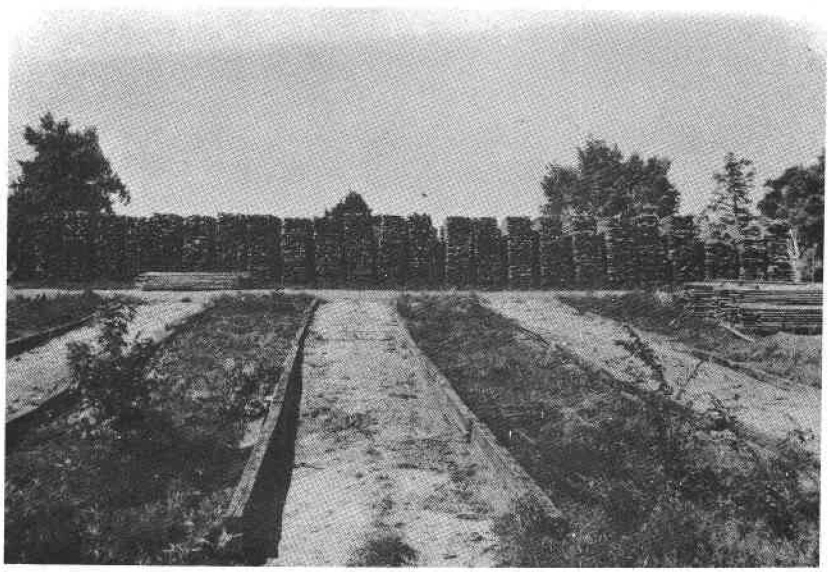


Figure 18. --The pile foundations in this yard consist of timbers spaced 9 feet apart to permit the use of a fork-lift truck.

ZM 83677 F

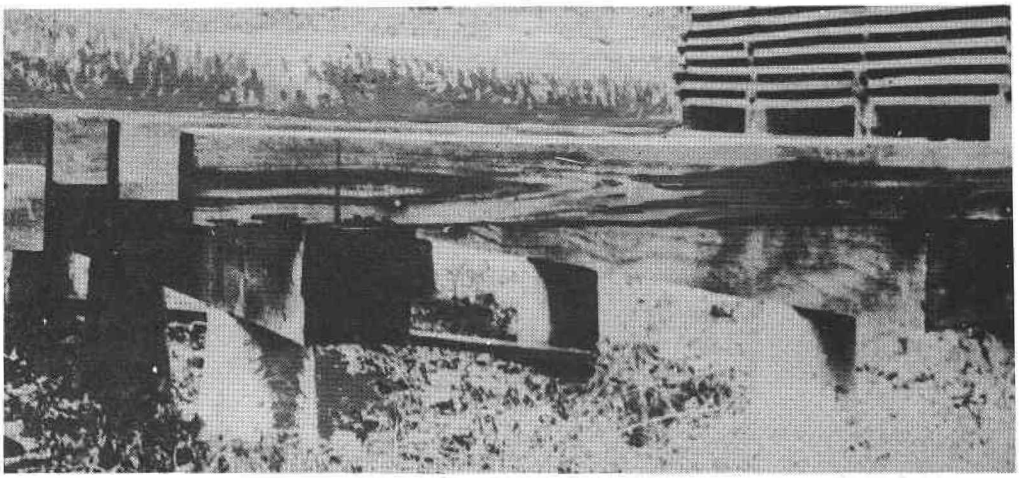


Figure 19.--This foundation for hand-stacked piles consists of concrete piers, stringers, and crossbeams and provides ample ground clearance.

Z M 107 780

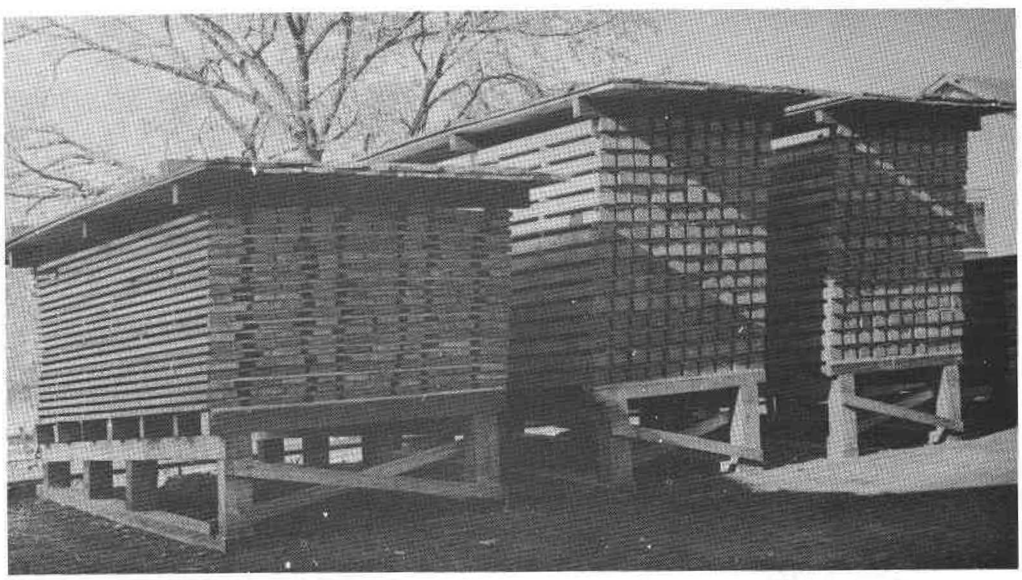


Figure 20.--When the piers of relatively narrow pile foundations do not extend into the ground, they should be braced to prevent lateral tipping. These experimental piles illustrate most of the features of good air-seasoning practice.

ZM 98089 F

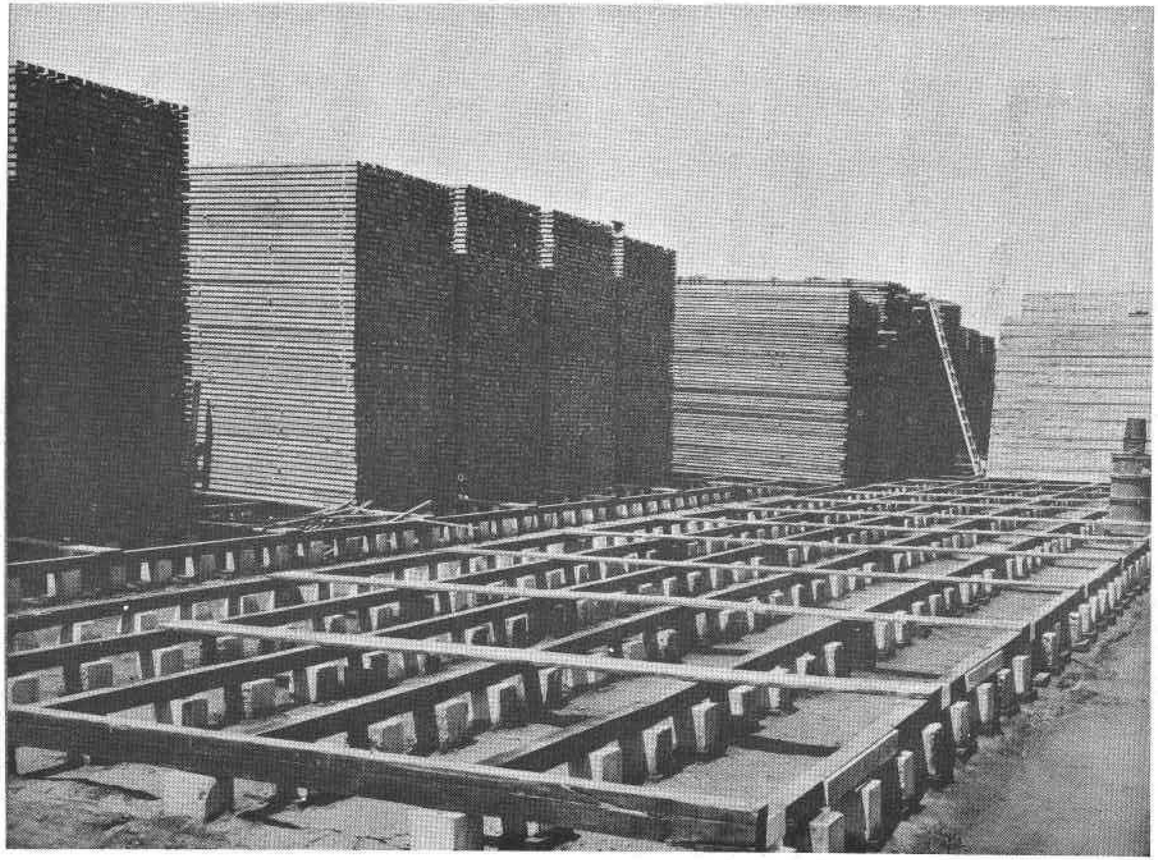


Figure 21. --This foundation for hand-stacked piles is made of continuous crossbeams which will accommodate a whole row of piles.

ZM 44084 F

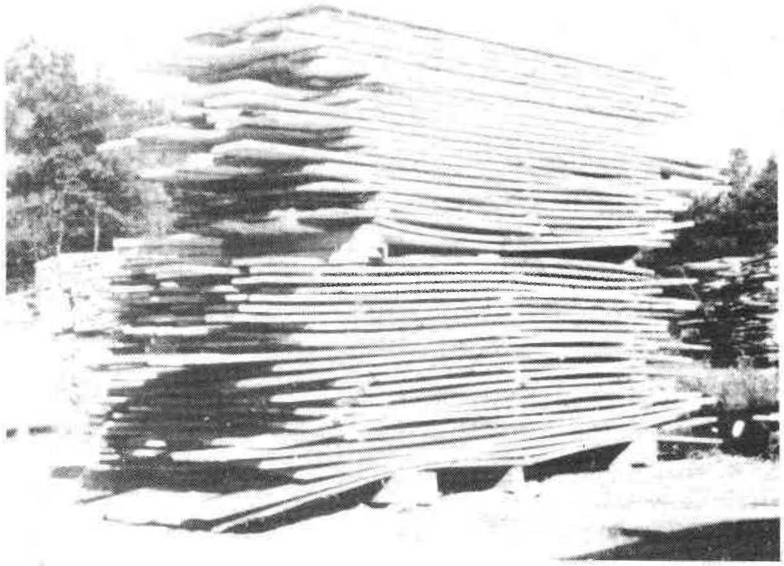


Figure 22. --The lumber in this package pile is so close to the ground that drying will be slowed and stain and decay promoted. The severe sagging of the lumber is due to inadequate stickering and bolstering and the misalinement of the stickers and bolsters.

ZM 82259 F

Figure 23. --Foundations of timbers resting directly on the ground do not provide adequate ground clearance.

ZM 82258 F

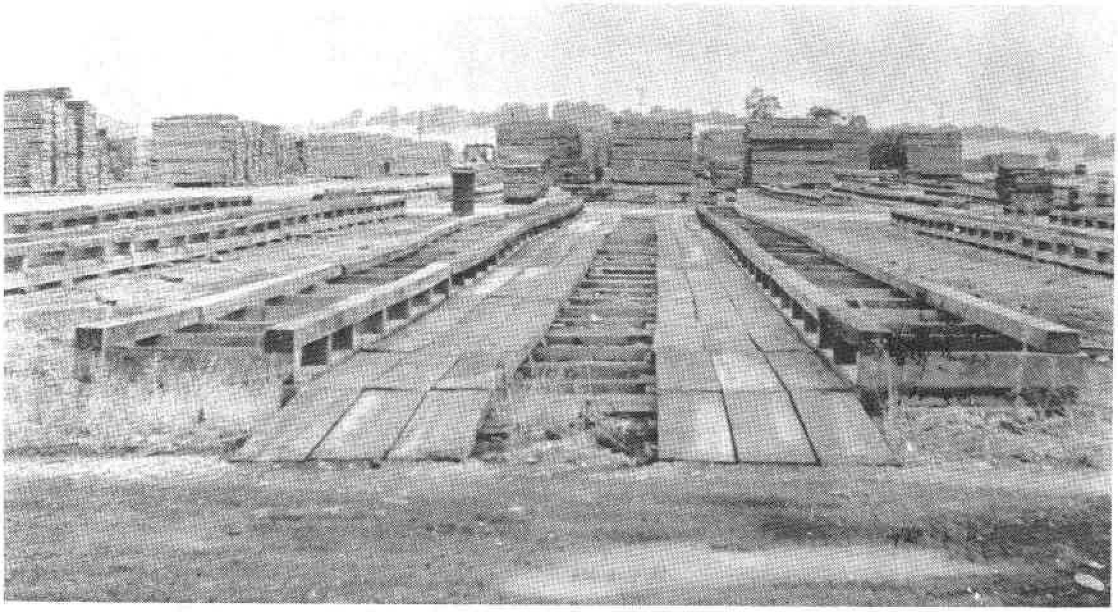


Figure 24. --This permanent or fixed foundation for package piles has planked runways for the wheels of the fork-lift truck. The planks rest on the sleepers of the foundation.

ZM 98835 F

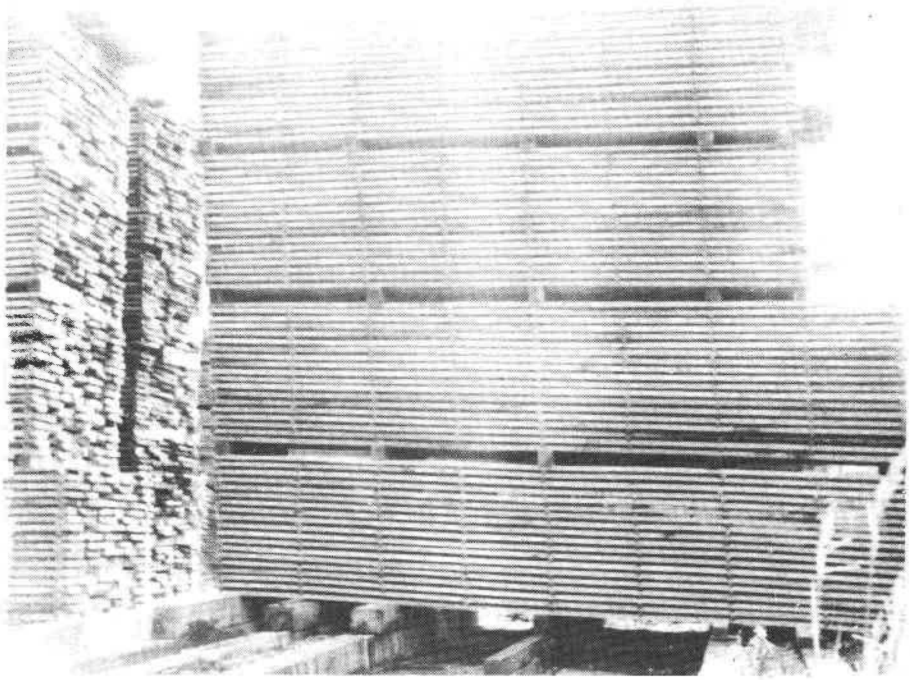


Figure 25. --A package-pile foundation consisting of 6 concrete crossbeams 2 feet apart with an 8-foot central space. The beams are blocked up with timbers to provide slope, and the center of the pile is supported by a removable crossbeam.

ZM 98245 F

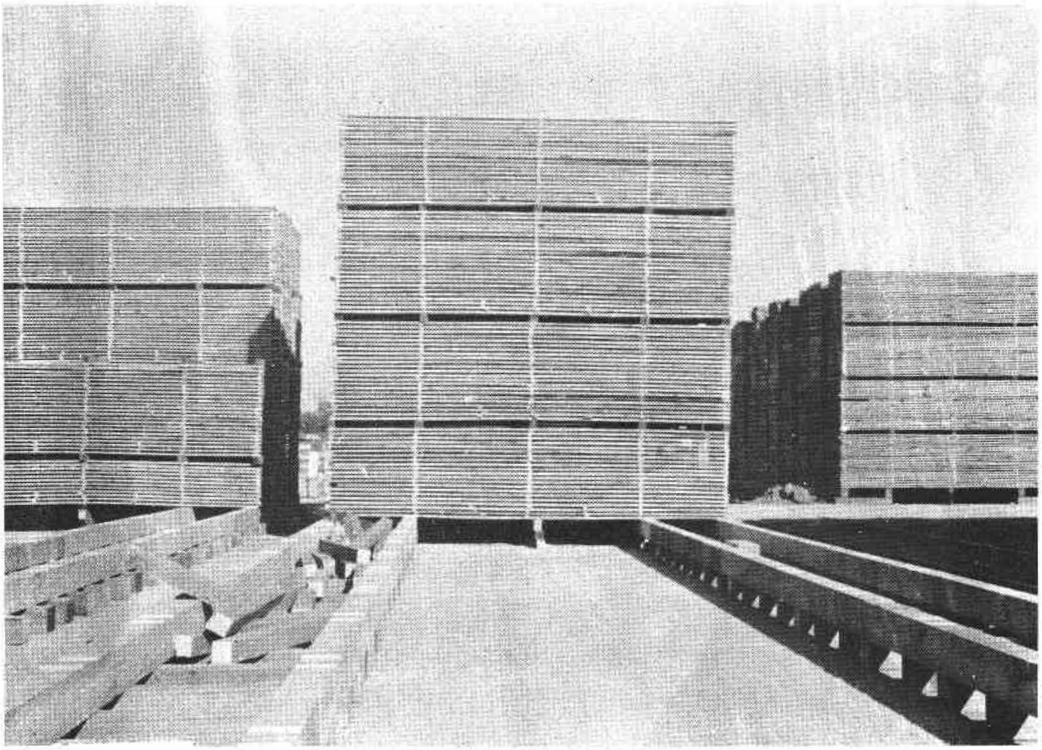


Figure 26. --A foundation made up of 4 fixed beams spaced 3-1/2, 9, and 3-1/2 feet apart and a movable center support that is put into place just before the pile is erected. The paint lines on the fixed beams are used for alining the piles.

ZM 98792 F

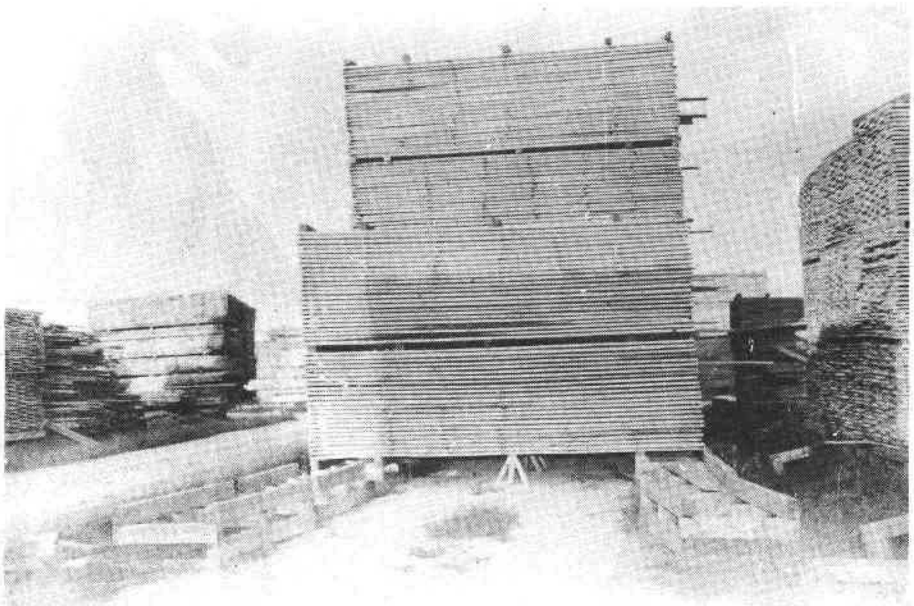


Figure 27. --A package-pile foundation consisting of two benches that support the crossbeams and a central horse that can be easily removed to permit movement of a fork-lift truck.

ZM 83684 F

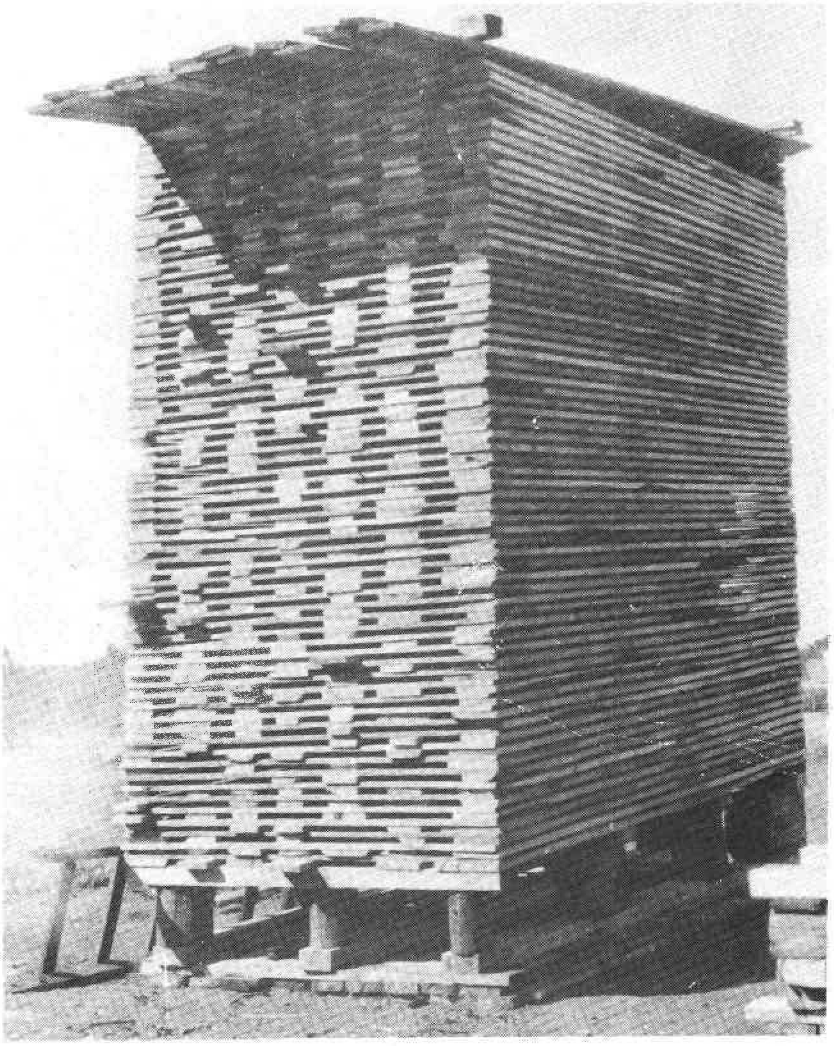


Figure 28. --A box pile of hardwood lumber containing boards of 7 different lengths and 5 different widths. The double-layered roof projects about 2-1/2 feet at the rear of the pile.

ZM 98088 F

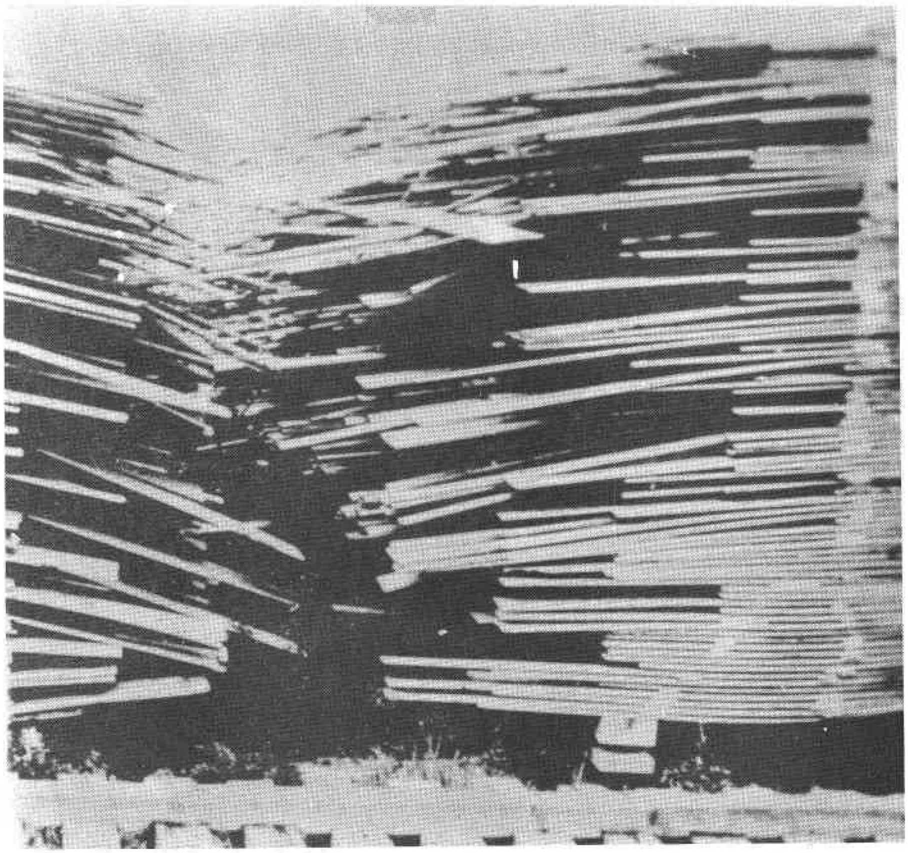


Figure 29. --These hand-stacked piles are examples of how not to pile for air drying. The overhanging ends obstruct the rear alley, the piles are poorly stickered, the foundations are inadequate, there is no roof, and vegetation is present.

Z M 107 781

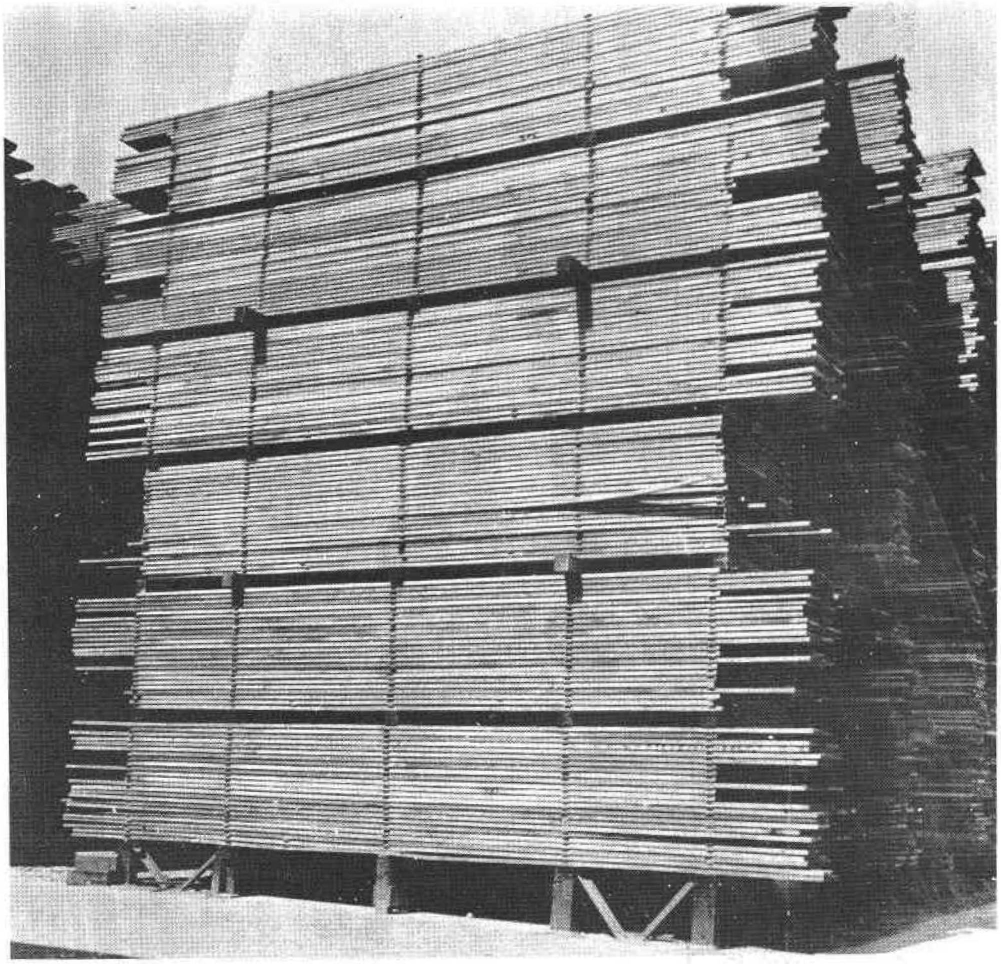


Figure 30. --Packages of 16-, 18-, and 20-foot boards placed on a 16-foot pile foundation. The 20-foot boards project 2 feet at each end.

ZM 98613 F

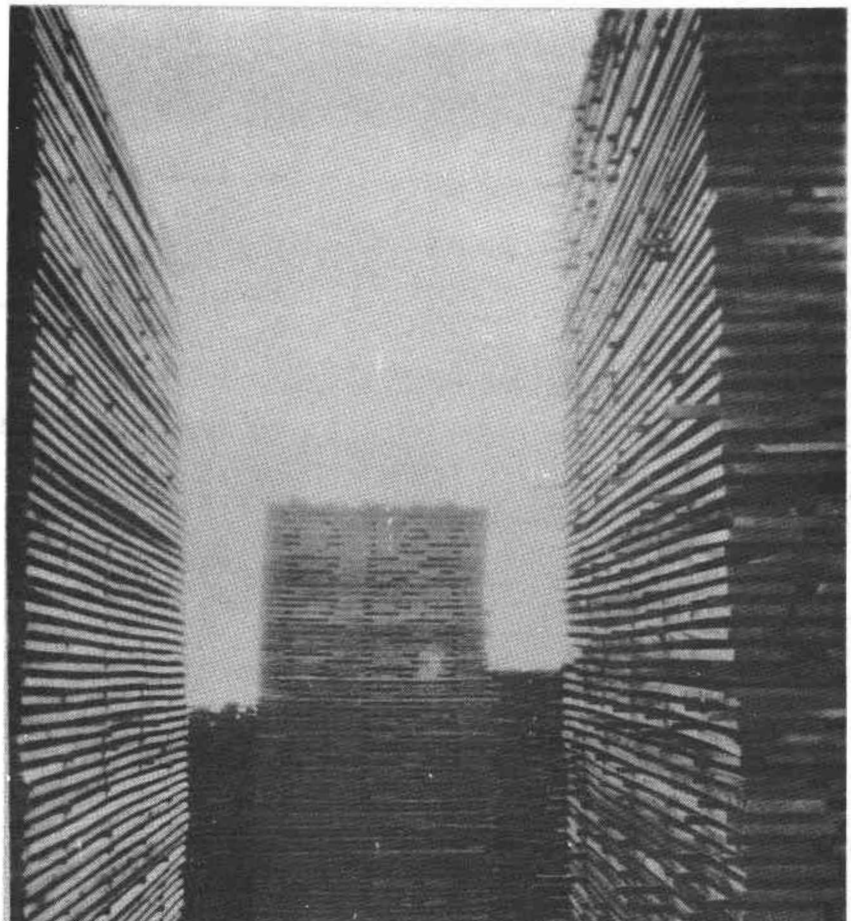


Figure 31. --These hand-stacked piles were staggered, with a pile opposite an open space across the alley.

Z M 107 782

Figure 32. --Since the lumber in this yard is destined for a cross-circulation kiln, the boards are edge-piled in packages 4 feet high and 7 feet wide, with a 1-foot-wide central chimney. The distance between the piles is 8 feet, and the distance between the rows of piles is 12 feet.

ZM 83687 F

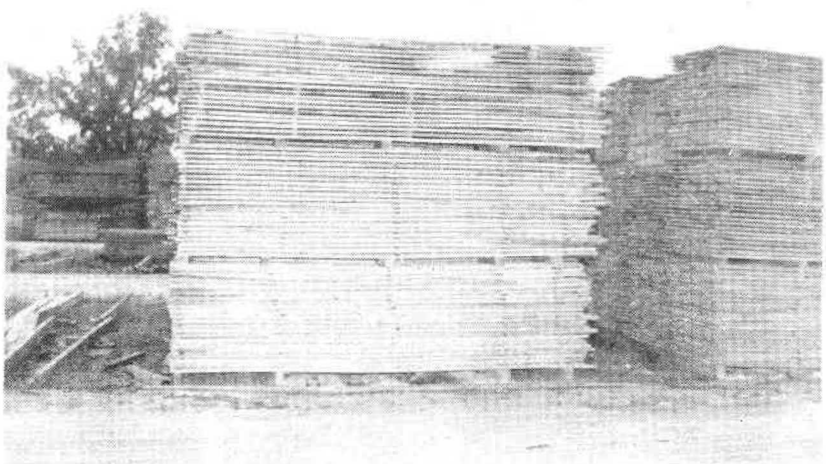


Figure 33. --Rows of package piles with a space of about 5 feet between the rows.

ZM 83673 F

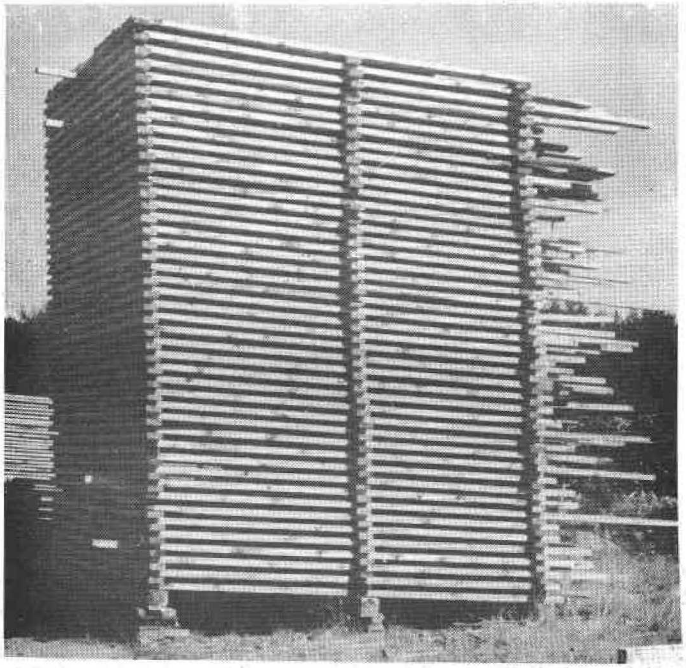


Figure 34.--Self-stickered piles of softwood lumber require no special stickers.

ZM 98246 F

Figure 35.--Piles of softwood lumber hand stacked with special stickers.

ZM 83671 F

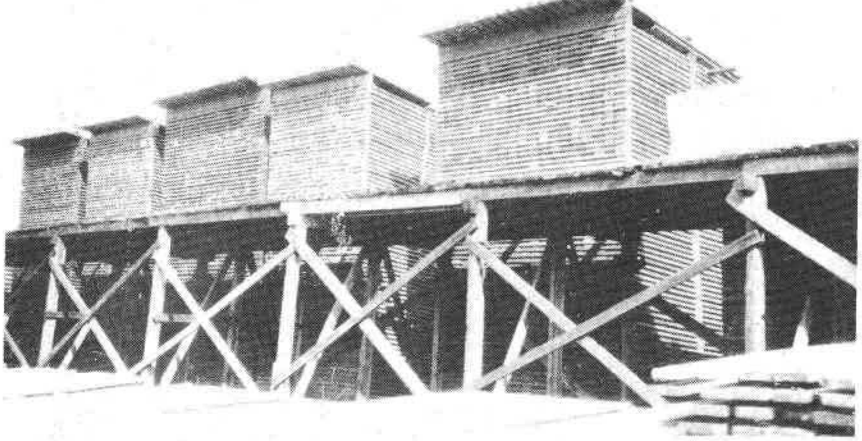


Figure 36. --Hand-stacked piles built with the aid of an elevated tramway. The pile roofs are composed of a double layer of boards laid double length.

Z M 107 783

Figure 37. --Several of these package piles have tipped and closed the lateral spaces.

ZM 83678 F

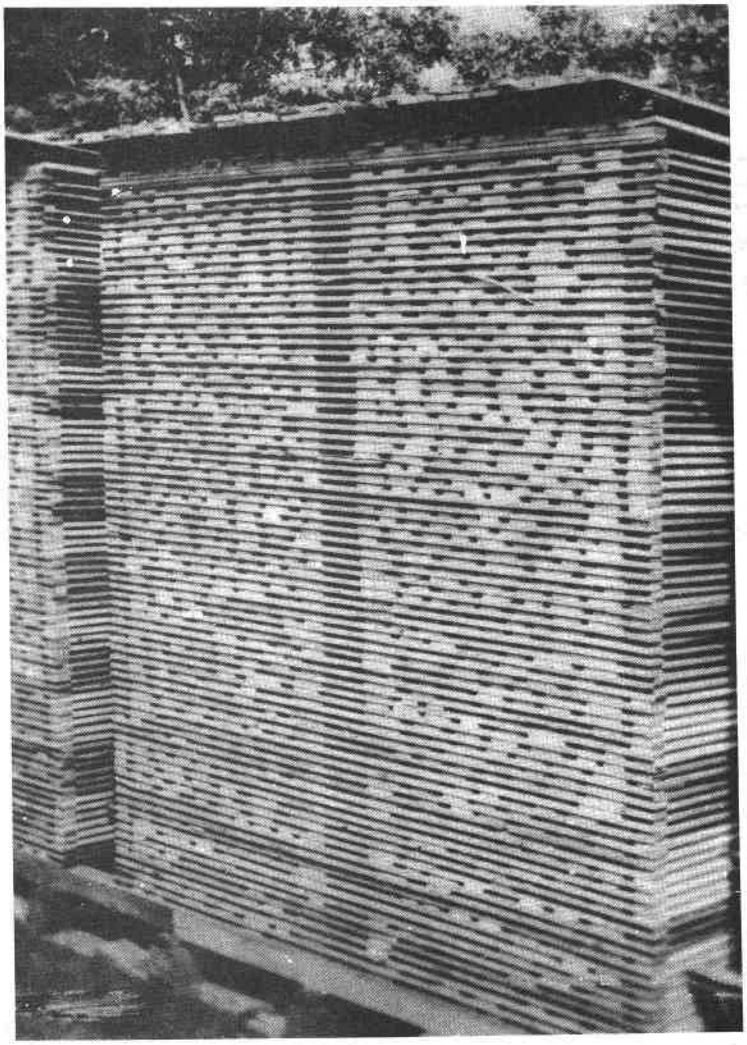


Figure 38. --A straight-sided central chimney in a pile of random-width lumber.

Z M 107 784

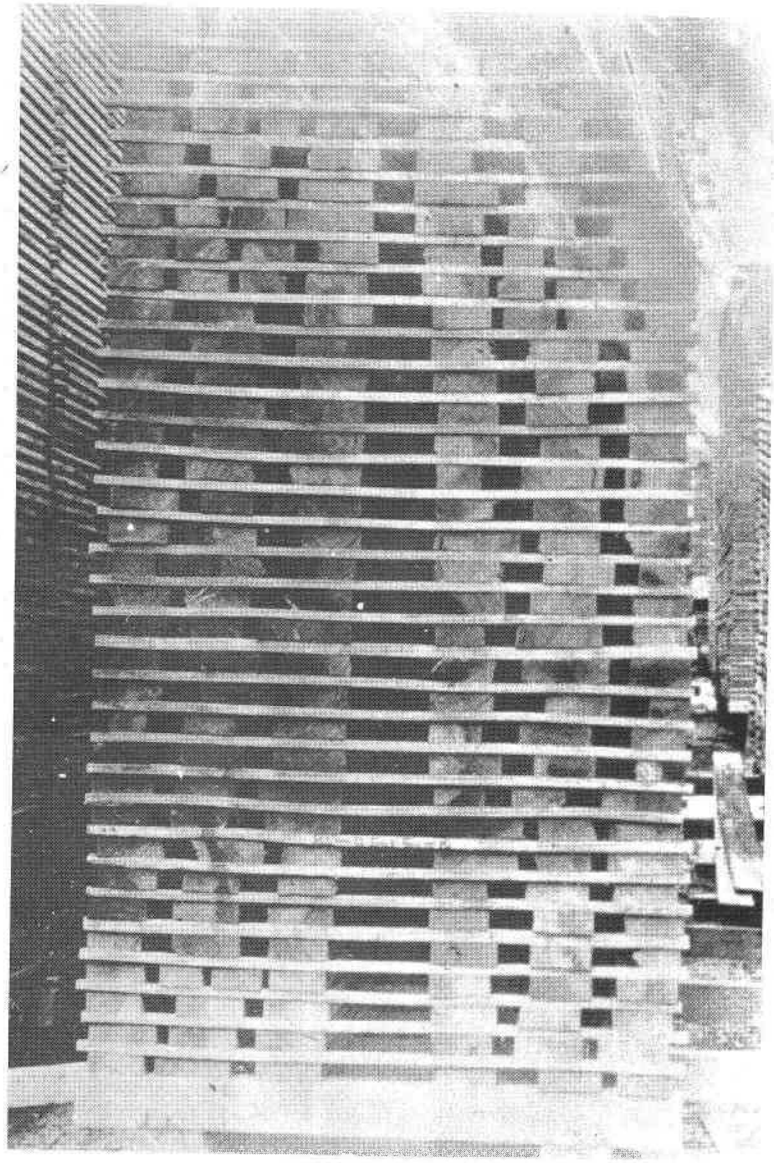


Figure 39. --A tapered chimney in a pile of random-width lumber.

Z M 107 785

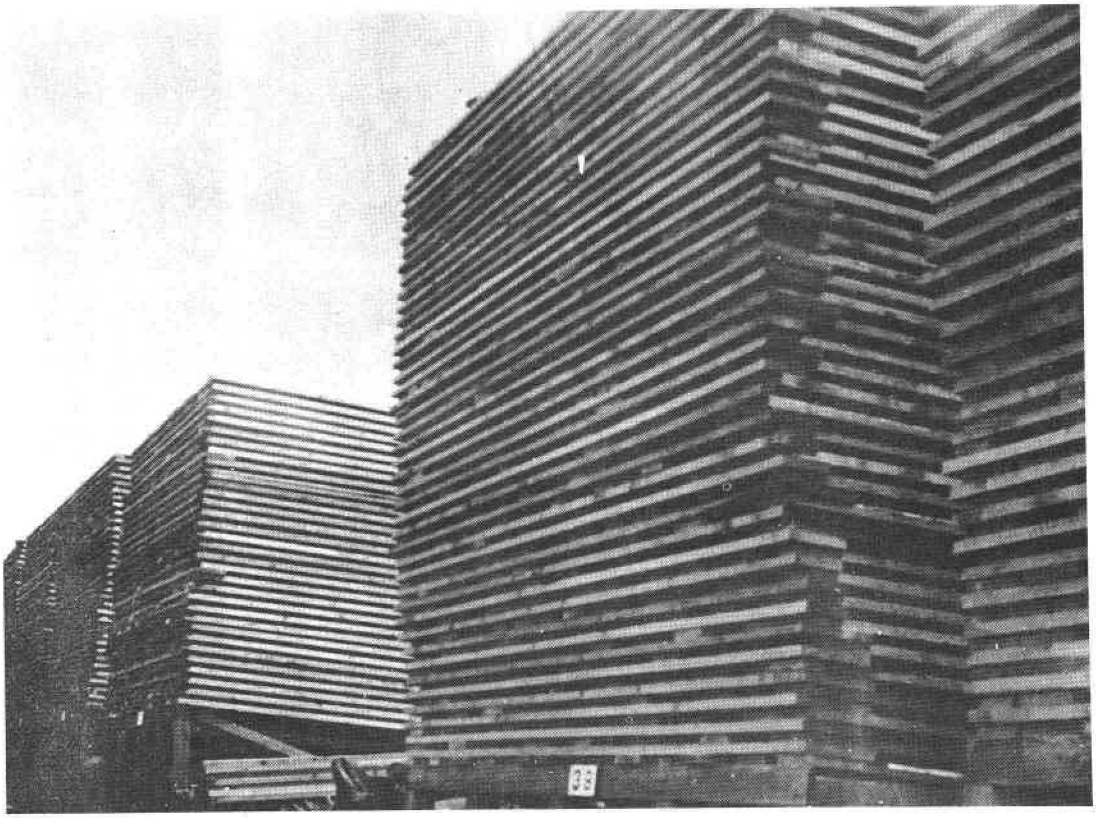


Figure 40. --Self-stickered piles of softwood lumber.

ZM 98091 F

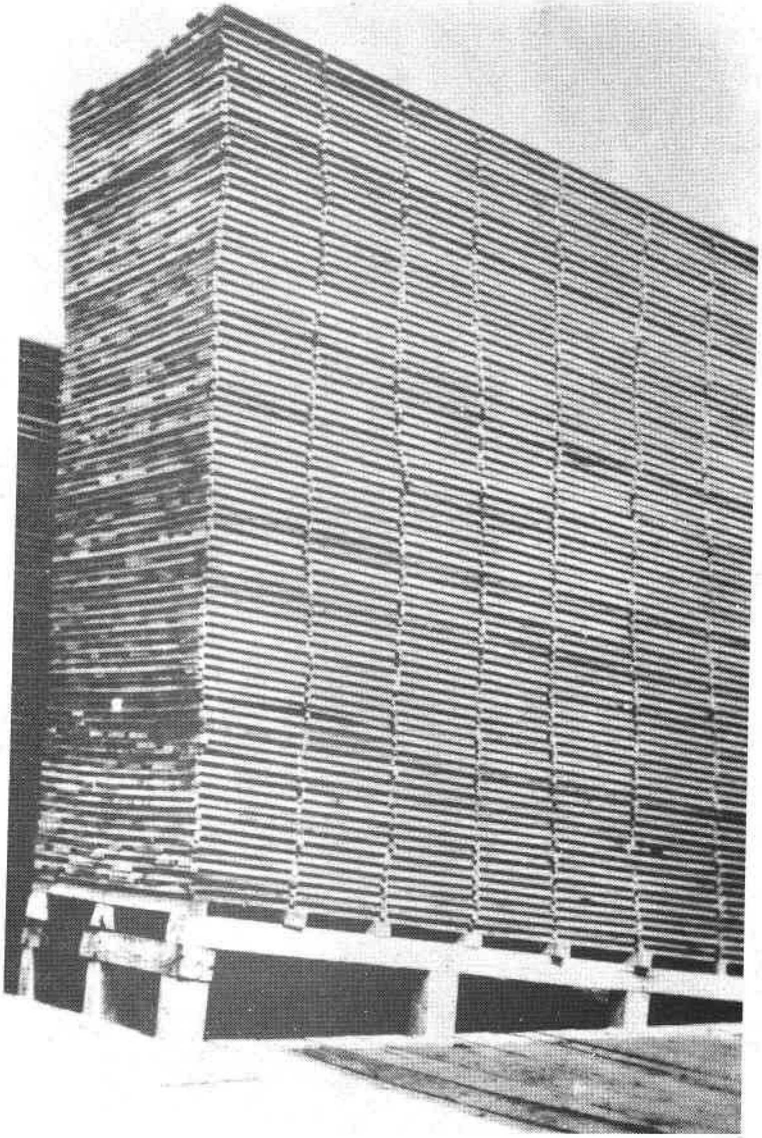


Figure 41. --The tiers of stickers follow the pitch of the pile, and each tier is supported by a crossbeam.

Z M 107 786

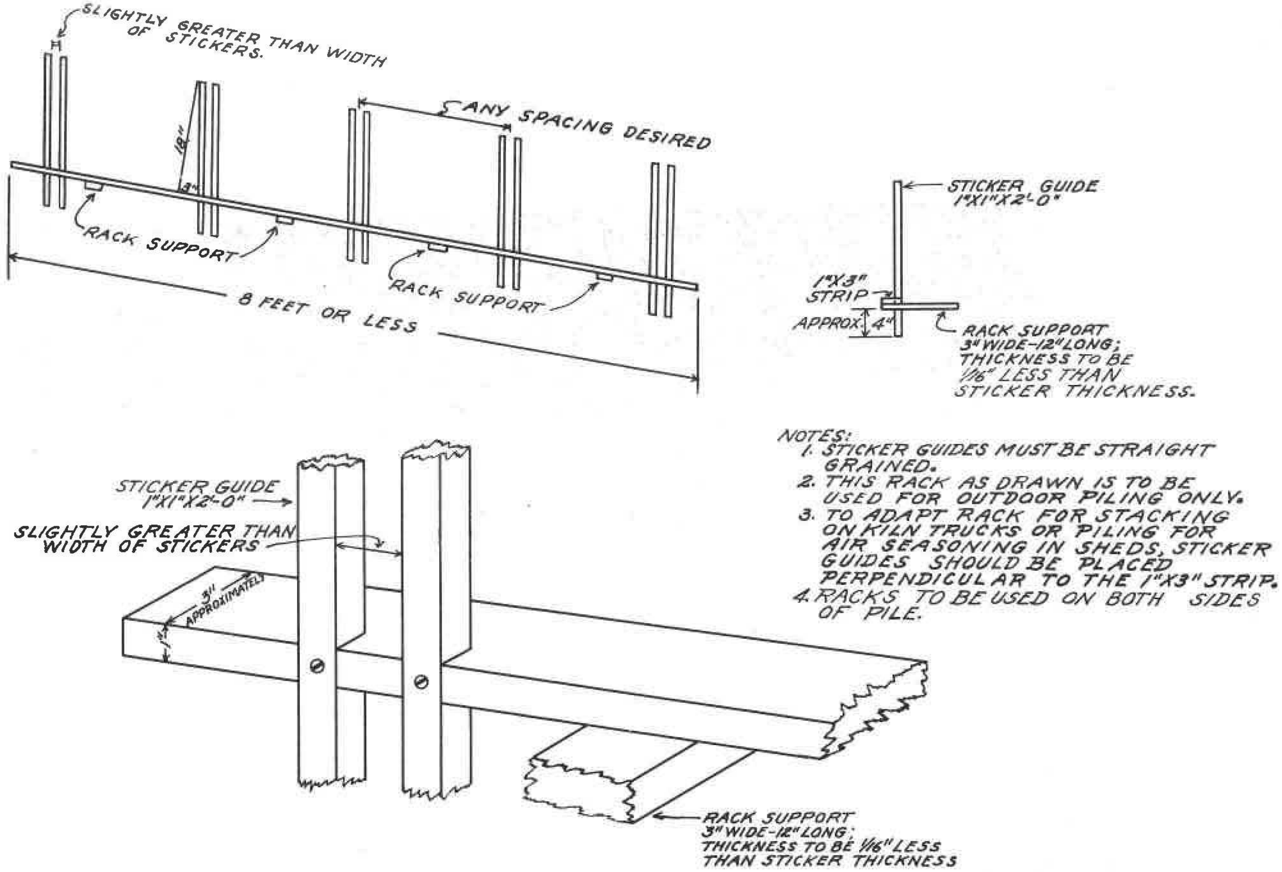


Figure 42. --Diagram of sticker guide rack for use in hand stacking piles.

ZM 64848 F

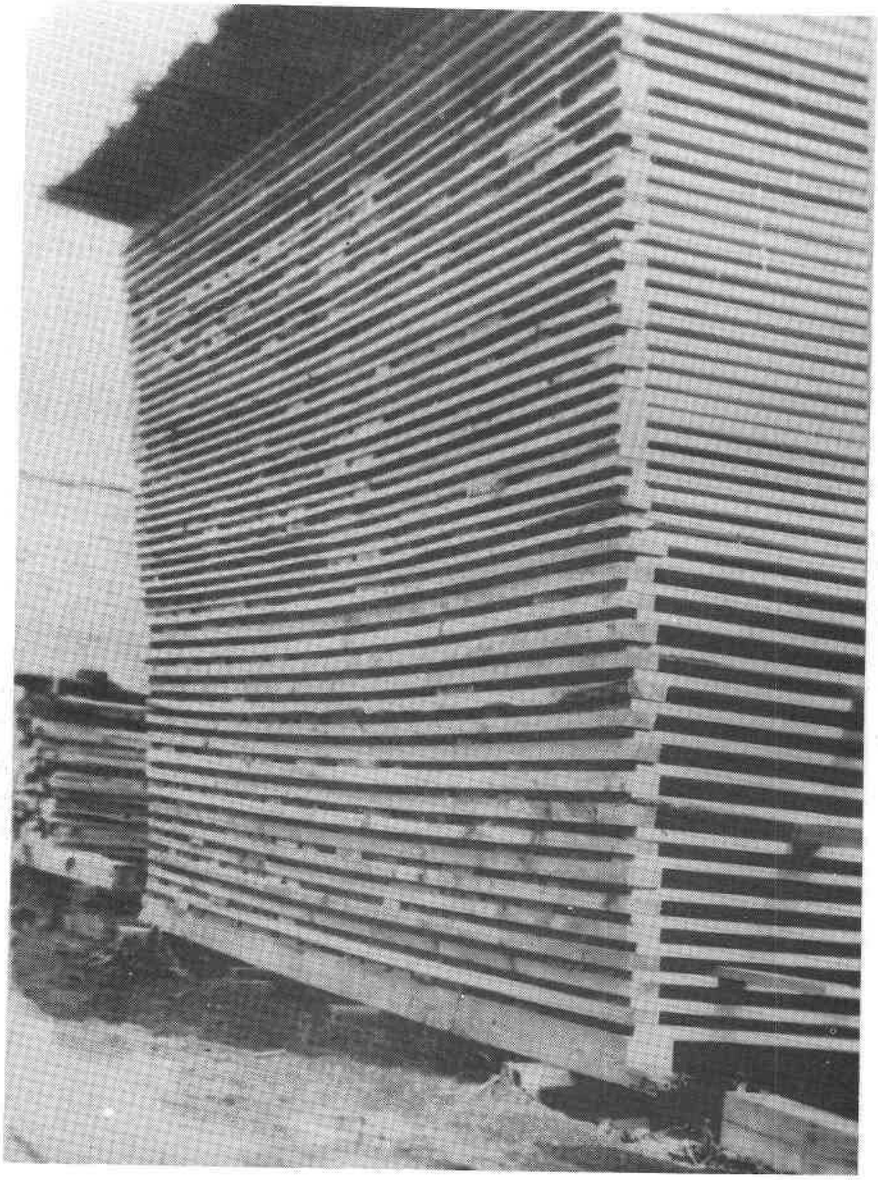


Figure 43. --The courses in the lower third of this pile are separated by stickers of greater thickness than in the rest of the pile. The stickers of the first tier project slightly beyond the ends of the boards.

Z M 107 787

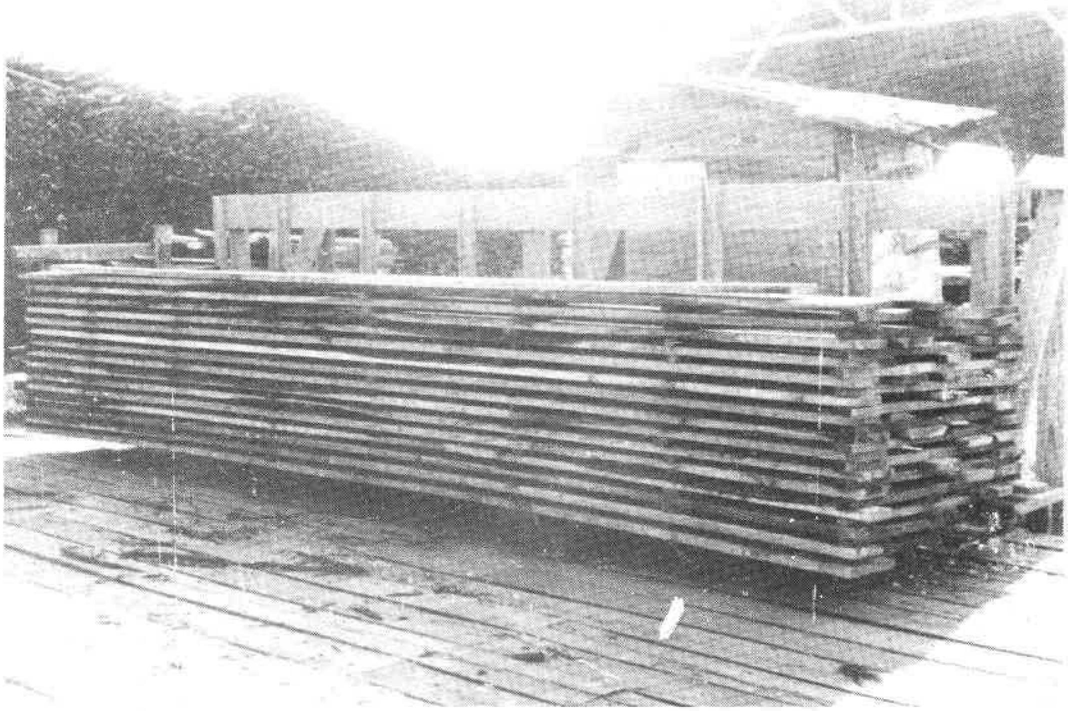


Figure 44. --A stacking rack used for alining the boards in packages can be rolled back when the package is to be picked up by the fork-lift truck.

ZM 98247 F

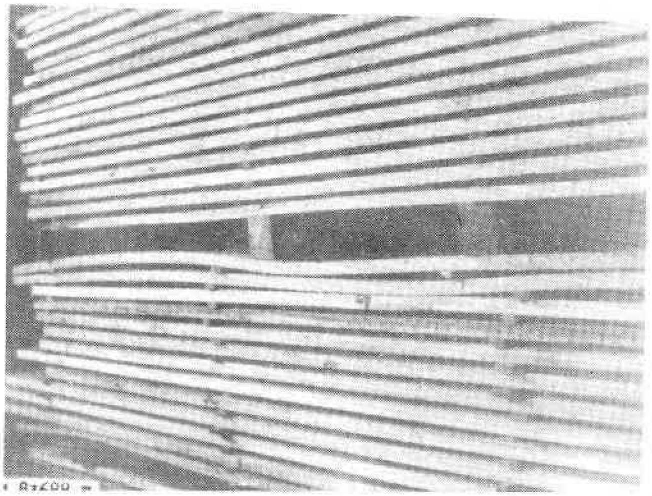


Figure 45. --Poor alinement of bolsters and stickers caused sagging of boards in this package pile.

ZM 83688 F

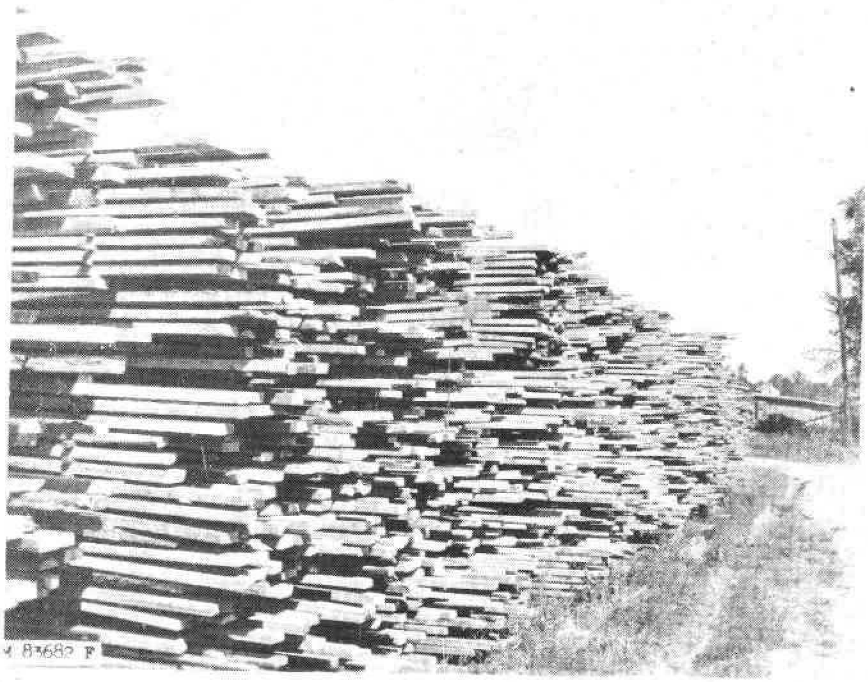


Figure 46. --Overhanging board ends in package piles.

ZM 83682 F

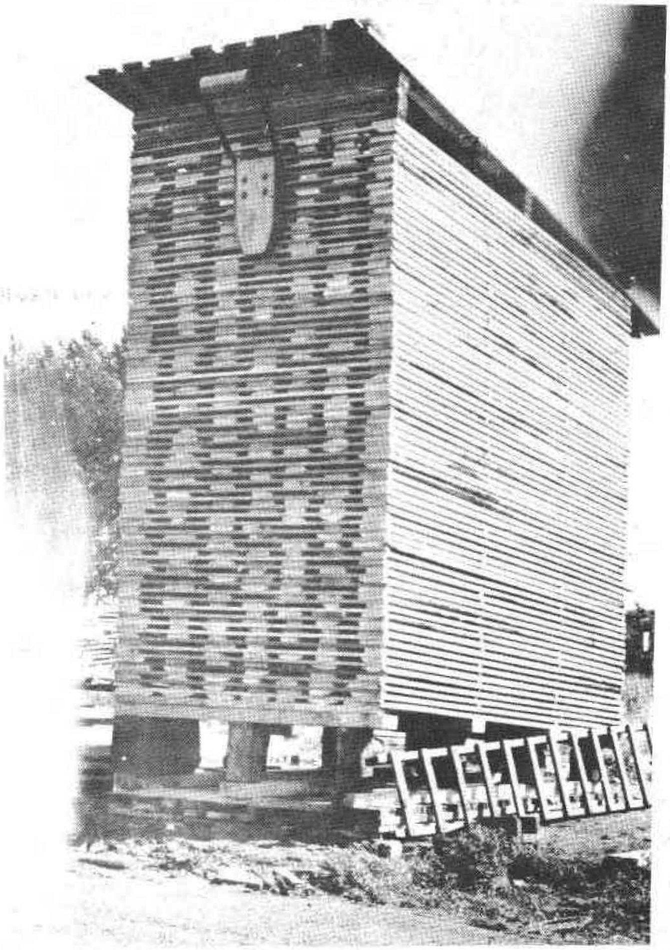


Figure 47. --The front of the double-layered board roof of this hand-stacked pile of hardwood lumber projects about 2 feet beyond the pile and is elevated to increase the pitch of the roof over that of the sloped pile.

ZM 98090 F

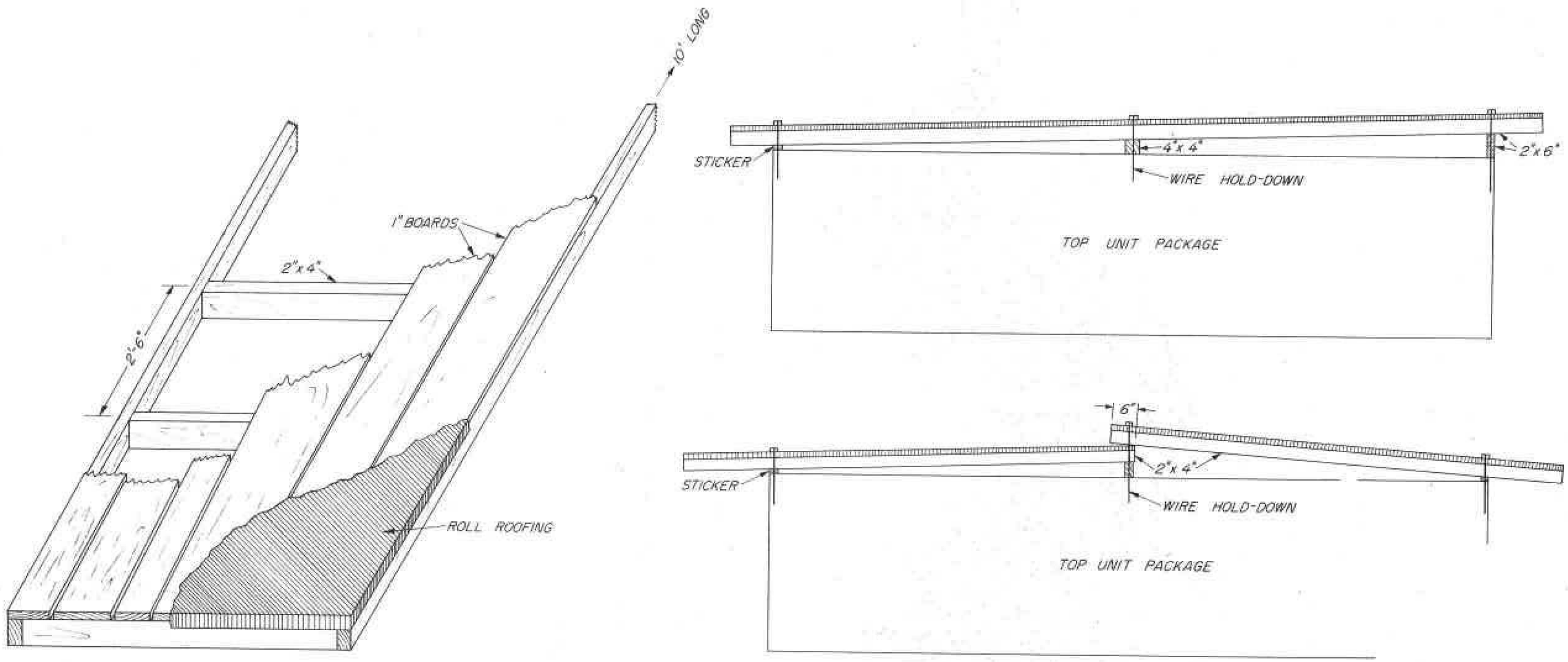


Figure 48. --Panels for roofing package piles may be made in single, full-length units or in double, half-length units.

ZM 92586 F

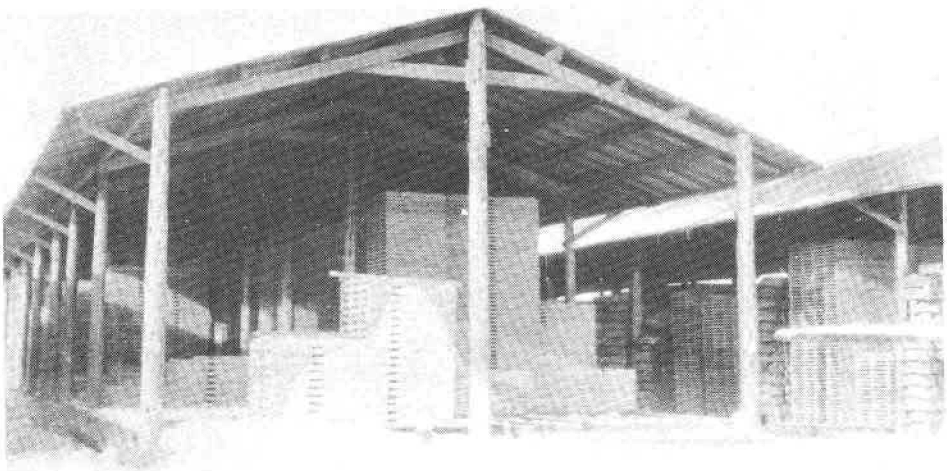


Figure 49. --Dimension stock piled for air drying in a shed open on all sides.

Z M 107 788

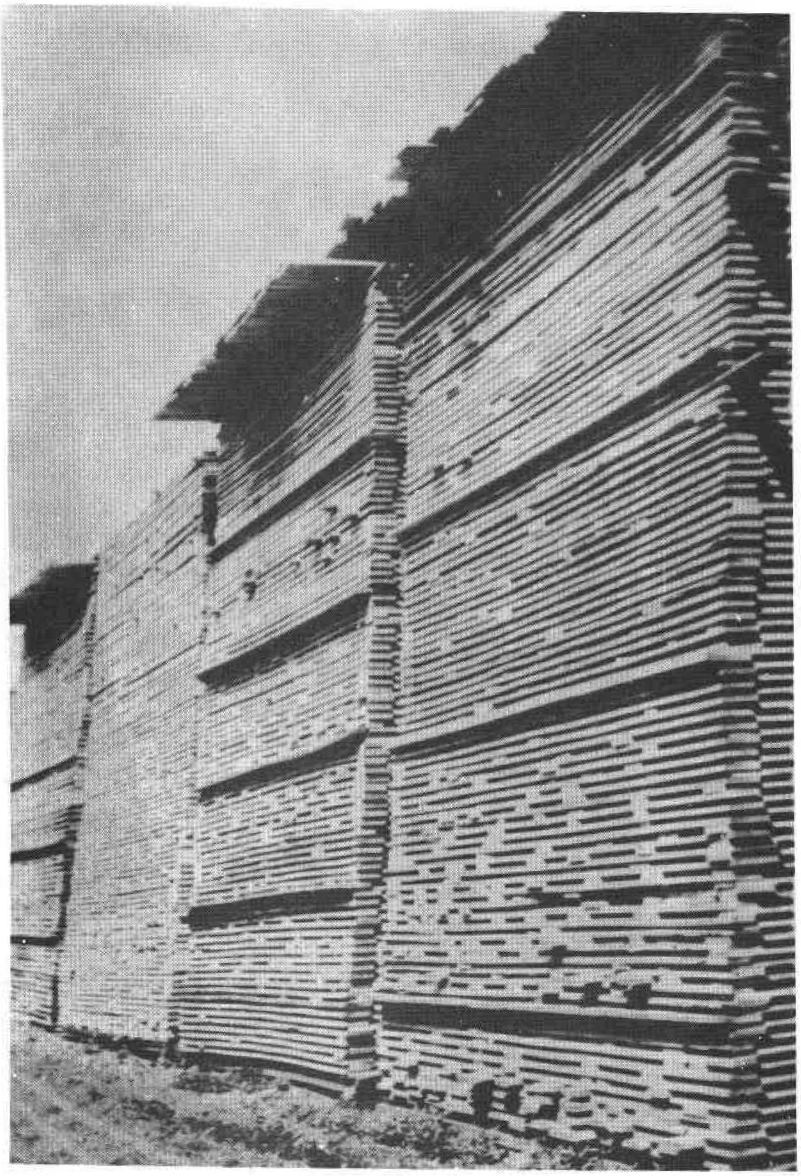


Figure 50. --Drip boards on the rear of a hand-stacked pile catch rain that may elude the overhanging roof.

Z M 107 789

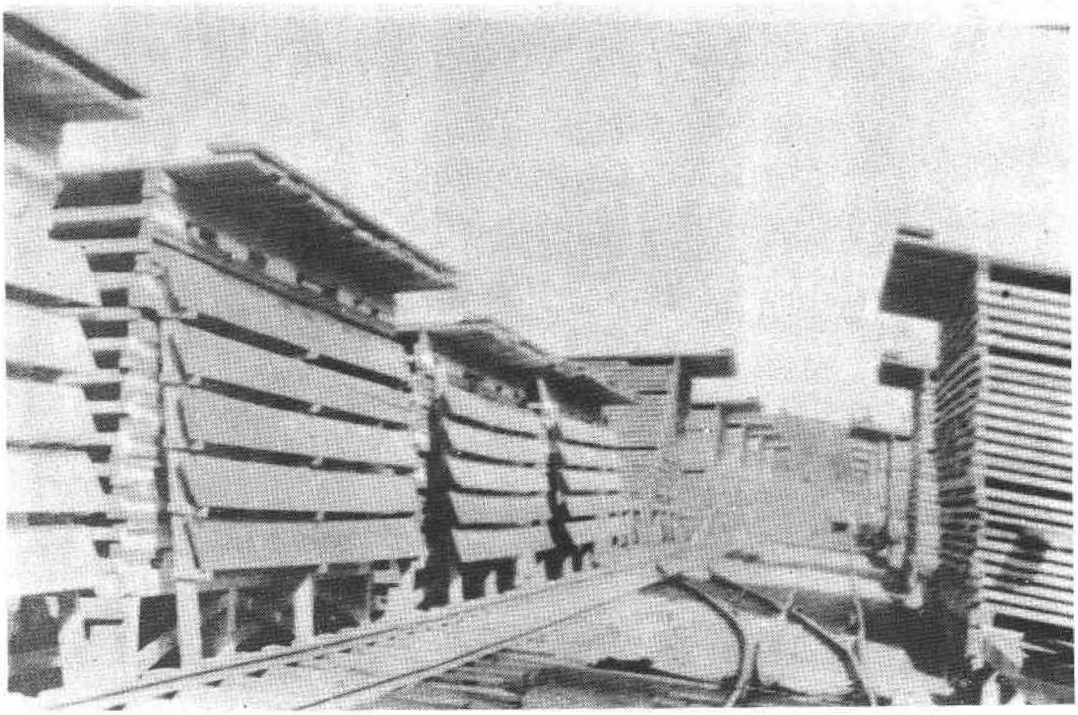


Figure 51. --Portable sun shields protect the ends of the lumber from the direct rays of the sun.

Z M 107 790

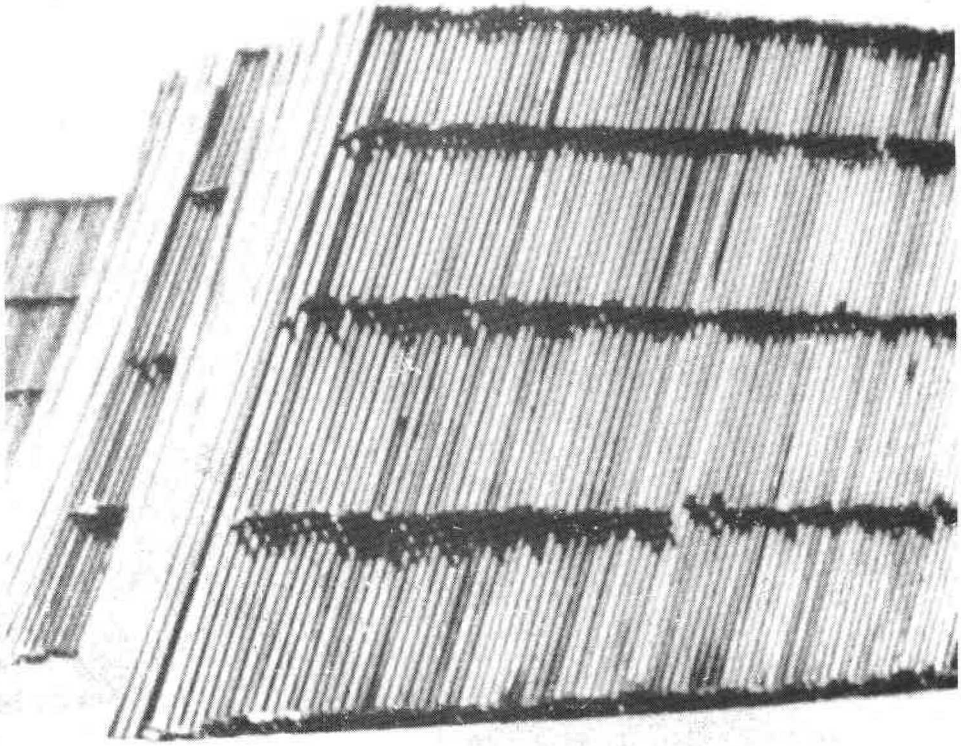


Figure 52. --End-piled lumber on a solid wooden platform.

Z M 107 791

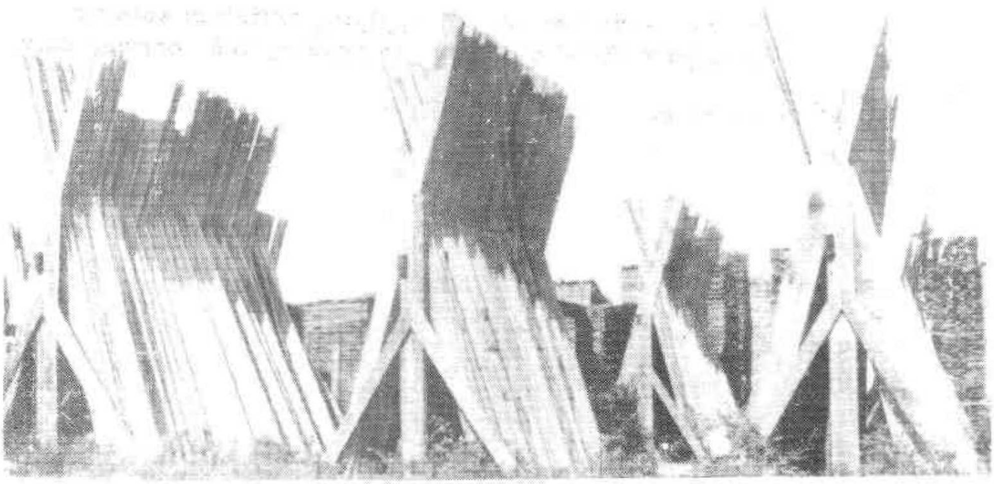


Figure 53. --End-racked yard lumber with boards crossing several feet from the top ends. Preferable procedure is to cross the boards at the top ends, forming an inverted "V."

Z M 107 792

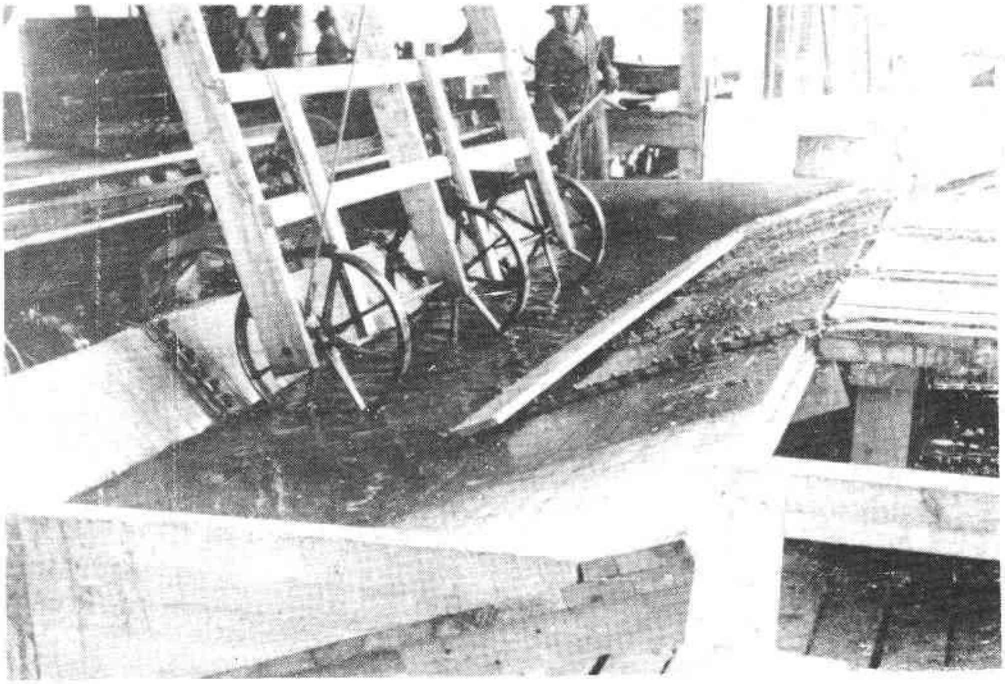


Figure 54. --Dipping vat for applying antistain solution placed just ahead of the green grading and sorting chain.

ZM 38233 F