

LAKE STATES ASPEN REPORT NO. 5

SEASONING OF ASPEN

BY

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LAKE STATES FOREST EXPERIMENT STATION

FOREWORD

During and since World War II, there has been increasing interest in aspen (Populus tremuloides) in the Lake States, its availability and supply, properties and uses, and management. Aspen is a tree of primary importance in 20 million acres or 40 percent of the total forest area of the three Lake States - Michigan, Minnesota, and Wisconsin.

At an informal meeting at Madison, Wisconsin, in January, 1947, forestry representatives of several federal, state, and industrial groups in the Lake States agreed that it would be desirable to bring up-to-date what is known on aspen and make it available to anyone interested. The job of preparing this information in the form of reports was assigned to each of the groups listed below. The reports will be duplicated as rapidly as completed, and the entire project should be finished by the end of 1947. Each report will concern one aspect of the subject. Copies will be available from the Lake States Forest Experiment Station or from each contributor.

<u>Report Number</u>	<u>Subject</u>
1	Aspen Properties and Uses
2	Aspen Availability and Supply
3	Logging Methods and Peeling of Aspen
4	Milling of Aspen into Lumber
5	Seasoning of Aspen
6	Aspen Lumber Grades and Characteristics
7	Mechanical Properties of Aspen
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9	Aspen Lumber for Building Purposes
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15	Aspen for Cabin Logs
16	Aspen for Excelsior
17	Aspen Defiberization and Refining of Product
18	Chemical Utilization of Aspen
19	Preservative Treatment of Aspen
20	Marketing of Aspen
21	Possibilities of Managing Aspen
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SEASONING OF ASPEN

By
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INTRODUCTION

Aspen is now the major forest type in the Lake States, and extensive stands are reaching maturity. Increasing quantities are being cut, and much is now being put to new and more exacting uses that require better air-seasoning and kiln-drying practices. The recent favorable market for green aspen lumber appears to be falling off, and the time may soon come when operators are no longer able to move green aspen. Such a change can be met by manufacturing better-quality aspen lumber and by carefully seasoning it to the desired moisture content to make it more acceptable. This report describes the principles of air seasoning and kiln drying as developed from research at the Forest Products Laboratory, with specific recommendations for the seasoning of aspen lumber, flitches, and shook stock. More detailed information may be obtained from the publications listed at the end of this report, most of which are available at the Forest Products Laboratory.

AIR SEASONING

Air seasoning is the oldest and simplest method of drying lumber. Little or no special equipment is required, and by following the proper procedure, a satisfactory job of seasoning can be accomplished. Thoroughly air-seasoned lumber is sufficiently dry for many use requirements. Further, the loss due to stain, mold, and insect attack in use is considerably less with air-seasoned lumber than with green lumber, and the reduction in weight results in saving in shipping costs.

Air seasoning has certain limitations, however. The rate of drying is limited by weather conditions, and the minimum final moisture content that can be attained is dependent on both the length of drying and upon the season of the year. In general, the moisture content of thoroughly air-seasoned aspen is between 12 and 15 per cent during the dry season. For many uses, such as furniture and interior trim, a lower moisture content is required. A relatively large yard space is required for air seasoning, and the lumber that is held in piles for a long period of time represents a large capital investment. Despite these limitations, air seasoning is the most practical method for small producers.

1/ Maintained by the U. S. Department of Agriculture, Forest Service, in cooperation with the University of Wisconsin, Madison, Wisconsin.

General Principles of Air Seasoning

The effectiveness of air seasoning is governed by (1) circulation, or air movement through the piles, (2) relative humidity of the air, and (3) temperature of the air. Yard site and layout and pile construction must be studied with these three factors in mind.

Air seasoning is to some extent subject to the vagaries of the weather. During the year there are definitely favorable and unfavorable drying seasons. Nevertheless, much can be done to harness favorable weather conditions more effectively to the work of lumber drying.

Circulation

Circulation of air through the pile can be controlled by yard layout and by piling methods. In general, air circulates in two ways: (1) In a horizontal direction, due primarily to local wind currents, and (2) in a vertical direction, due to temperature variations within the pile.

Horizontal circulation is influenced to a great extent by the arrangement of pile alleys, rear alleys, and the spacing of piles on the same alley. Likewise, the clearance under the pile and the actual inlet and outlet of the wind currents to and from the pile are greatly affected by the method of pile construction.

Vertical air circulation generated within the lumber pile is a drying factor of great importance. As green stock dries, the evaporation of the water requires heat, which is furnished by the air. The air is thus cooled, becomes heavier, and tends to drift downward through the pile. A lumber pile should, therefore, be constructed so that vertical spaces between the boards form passageways to facilitate this downward movement. In order to prevent stagnation of the air in the lower portion of the pile, some means of escape must be provided. This is accomplished by the proper yard layout and by adequate pile foundations that facilitate horizontal circulation, particularly in the lower portion of the pile and beneath the pile. As the cooled air is moved from the bottom of the pile, warmer, drier air can enter the top of the pile. A positive, continuous vertical air movement is thus established within the pile. Without adequate provision for removing the cool air that drifts to the bottom of the pile, stagnation results, and the rate of drying in the lower portion of the pile is greatly reduced. Relative humidity next to the wood surface is the most important factor affecting drying rate and is controllable only by piling arrangements that affect the rate of air movement through the load.

Relative Humidity

The rate of drying is greater if the air itself is dry--that is, if the relative humidity of the air is low. Thus, lumber will dry faster and to a lower moisture content in dry weather than in damp weather. The relative humidity within the pile can also be controlled to a marked degree to maintain the desired drying conditions. This again

is accomplished through control of circulation by the proper arrangement of pile alleys, rear alleys, pile spacing, and method of piling.

Temperature

In general, the rate of drying increases with increases in temperature. This is one of the reasons why climatic conditions during the different seasons of the year affect drying periods. At any one time and place, however, control of temperature within an air-seasoning pile is ineffective as far as the effect of temperature on drying rate is concerned. Therefore, the small temperature differences within a lumber pile are important only as they affect relative humidity conditions.

The Air-seasoning Yard

Effective air seasoning depends fundamentally upon the factors of air circulation, temperature, and relative humidity within the pile, already discussed. These factors, in turn, are governed largely by the conditions prevailing in the air-seasoning yard, such as yard location, and layout, methods of piling, and yard sanitation.

Yard Site

Drying conditions vary locally as well as climatically throughout the United States. Even though an operator may not have much control over the section of the country in which he locates his yard, he usually has some choice of yard site within a limited area. Often one location is considerably more desirable for a lumber air-seasoning yard than an alternate near-by location.

The suitability of a yard site for the seasoning of aspen lumber depends upon four factors:

1. The site should be high, so that prevailing winds are not screened by hills and other obstructions.
2. The site should be open, because high trees and other vegetation around the site obstruct wind.
3. The site should be well drained, because standing water or high water tables influence relative humidity.
4. The site should be on land away from water, because presence of free water builds up relative humidity.

Yard Layout

In order to maintain the maximum rate of air movement through the piles, the yard must be laid out so that wind movement will be favored.

The width and spacing of the alleys and the location of the lumber piles along the main alleys determine the efficiency of an air-seasoning yard.

A well laid-out yard should:

1. Provide for main alleys that are at least 20 feet wide to permit adequate room for transporting the lumber and for good air movement. If yard space permits, wider alleys may be advisable. The direction of the main alleys in relation to the prevailing winds apparently has little influence on the drying rate. Main alleys that extend in a north and south direction will, however, tend to be drier and more free of snow than will alleys that extend in other directions. The position of the yard area in relation to existing buildings and roads will usually determine the direction of the main alleys.
2. Provide sufficient distance between main alleys for rear alleys of 6 to 8 feet. Where 8-foot aspen lumber is being piled, a distance of 22 to 24 feet between main alleys is sufficient, provided all piles are only 8 feet long and longer lumber is piled elsewhere in the yard.
3. Provide ample spacing between piles. This important consideration is often slighted. A spacing of lumber piles along the main alleys of not less than 4 feet is recommended. The primary purpose of the spaces between piles is to aid air circulation, not only to supplement the alleys in building up general air currents in the yard but also to exert a very definite effect on the horizontal circulation in the lumber pile. The front and rear of a pile of lumber present an almost solid face because of the location of the front and rear stickers. The sides of the pile offer the easiest inlet and outlet for air circulation within the pile. A very definite circulation along the sides of the pile is essential to fast drying.

In some yards, particularly where pile foundations are used a second time or many times, there may be an advantage in piling on alternate foundations until the whole yard is one-half full and then return and use the foundations between the piles that were first laid up. In this way, many piles will be standing by themselves with open sides exposed much of the drying season. Such open piling is desirable in order to facilitate drying.

Method of Piling

The position of the pile in the yard and to a considerable extent the shape and slope of the pile are predetermined by the foundation. The most suitable method of piling should be determined, and then a pile foundation built to conform to these standards.

Pile Foundations

Adequate pile foundations are essential to fast air seasoning. A good foundation provides solid, even support and holds the pile well up from the ground. A high, open-pile foundation stimulates horizontal air

circulation below the pile, thus removing the air that drifts down through the pile and maintaining vertical air circulation. Foundations that are too low, unstable, and uneven greatly reduce the effectiveness of otherwise good piling.

Temporary pile foundations are used in many aspen air-seasoning yards for one or, at the most, a very few years. Such foundations can be built to provide solid, even support and hold the pile well up off the ground.

Figure 1 shows a suggested temporary foundation built of 8-foot logs that have been slabbled to a thickness of 5 inches. Six full-length logs and four 1-foot pieces are required. The two outer sills are laid down about 7 feet apart at right angles to the alley, and leveled. Similar logs are laid across the front and back ends of the two sills. At the center of each sill, 1-foot blocks are placed to support the center cross member. One-foot blocks are also placed on the ends of the front cross member and a second cross member is placed on top. This pile foundation raises the rear of the pile about 10 inches above the ground and the front about 20 inches. The pieces can be moved easily for re-use elsewhere in the yard or, when of no further use as pile foundations, can be used for fuel.

Obviously such foundation construction, with untreated logs in direct contact with the ground, is exposed to decay and hence is only temporary. Figure 2 shows a standard pile with a more permanent foundation adequately designed for long-time service.

Size of Pile

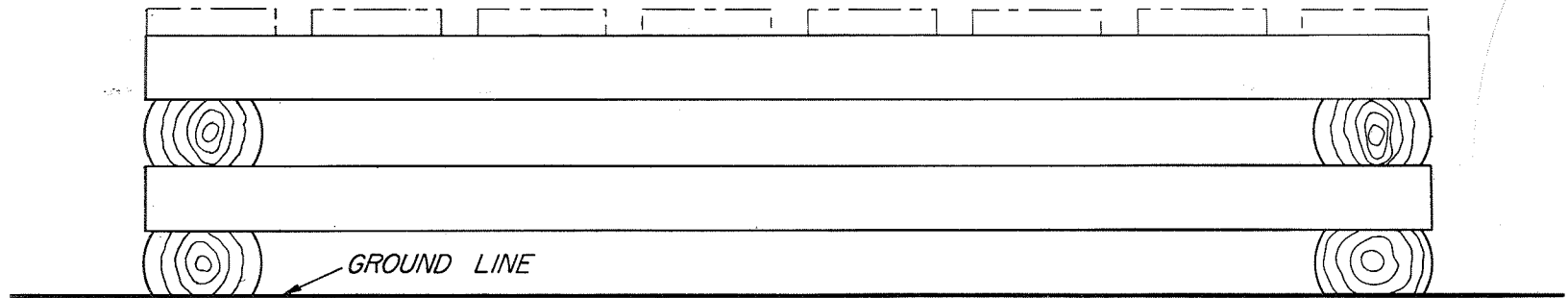
Aspen logs are usually cut 8 feet 4 inches (100 inches) long, and the common size of the pile is 8 feet wide, 8 feet long, and 10 to 14 feet high. A pile of this size is conducive to rapid drying.

Slope of Pile

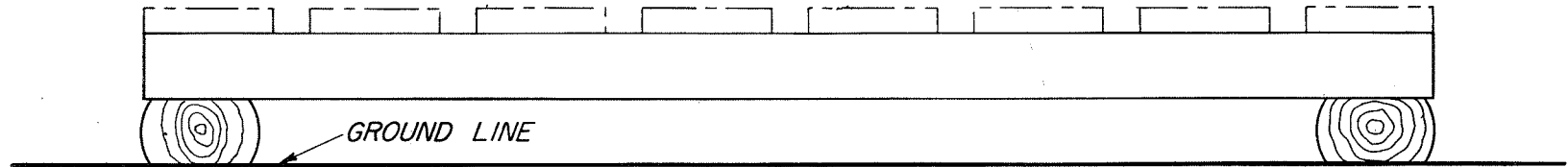
A slope of the pile of $1/2$ inch to 1 inch per foot of length is commonly used (fig. 1). If this slope is maintained to the top, it provides adequate slope for the roof and consequently good runoff of rain water. Also, water leaking into the pile will drain off more rapidly. Slope of the pile, while a conspicuous feature, is not so important as other considerations, such as width of alleys, height of foundations, or spacing of piles. While the foundation shown in figure 1 shows a slope of 10 inches in 8 feet, somewhat less slope may be equally good.

Forward Pitch of Pile

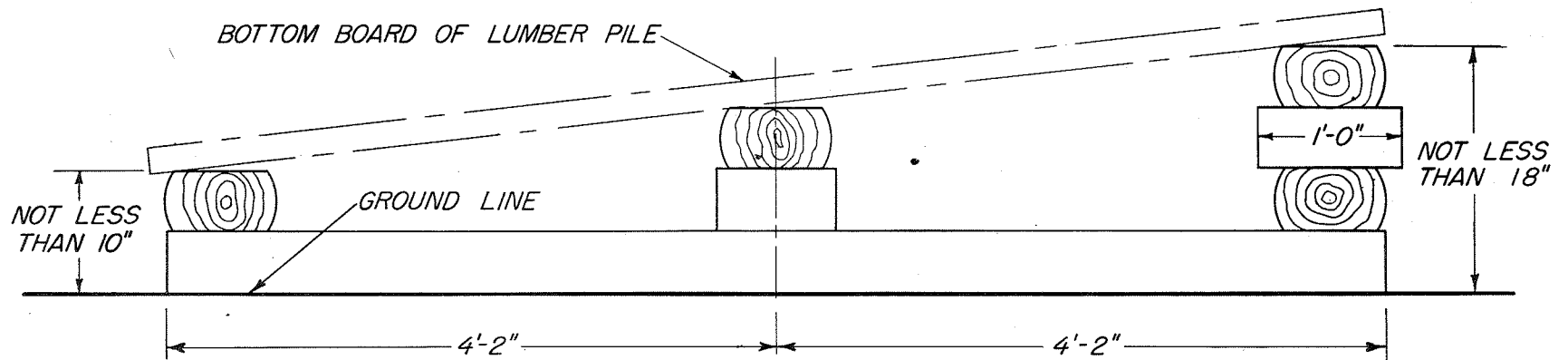
The forward pitch, or incline toward the main alley, results in an overhang at the front of the pile that allows the drip from the front stickers to fall clear of the pile instead of draining into it. A



FRONT ELEVATION



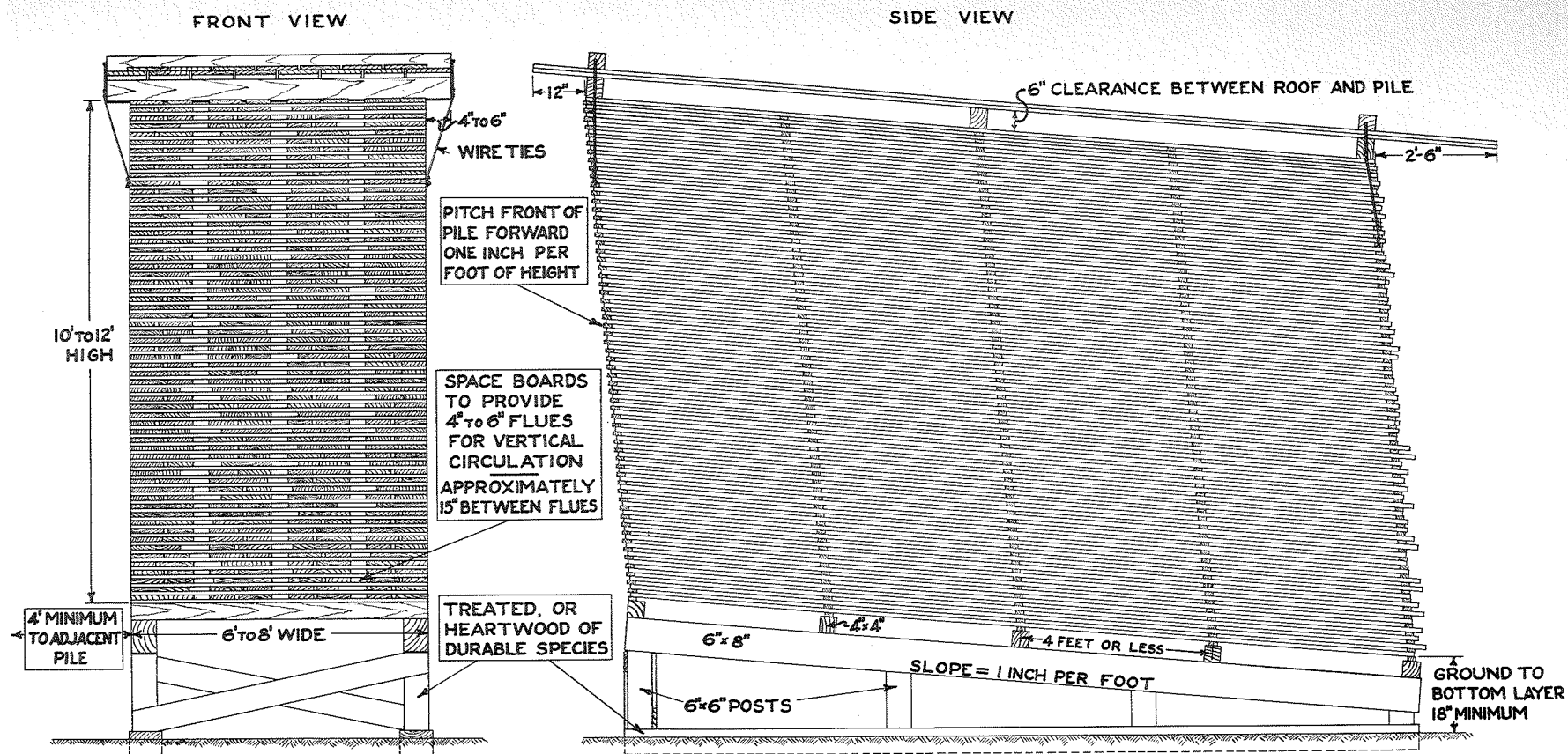
REAR ELEVATION



SIDE ELEVATION

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Figure 1. --Suggested temporary foundation.



FOR ITEMS REQUIRING SLOWER DRYING.
MODIFICATIONS TO MINIMIZE CHECKING.

1. Decrease height of foundation.
2. Decrease spacing between piles.
3. Decrease width of flues.
4. Increase width of pile.
5. Use thinner stickers.
6. Avoid the use of stock for stickers
(narrow, dry, special stickers are
less conducive to checking).

ESSENTIAL FEATURES IN PILING
FOR RAPID AND UNIFORM AIR SEASONING

Intended Mainly for Low-grade
Easy-drying Lumber

U. S. Department of Agriculture
Forest Service - Forest Products Laboratory
Madison, Wisconsin

Figure 2. --Standard permanent pile with adequate foundation.

good roof with adequate overhang will help to serve the same purpose. Usually it is considered that a forward pitch of about 1 inch in each foot of height is desirable.

Stickers

The stickers, or strips placed between the courses of lumber at right angles to the boards to facilitate drying, affect the horizontal air circulation in the pile. The size and kind of stickers, the number used per course, and the placing of stickers are of considerable importance in piling aspen lumber for fast drying.

Special stickers, cut for the purpose, are much to be preferred to the use of stock for stickers. These special stickers are usually 1 inch thick by $1\frac{1}{2}$ to 3 inches in width, and as long as the standard pile width. Their use in piling aspen will reduce the drying time and will result in a more nearly uniform final moisture content than can be obtained when green stock stickers are used. In larger air-seasoning yards, and especially in yards where kiln-drying facilities are available, special stickers should be used.

In small and temporary yards, such as are found at many mills that manufacture aspen lumber, the added cost of special stickers often outweighs the advantages, and stock is ordinarily used as stickers in piling for air seasoning. The use of stock for stickers permits rapid piling, increases the volume of material in the piles, and eliminates the necessity of carrying a large amount of stock in the form of stickers. Slower and less uniform drying can be expected, however, when stock is used for stickers. Stain and checking also are likely to be more serious.

These objections to the use of stock for stickers can be reduced by using very narrow boards and by projecting the stickers well out from the front and rear of the pile. Usually the front and rear stickers project 1 or 2 inches.

A sufficient number of stickers per course should be used to keep the lumber flat during drying. When dry stickers are used, four or five stickers per course of 4/4 stock may be desirable. When green stock is used for stickers, the danger of stain and uneven drying is great, and three or possibly only two stickers per course may be a desirable compromise. The use of only two stickers per course will eliminate the probability of a wet area at the center of each board where the third sticker would be, but the lumber is unsupported over an 8-foot span and is more likely to warp (fig. 3). For some uses, however, warp is not objectionable. Regardless of kind or number of stickers per course, the stickers should be aligned vertically over a solid beam. Poor vertical alignment of the stickers will produce warping of the lumber during drying.

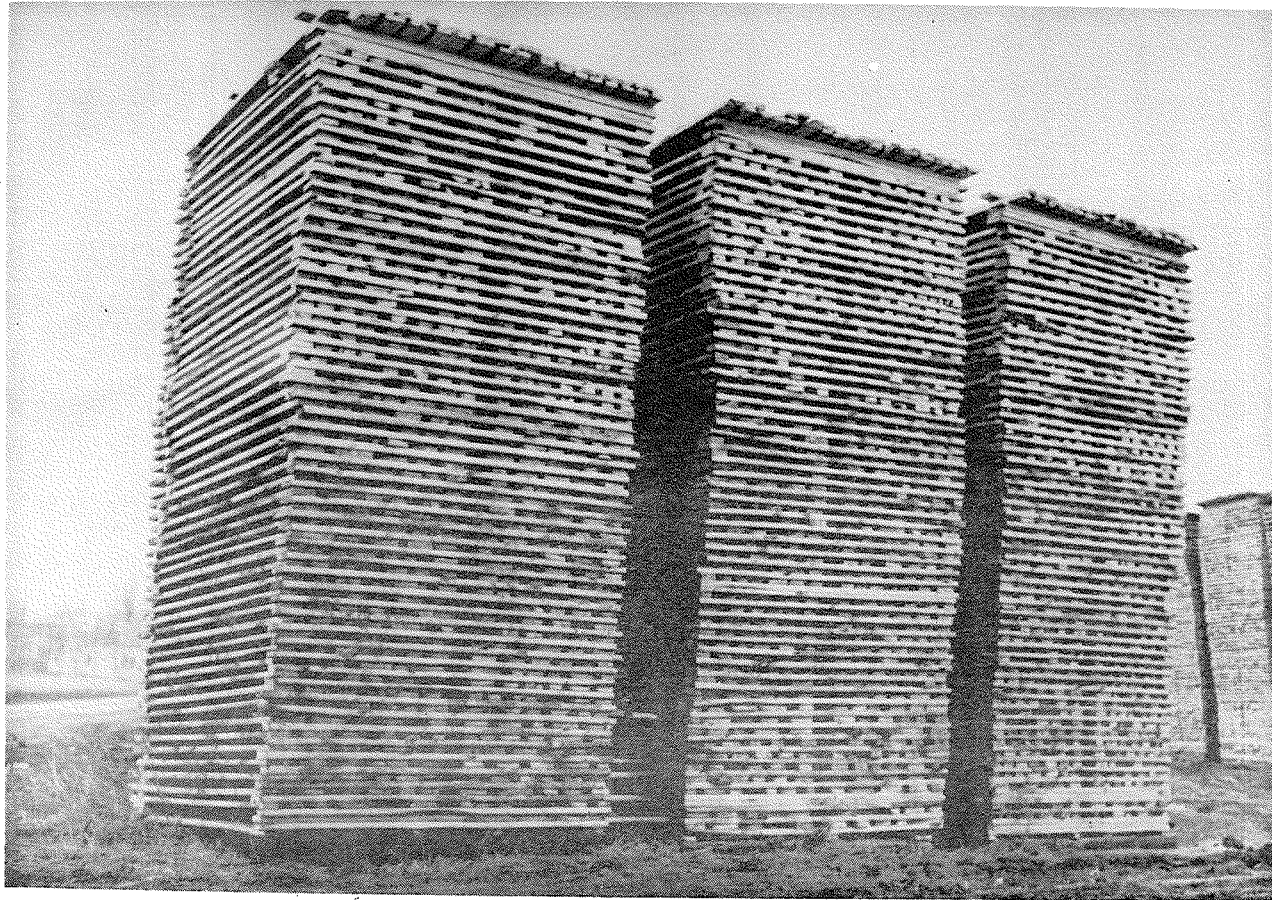


Figure 3. --Air-seasoning piles of aspen lumber laid up with two stickers per course and 6-inch wide central flues. A wider spacing of the boards and piles, and higher and more open foundations would improve the drying rate.

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Spacing the Boards

Wide spacing of boards in each course of lumber is the most effective way of providing vertical flues through the pile that are necessary to promote the downward circulation of air due to the cooling effect of evaporation. In piling random-width stock, the construction of continuous vertical flues is somewhat difficult; a relatively wider spacing between the boards in each course may prove more convenient.

In the early days throughout what is now the aspen area of the Lake States, vast quantities of white and red pine were manufactured into lumber. In piling this lumber for air seasoning, the practice was to place the boards with little or no space between adjacent boards in each course. Apparently this early practice has influenced the present method of piling aspen, for on most yards the boards in each course of a pile are too close together for rapid drying (fig. 4).

Air-seasoning studies on western white pine have shown that the rate of drying can be increased materially by increasing the spacing of the boards in each course from 2 to 4 inches. Under certain conditions, similar improvement in the drying rate of aspen can be expected. Opening the pile and providing for vertical circulation by wider spacing of the boards is an effective and easily applied method of improving the air-seasoning of aspen. No new equipment or yard layout is required; it is simply a matter of laying only 10 7-inch boards per course instead of 12 or 13, or similarly reducing the number of boards per course when piling lumber of other widths.

Flues

Flues are vertical openings in a lumber pile that provide passageways through which air can circulate downward. When piling boards of even width, several continuous vertical flues can be provided by spacing the boards uniformly on all courses. When piling random-width boards, the spacing should be wider and a central flue 6 to 8 inches wide may be provided in each pile to increase vertical circulation. A central flue may be made with parallel sides (fig. 3), or be tapered toward the top, but in either case should extend up through the entire pile to the space beneath the roof. In piling aspen for air seasoning, the need of a central flue is perhaps less than in piling other lumber because of the relatively narrow pile. When piling boards of uniform width, a wide central flue is not essential if the boards in each course are spaced 3 or 4 inches apart.

Roofs

The pile roofs observed in most aspen yards are formed by a double course of low-grade or log-run lumber that is held up from the pile by two or more layers of stickers. The roof is either located directly above the pile or projects forward 4 to 6 inches; in the latter case, the roof does not extend to the rear of the pile.

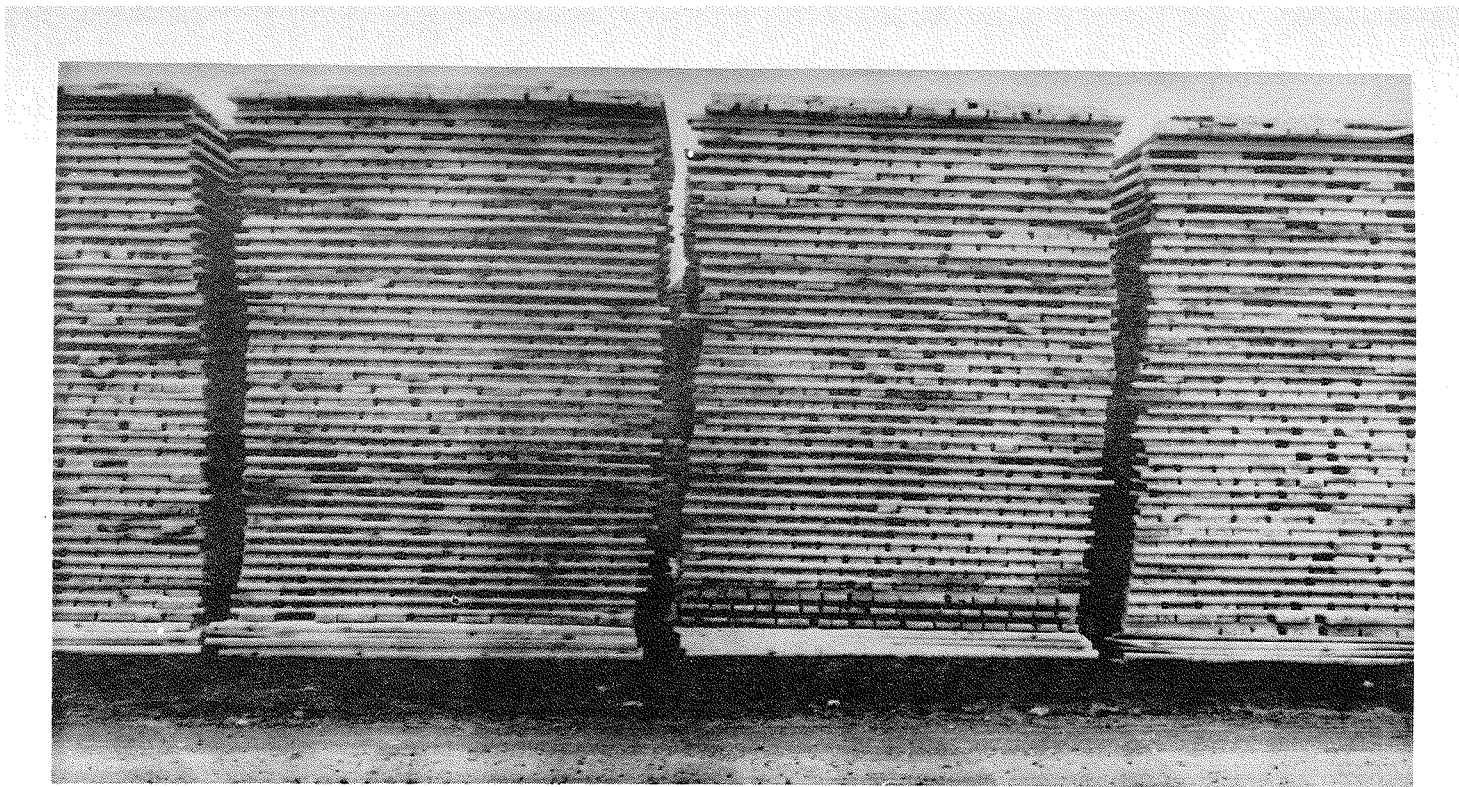


Figure 4. ---Air-seasoning piles of aspen lumber laid up with insufficient spacing of the boards in each course. A wider spacing of the boards and the piles, and a higher and more open foundation would also improve the drying rate.

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An improvement over this type of roof is one built up of two lapped sections, the front section overlapping the rear. The roof can thus be made to project well out over both the front and rear of the pile to afford additional protection from rain. The extra time required to build this better roof should be well repaid in more evenly and faster-dried aspen lumber.

Yard Sanitation

Many of the advantages of excellent piling in an otherwise good air-seasoning yard can be lost by poor yard sanitation. A rank growth of weeds or an accumulation of decayed or scrap lumber, stickers, pile foundations, and similar debris can impede air movement materially and thus retard the rate of drying. Many yard sites in the woods are cleared off with bulldozers, leaving a mass of debris around the yard. This not only tends to restrict the movement of air and thus reduce the efficiency of the yard, but also presents a serious fire hazard that an operator can ill afford. In some cases, the length of time required to dry lumber to a thoroughly air-seasoned moisture content may be doubled because of poor yard sanitation.

Weed growth can be kept down by grazing the yard with sheep, goats, or cows. Chemical weed killers, such as waste crank-case oil or rock salt, are also effective. Alleys in more permanent yards are often paved with crushed rock or cinders to improve them for transporting the lumber and to keep down the weeds.

Removal of the waste materials that accumulate is a matter of good housekeeping. Poor yard sanitation, whether in the form of weed growth or waste materials, often leads to careless piling of lumber, whereas a clean yard will foster careful piling.

Drying Time

Under some air-seasoning conditions, it is reported that 4/4 aspen lumber can be dried to 20 per cent moisture content (based on the oven-dry weight of the wood) in from 40 to 60 days. Under the most favorable conditions, this time may be reduced to less than one month. A somewhat drier condition, however, is desirable for most uses including boxing and crating lumber.

The proper yard layout and method of piling have a pronounced influence on the rate of drying and the minimum moisture content to which lumber will dry. Seasonal weather changes also influence both the rate of drying and the minimum moisture content. The best drying season is during June, July, and August, when the temperature is high and the relative humidity is lower than during other months (fig. 5). The rate of wind movement is somewhat less during this season, however. Because winds are relatively stronger during March and April than at other times during the year, the rate of drying is usually good during this season even though the temperature is fairly low. In localities where normal wind movement is slow, and in yards where natural obstructions reduce the effectiveness of the wind, greater emphasis should be

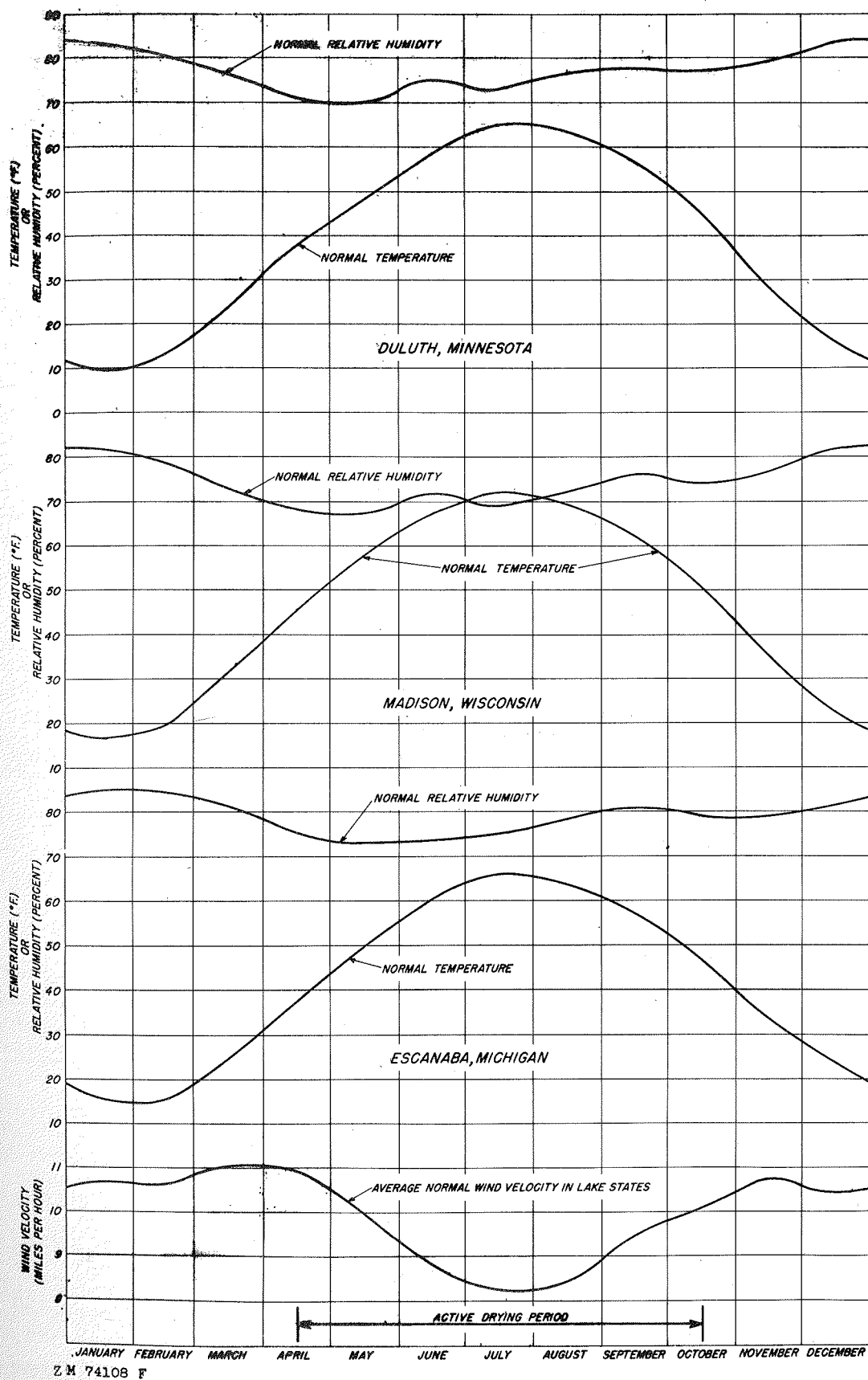


Figure 5. --Normal temperatures, relative humidities, and wind velocities in Lake States areas.

placed on careful piling in order to air season aspen rapidly.

Lumber will dry to a thoroughly air-seasoned condition only during the active drying season. Lumber that is piled during the fall and winter is not thoroughly air seasoned until early summer. Lumber that is sawed in the spring may be thoroughly air seasoned after only two or three months of drying during the favorable drying season.

The uniformity of final moisture content depends to a great extent on the accuracy of sawing as well as the method of seasoning. Six-quarter lumber that varies from 5/4 to 8/4 cannot be expected to dry uniformly fast, and consequently wide variations of final moisture content can be expected. If the stock is allowed to remain on the yard until the thicker pieces are sufficiently dry, considerable time will be lost moving accurately cut pieces.

KILN DRYING

The minimum moisture content to which aspen will dry in a good air-seasoning yard is not sufficiently low for many of the high-quality products for which it is now being used. For core stock, furniture, interior trim, and similar items, a moisture content of 6 to 8 per cent is desirable, and kiln drying is required.

Aspen is a relatively easy species to kiln dry, either green from the saw or after air seasoning. Sapwood and normal, sound heartwood dry rapidly with few or no drying defects. Checking, which is a serious problem in kiln drying of many species, is not serious in aspen, and the development of warp and drying stresses (case hardening) is no more serious than in many other woods. Some darkening of the bright, white wood to a buff color results from use of very high temperatures.

Aspen is peculiar in one respect, however. The heartwood adjacent to the sapwood and areas in the older heartwood sometimes contain abnormal wood that it is exceedingly difficult to dry without the occurrence of serious defects in the form of checks, shake, and collapse. This abnormal wood occurs in appreciable amounts. It can be detected in a freshly cut board by the darker color caused in part by the extremely high moisture content. A few tests have shown a moisture content of approximately 100 per cent in the sapwood, and as high as 230 per cent in abnormal areas of adjacent heartwood. The sapwood of most species usually has a higher moisture content than the heartwood. Aspen wood generally shows an acid reaction, while wood in this extremely high moisture-content zone shows an alkaline reaction, indicating the presence of bacterial or decay organisms. It is doubtful whether a practical drying procedure can be developed to overcome this condition. When such stock is used, however, sufficient drying time should be allowed to obtain uniformity of moisture so as to prevent further distortions after machining.

Experiments carried on at the Forest Products Laboratory in the kiln drying of 4/4 and 6/4 aspen showed that sound, white wood of this species can be dried successfully at high temperatures and low relative

humidities, but that abnormal heartwood will open along the growth rings and collapse even at very mild drying temperatures. In fact, considerable collapse occurred in abnormal wood when dried at only 80° F., and further study to determine the possibilities of kiln drying this wood without collapse was believed impractical. Apparently some defects that develop in lumber containing this abnormal wood will have to be accepted as inevitable in the kiln-drying operation.

Piling for Kiln Drying

Greater care is required in piling aspen for kiln drying than for air seasoning because wood becomes more plastic at usual kiln temperatures and is more likely to warp during drying. Special stickers are essential and at least four, and preferably five, are required per course of 8-foot stock. The stickers should be aligned vertically over the beams that make up the kiln trucks to give each course of lumber level support and to hold the lumber flat during drying. The end sticks in each course should be at the ends of the lumber to reduce warping and end checking.

Stickers are usually sawed 1 x 1½ inches in size from straight-grained and fairly clear wood.

Temperature

The maximum initial temperature suitable for drying aspen depends on the heating capacity of the kiln and the discoloration of the wood. An initial temperature of 180° F. or above with a relative humidity of 60 to 80 per cent will darken the wood somewhat, and if bright, white wood is desired, an initial temperature of 160° F. or less should be used. This limitation is not objectionable because aspen placed in the kiln green from the saw dries very rapidly, and after it has dried to a moisture content of 40 per cent or lower, temperatures of 170° and 180° F. can be used without noticeable discoloration.

Relative Humidity

The initial relative humidity also seems to be governed to a certain extent by the heating and venting capacity of the kiln. Unusually low humidities can be used, and because the wood dries fast some kilns may lack sufficient venting capacity to remove the moisture as fast as desired. A relative humidity of 35 per cent can be used successfully, but a more moderate relative humidity gives an excellent drying rate and less drying stresses. Extremely low initial relative humidities are, therefore, not necessary. An initial relative humidity of 60 per cent (19° wet-bulb depression at a dry-bulb temperature of 160° F.) is both conducive to rapid drying and a condition that can be maintained at the first of the run in most kilns.

In most modern forced-circulation kilns having uniform drying conditions, the relative humidity can be lowered after one day of drying. A drop of the relative humidity from 60 per cent to as low as 5 per cent after one day of drying in an experimental kiln produced good results. Very

low, intermediate and final relative humidities are conducive to fast drying and bright, white wood, but often result in an unnecessarily low moisture content in some boards. The desirable final relative humidity appears to be about 25 per cent, which, at a temperature of 180° F., is equivalent to an equilibrium moisture content of about 3 per cent.

Conditioning

The usual practice for conditioning lumber to relieve case-hardening stresses after it is kiln dried is to steam it at a relative humidity equivalent to an equilibrium moisture content about 2 to 4 per cent higher than the average moisture content of the lumber and at a temperature equal to or somewhat higher than the final kiln temperature. The pickup of moisture in the surface fibers and the plasticizing effect of the heat cause an equalizing of the stresses. The most effective stress relief is possible if the charge has been dried to a uniform moisture content, for a steaming treatment that produces good stress relief in lumber at one moisture content will be too severe or too mild for lumber at a lower or higher moisture content. Both the duration of the conditioning treatment and the thickness of the stock will also influence the temperature and relative humidity used. Excessive temperatures and relative humidities, if continued for too long a time, will result in a reversal of the drying stresses. Aspen lumber that is dried to a moisture content of 12 to 18 per cent does not offer the best chances for good stress relief, but aspen that has been kiln dried to a lower uniform moisture content can be conditioned readily.

Suggested Schedule

The schedule shown in table 1 is conducive to rapid kiln drying with a minimum of drying defects. Also the conditioning treatment will relieve the drying stresses satisfactorily. This schedule, based on the moisture content of the stock, is suitable for drying 4/4, 6/4, and 8/4 aspen lumber green from the saw, or aspen lumber that has been previously air seasoned. Accurate control, to assure uniform drying conditions throughout the kiln, and fast air circulation are required for uniform and rapid drying. These conditions are maintained best in a modern forced-circulation kiln having adequate heating and venting capacity. Kiln samples are used to check moisture content of the lumber at various stages of the drying process, as indicated in the schedule given in table 1. (Forest Products Laboratory Report No. R1607 gives a detailed explanation of how to use kiln samples.)

In kiln drying aspen lumber that has been previously air seasoned, the same conditions of temperature and humidity can be maintained in the kiln that are called for by the schedule for stock of similar moisture content. Thus, thoroughly air-seasoned stock (having a moisture content of 18 to 20 per cent or less) can be dried at the final conditions of 180° F. dry bulb and 130° F. wet bulb.

Table 1.--Dry-kiln schedule for 4/4, 6/4, and 8/4 aspen lumber

Moisture content at which change should be made	Temperatures		Relative humidity	Equilibrium moisture content
	Dry bulb	Wet bulb		
<u>Per cent</u>	<u>° F.</u>	<u>° F.</u>	<u>Per cent</u>	<u>Per cent</u>
Above 60	160	140	58	7.9
60	160	130	43	5.8
40	170	120	24	3.2
20 to 7	180	130	26	3.3
Conditioning treatment (2 to 4 hrs.)	180	170	80	11.4

Drying Time

In a kiln having fast air circulation and good control of drying conditions, 6/4 aspen lumber can be dried green from the saw to a moisture content of 6 to 8 per cent in five days. In kilns that have slower circulation and less uniform drying conditions, the time is increased by several days.

The cost of kiln drying varies considerably, depending on the kind of kilns and the kind of material being dried. No exact cost figures for drying aspen are available, but \$1.00 per M board feet per day of kiln drying can serve as a very rough estimate. By this rule, 6/4 aspen that is kiln dried in five days would cost approximately \$5.00 per M board feet to dry.

The cost of lumber dry kilns also varies greatly. Some kilns with a capacity of approximately 6,000 board feet have been built for as little as \$3,000, while some of similar capacity may cost more than twice that amount. During the years 1939 to 1941 a kiln having a capacity of 30,000 to 36,000 board feet could be built for approximately \$15,000 to \$18,000.

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