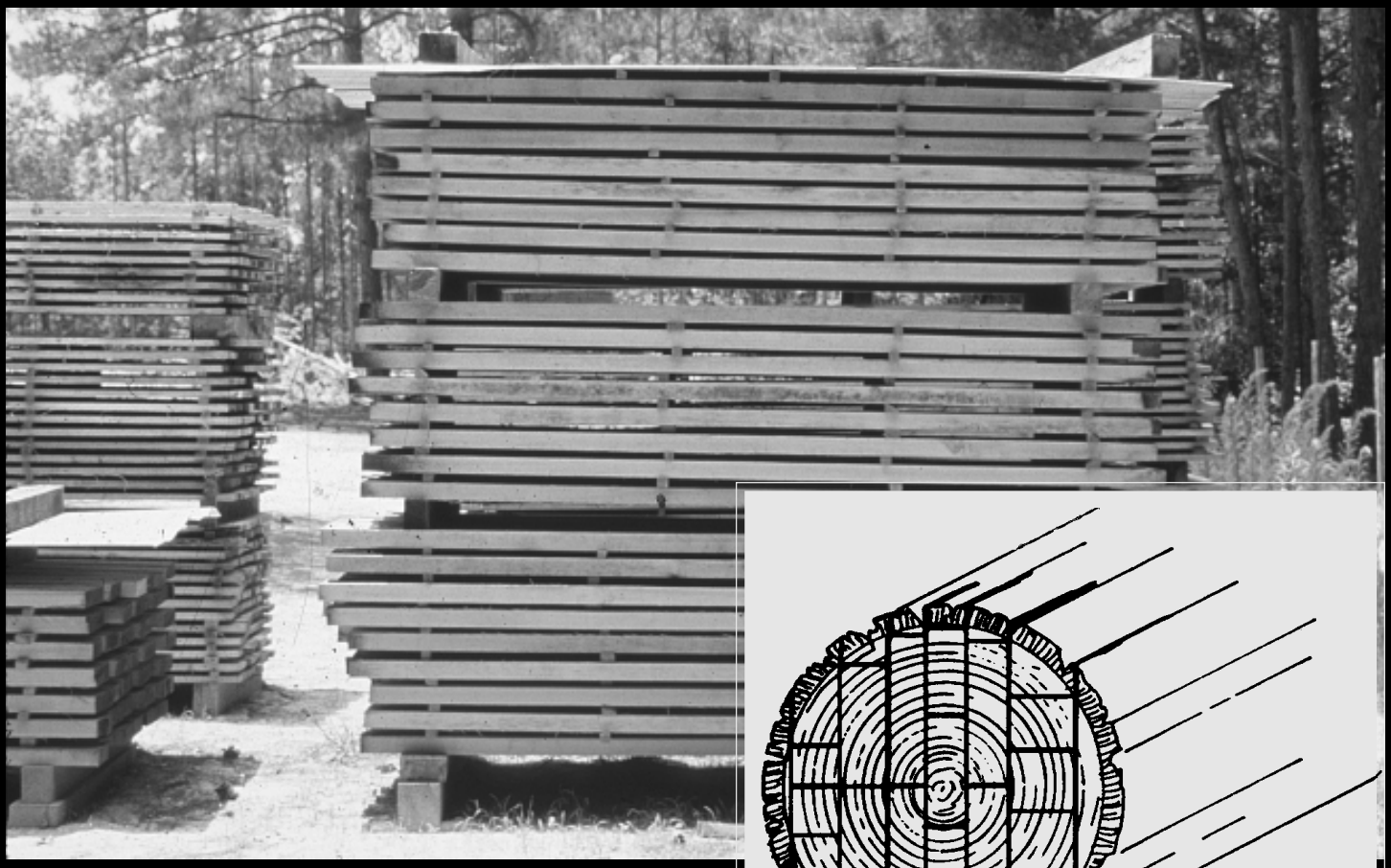
Seasoning to Prevent Defects in Green Wood



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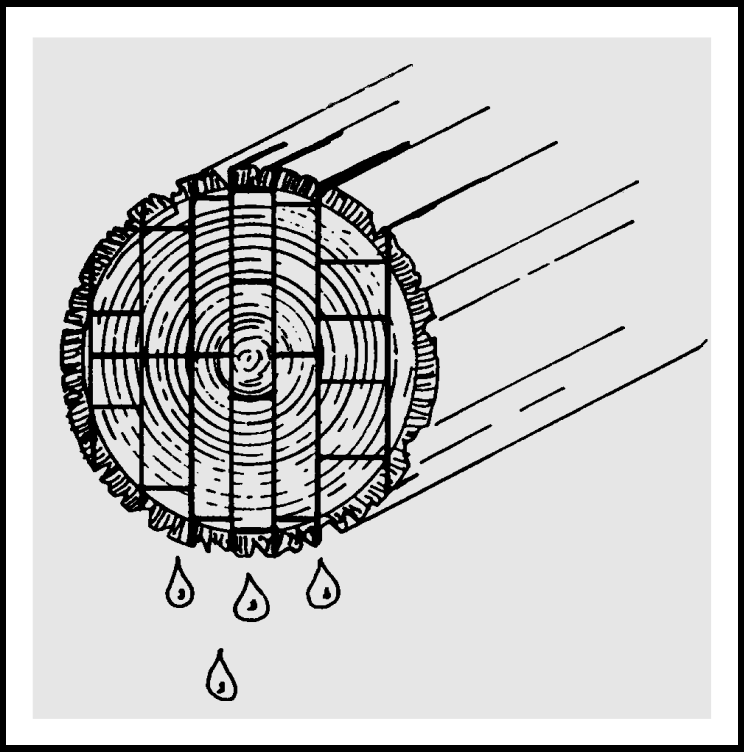

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Introduction

This publication provides information on some of problems and basic principles involved in seasoning lumber, wood disks and other small pieces of wood. It is intended to help individuals who would like to season small quantities of wood inexpensively and without sacrificing quality. Small mill owners may also find this information useful in the manufacture of dried wood products.

In addition to information on the seasoning processes, this publication covers pre-drying treatments that reduce defects like mold, stain, decay, check, splitting and warp. The pre-drying procedures include treating wood with PEG (Polyethylene glycol-1000), salt paste, pre-surfacing, end-coating and dipping in fungicides. Some solar dry kiln issues are included. A troubleshooting section deals with some potential pitfalls that can easily be avoided when drying wood.

When wood is first sawn from a green log, up to two-thirds of the weight of the wood is water. Much of this water must be removed from the lumber before it can be made into useful products. The moisture content (MC) of wood is defined as the weight of the water in the wood as a percentage of the weight of the oven-dried wood:

The moisture content of green hardwoods may be more than100 percent. Extra care is needed from the time a tree is felled until the lumber has been correctly seasoned for the intended use. Most dense, native woods (like oak, hickory, sycamore, beech, walnut, ash and elm) require even more careful drying than pine or some of the other light woods (like basswood, yellow-poplar, soft maple or cherry). Extra care and proper seasoning,however, will pay off with these advantages:

1. Drying reduces the likelihood of insect infestations, mold, stain and decay during storage and use. Fungi and termites cannot grow in wood with a moisture content of less than 20 percent.

2. The shrinkage that accompanies seasoning is completed before the wood is put to use.

3. Drying reduces weight and increases most strength properties of wood.

4. Only relatively dry wood can be successfully glue-jointed, finished, machined and treated with chemicals.

$$MC\ (\%) = \frac{\text{initial weight - ovendry weight}}{\text{ovendry weight}} \times 100$$

Principles of Wood Drying

Wood dries by movement of free water through fiber cavities, movement of bound water through fiber walls and movement of water vapor through wood fiber spaces. When wood dries to about 30 percent MC, or the condition in which the water has been removed from the fiber cavities but water in the fiber walls remain saturated, it is said to be at fiber saturation point (FSP). Shrinkage of wood begins only when the moisture content drops below the FSP.

Because wood is not homogeneous, it shrinks more along the growth rings than across the rings (Figure 1). The least shrinkage or swelling of wood is found in the longitudinal or "tree trunk" direction. These shrinkage variations cause drying defects like warping and checking. Shrinkage and swelling cease as the MC of wood approaches an equilibrium with its environments. Species of wood vary in the rate and amount of shrinkage.

An individual piece of wood will display unique shrinkage or swelling patterns in the three planes of the wood. The three primary directions of wood movement are: tangential (perpendicular to the growth rings), radial (parallel to the growth rings) and longitudinal (parallel to the grain, the direction of the standing tree) (Figure 2). Tangential dimensional change is often nearly twice that of radial movement for most domestic wood species. Longitudinal dimensional change is almost always negligible for most domestic wood species unless abnormal wood tissue is present.

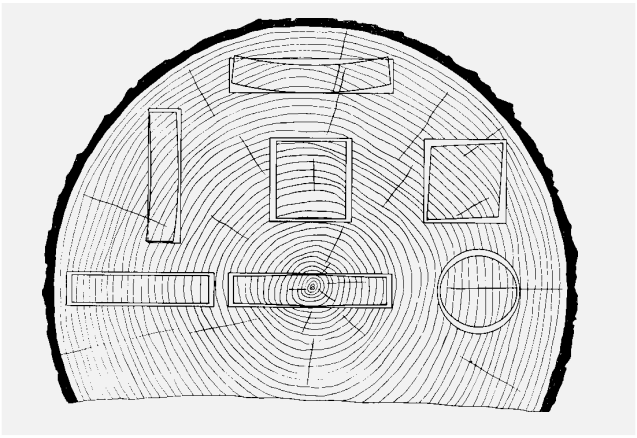

***Figure 1**. Wood shrinkage and distortion of flats, squares and rounds as affected by the pattern and direction of annual growth rings. (Source: USDA Forest Products Laboratory 1987)*

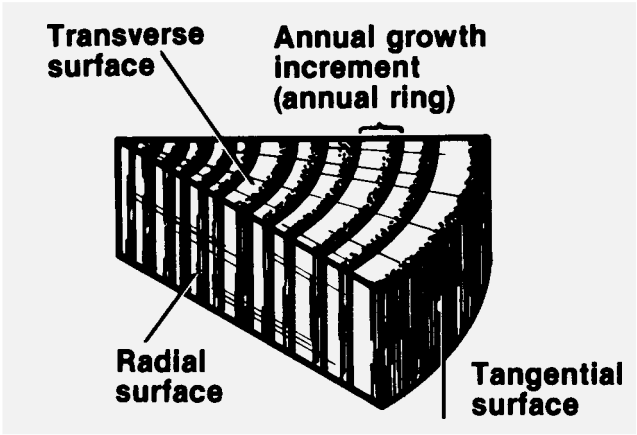

Figure 2. The three primary surfaces of wood. Dimensional movement is unique in each of these three planes. (Source: USDA Forest Products Laboratory 1987)

Wood will give off or take on moisture when surrounded by air at a given relative humidity (RH) and temperature. When moisture gains are equal to moisture losses, the wood is said to be at a constant MC. The green MC will vary between the wood in the middle of a log (heartwood) and near the bark (sapwood) of most wood species (Table 1). In the average home, where air conditioning and central heating keep RH at 25-50 percent and the temperature around 70 degrees Fahrenheit, the MC of wood ranges between 5 and 9 percent. The wood framing (joists, rafters and studs) in a building attain an average MC of about 12 percent. Under warm, humid conditions, as in a greenhouse with an RH of 90 percent, wood will have MC of about 20 percent. Table 2 gives wood MCs for different temperatures and relative humidities. Table 3 shows the recommended MC values for various wood articles at time of installation. Table 3 shows that the MC of other wood-based materials such as particleboard, hardboard and laminates is between 20 percent and 60 percent lower than in lumber or plywood, depending on the resin content, type of finish and treatment.

To avoid shrinkage, warping, checking and splitting in the finished product, lumber must be dried to a final MC close to the middle of the range of expected in-use moisture content. In Louisiana, most furniture, cabinetry and store fixtures are normally exposed to an indoor temperature ranging from 30 degrees to 100 degrees Fahrenheit and a relative humidity ranging from 30 percent to 90 percent. Figure 3 illustrates that the recom-

mended MC for interior wood is 11 percent for all of Louisiana. Louisiana is fortunate in that there are essentially 12 months a year of good air drying conditions (Figure 4). See Table 4 for the estimated time to air-dry green 1- and 2-inch thick eastern hardwoods. Table 1 shows that within this narrow range, the variation in temperature has little effect on the MC. It appears the RH plays the more important role in determining the MC of lumber.

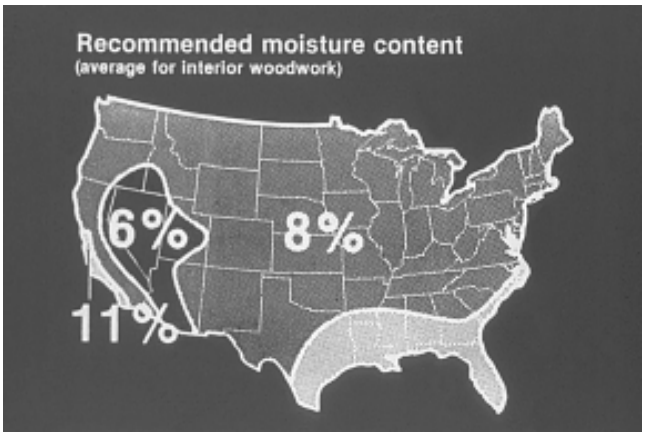

Figure 3. The recommended moisture content at the time of installation for interior wood and wood-based products varies throughout the country. Producers should be aware of the recommended moisture content values for wood and wood-based products when selling goods to these areas. Source: Peck (1955).

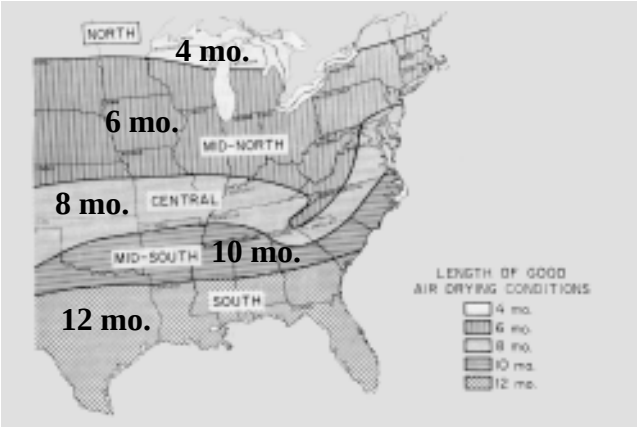

Figure 4. Air-drying map for the Eastern United States. Source: McMillen and Wengert (1978).

Table 1. Moisture content (percent) of green wood of some commercially important species.

Species	Moisture Content (Percent)	
	Heartwood	*Sapwood*
	Hardwoods	
American basswood	81	133
American beech	55	72
American elm	95	92
American sycamore	114	130
Black cherry	58	—
Black walnut	90	73
Hackberry	61	65
Paper Birch	89	72
Pecan (Mockernut)	70	52
Pecan (Water)	97	62
Sugar maple	65	72
Sweetgum	79	137
Water tupelo	150	116
White ash	46	44
White Oak	64	78
Yellow-poplar	83	106
	Softwoods	
Bald cypress	121	171
Douglas-fir (Coast type)	37	115
Eastern hemlock	97	119
Loblolly pine	33	110
Eastern red cedar	33	—
Eastern spruce	34	128
Redwood (Old-growth)	86	210
Western white pine	62	148

Source: USDA forest products Laboratory (1987).

Table 2. Moisture content (percent) of lumber at various temperatures and relative humidities.

Temperature (degrees Fahrenheit)	*Relative Humidity (Percent)*								
	10	20	30	40	50	60	70	80	90
30	2.7	4.7	6.4	8.0	9.7	11.4	13.8	17.2	22.5
40	2.6	4.6	6.3	7.9	9.5	11.2	13.4	16.8	21.8
50	2.5	4.6	6.3	7.8	9.4	11.1	13.3	16.5	21.4
60	2.5	4.5	6.2	7.7	9.3	11.0	13.2	16.3	21.0
70	2.4	4.5	6.1	7.6	9.2	10.9	13.1	16.1	20.6
80	2.4	4.4	6.0	7.5	9.1	10.7	12.8	16.0	20.4
90	2.3	4.3	5.9	7.4	8.9	10.5	12.6	15.7	20.0
100	2.2	4.1	5.7	7.2	8.7	10.3	12.4	15.5	19.6
Average	2.5	4.5	6.1	7.6	9.2	10.9	13.1	16.3	20.9

Table 3. Recommended moisture content for various wood items at time of installation.

Moisture Content (Percent)		***Wood Use (Indoor and Outdoor)***
Range	**Average**	
6-9	8	Hardboard, laminates
6-10	8	Common interior trims, finished furniture, particleboard, kiln-dried lumber, toys, paneling, cabinetwork and other woodwork in centrally heated rooms.
10-14	12	Doors, windows, moldings, sports equipment, tool handles, exterior trim and millwork, siding, sheathing and furniture for slightly heated rooms.
12-19	12	Garden furniture, decking, shingles, housing frame lumber (such as joist, rafters and studs), boxes and crates
20-25	22	This moisture content is sufficient for the growth of termites, stain and decay-causing fungi!
12-30	30	Max. Piling, bridge trestles, underground construction and wood (Fiber saturation that will be treated with preservatives or fire-retardant point) chemicals.

Table 4. Estimated time to air-dry green 1- and 2-inch eastern hardwood lumber to approximately 20 percent average moisture content.

Species[1]	Size	Estimated time by region[2]	
	Inch	*South Days*	*Mid-South Days*
Ash	1	45-70	45-75
	2	180-210	180-220
Beech	1	45-70	45-75
	2	180-210	180-220
Cherry	1	45-70	45-75
	2	180-210	180-220
Cottonwood	1	40-65	40-70
	2	170-200	170-210
American Elm	1	40-65	40-70
	2	170-200	170-210
Hackberry	1	40-65	40-70
	2	170-200	170-210
Hickory	1	50-80	50-95
	2	190-230	190-240
Magnolia	1	40-75	—
	2	170-220	—
Soft Maple	1	40-65	40-70
	2	170-200	170-210
Hard Maple	1	45-70	45-75
	2	180-210	180-220
Red Oak	1	60-120	55-100
	2	240-360	215-300
White Oak	1	60-120	55-100
	2	240-360	215-300
Pecan	1	60-120	65-100
	2	240-360	215-300
Sweetgum	1	50-80	50-95
	2	190-230	180-240
Sycamore	1	40-65	40-70
	2	170-200	170-210
Tupelo-gum	1	60-110	45-90
	2	210-300	180-220
Black Walnut	1	45-70	45-75
	2	180-210	180-220
Black Willow	1	30-65	35-70
	2	150-200	160-210
Yellow-poplar	1	40-65	40-70
	2	170-200	170-210

[1]Forest Service official tree names; corresponding botanical names are included in Appendix D of McMillen and Wengert (1978).

[2]Regions of approximately equal number of months of "good" air-drying weather in accordance with figure 5 of McMillen and Wengert (1978).

Source: McMillen and Wengert (1978).

Protecting Logs and Bolts

Before wood seasoning actually begins, a number of steps are important to reduce drying defects. If great care is not taken in the early stages of the lumbering process, subsequent drying may be ineffective in reducing defects. The first several weeks are especially crucial.

Precaution must start with the logs. Freshly cut logs and bolts are subject to long-term and short-term hazards. Stresses in the living tree may cause severe checking and splitting at the time of felling or soon afterward. Long-term hazards include end-checking, stain, decay and insect attack. Damage is most rapid in logs cut between April and October, when fungi and insects are most active.

The following procedures will help protect logs and bolts from damage:

1. Keep logs continually wet or store them under water if possible during spring, summer and fall.

2. Orient green logs and bolts carefully. Ends of logs oriented east to west are not as adversely affected by solar heating. South ends of logs and lumber oriented north to south receive intense solar heating. This promotes severe checking and subsequent loss of wood. End coating may help prevent checks during storage.

3. Saw the logs into lumber as soon as possible, or within 15 days of felling. This is especially important during warm weather.

4. If logs must be dry stored for longer than a month, debark the logs and spray the ends and sides thoroughly with a combined fungicide-insecticide within 10 days of cutting. To prevent discoloring stain penetration, spraying should be done within 24 hours of cutting during the warm season.

5. Use an end-coating to reduce log and bolt end checks. Commercial solutions, asphalt, coal-tar pitch, crude petroleum, oil-based paint and paraffin can all be used.

6. Fungicide-insecticide treatment (applied with a hand-operated garden sprayer) should be followed by an end-coating. Use a sprayer or brush to apply a thick film of end-coating to the ends of logs and bolts. Do not apply sealer to outside of logs, only the ends.

7. Debarking logs will help prevent stains and insects. A straight neck hoe or commercial debarker can be used to remove bark.

Follow precautions when using pesticides! Fungicides and insecticides used improperly can injure humans, animals and plants. Follow the directions and heed all precautions on the labels. Do not apply pesticides when there is danger of drift. Wear and use protective clothing and equipment specified on the container. If your hands or eyes become contaminated with a pesticide, follow the first-aid treatment given on the label and get prompt medical attention.

Outdoor Air Seasoning

There are several methods available for drying lumber, ranging from air- and kiln-drying to special seasoning processes. The customary method for many hardwood species has been to air-dry the lumber to 20-25 percent moisture content, then kiln-dry to specific requirements beyond that point.

Air seasoning is the most economical and widely used method of removing large quantities of water from lumber. Air-dried lumber has satisfactory dimensional stability for many applications involving outdoor exposure such as sheds, barns, bridges and other general building construction. Hardwood for interior uses is generally air-dried before kiln drying to reduce overall drying costs and defects. Small quantities of hardwood lumber can be air-dried outdoors, however, and then dried further by various techniques more appropriate for noncommercial operations. The objective of outdoor air-seasoning is to reduce the MC of lumber to a value consistent with climate conditions and to accomplish this in the shortest time with minimum drying defects.

A couple of "sawyer's rules" will hasten drying and improve finished products: *1)* Try to cut lumber to the smallest usable dimensions or thickness before you start the drying process. If the thickness of lumber is doubled,

the drying time more than doubles. If a finished wood item will be over 2 inches thick, it is best to make it from two or more pieces glued together after drying and planing. *2)* When the logs are sawed, it is best to cut each piece of lumber to 1/4 inch over final size (plus or minus 1/8 inch) to allow for shrinkage and planning.

Piling Your Lumber Properly

Freshly cut green hardwood lumber should be properly stacked or piled to hold it straight and flat while it dries outdoors. As the water is removed, lumber has a tendency to warp, twist, cup and bow. These defects are illustrated in Figure 5. The extent of drying defects depends on the species of wood (Table 5). The following are important considerations in piling lumber:

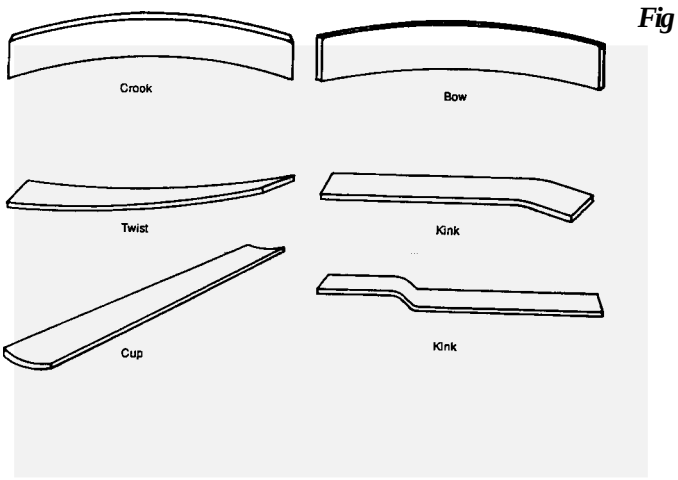

Figure 5. Drying defects that can occur in improperly seasoned lumber.

Figure 6a. A poor commercial site for seasoning native hardwood. This low-land site has poor air circulation and is subject to flooding. Stacks should be covered.

Figure 6b. A poor stacking job with no stickers between boards. There is little ventilation under or inside the pile. Lumber piled in this fashion may lead to warp, check, stain and decay.

1. Site: Pick an open, well-drained site for the pile. Avoid low areas where buildings will slow down the air currents. Remove weeds and trash from around the pile to lower moisture hazard and increase air movement into the pile. A hard surface or built-up gravel is preferable for ground preparation.

2. Foundation: Build a firm foundation which presents a perfect plane for the first layer of lumber. A slope of 1 inch per foot of pile length will aid drainage. Space the piers 4 feet apart. Sink the piers in a solid foundation (Figure 6).

3. Pile clearance and width: Make the distance from the ground to the bottom layer of lumber at least 12 inches. Make the pile as long as the longest boards and not over 6 feet wide. On the top of the piers, place 4- x 6- inch stringers as long as the pile width. Across the stringers put 4- x 6- inch supports every 2 feet. When you cannot find stringers as long as the pile, lap the joints directly on the piers (Figure 7).

4. Stacking: Each layer should contain lumber of the same thickness and length. This will hold warpage to a minimum. Place a single layer of lumber on the cross supports. Put stickers to make lumber season straight, and space boards about 1 inch apart. Large stacks of

winter stored lumber will dry better with a chimney space left in the pile center. Twelve inches will usually suffice.

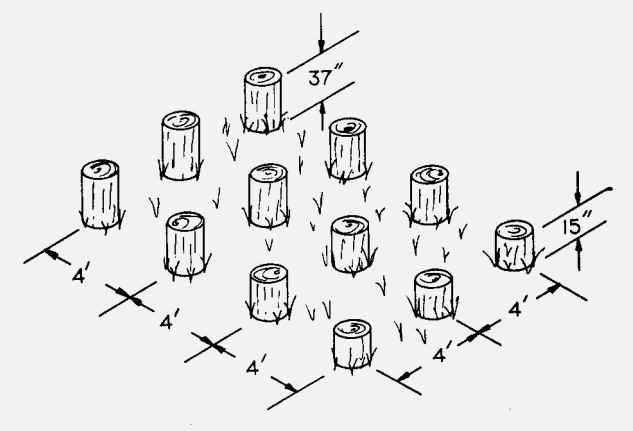

Figure 7a. A good foundation is needed for correct stacking and good seasoning. Use treated wood, steel or concrete.

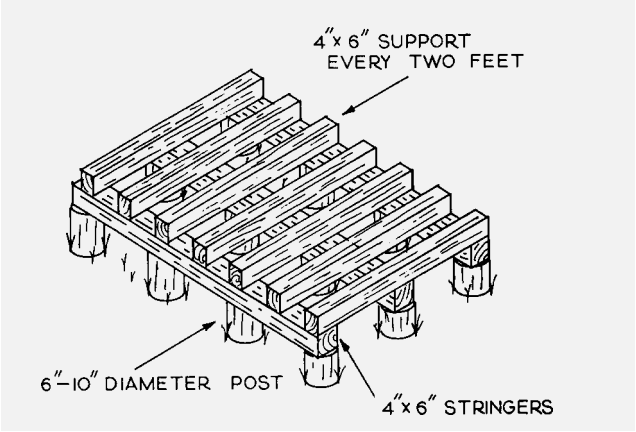

Figure 7b. Start the pile by alternate placing of all the shorter lumber inside the layer. Orderly piling and spacing make for good ventilation and even drying. Do not allow lumber ends to hang over more than 6 inches.

5. End-coating: Reapply the end-coatings on lumber where the end-coating has been trimmed off or damaged. A commercial solution is usually best and most convenient.

6. Stickers and spacing: Stickers are strips of wood used to separate the layers of boards. Stickers should be dried, stain treated, equal thickness (about 1 inch), and should be spaced 18 to 24 inches apart along the length of boards. Each sticker should be placed atop the green lumber directly over the stickers in lower layers. From the side of the pile, the stickers should appear to be aligned in perfectly vertical tiers. Stickers may be 1.5 to 2.5 inches wide. Use one of the wider stickers at the ends of the boards. This will reduce end-checking.

Figure 8. A new form of sticker is shaped like a dog bone. These stickers provide maximum ventilation between adjacent lumber, because they are curved and have less surface area in contact with the boards. These stickers will provide better ventilation than traditional stickers and minimize the possible area for the transfer of stain from a sticker to a board (sticker stain). It is always important to keep stickers dry and discard stained or broken stickers immediately.

7. Board spacing: To encourage good air circulation, place boards at least 1 inch apart as you lay them across the stickers for that layer. Place longest boards on the outer sides of the layer. Then alternate the shorter pieces so that one is flush with the front of the pile and the next is flush with the rear. Keep flat-piled pieces of lumber 2 inches apart for good air circulation.

8. Pitch: The front end of the pile should pitch forward 1 inch for each foot of height for water runoff.

9. Roof: Protect the stack with a roof that extends about 2 feet beyond the front and rear ends of the stack. The roof should drain to the rear and should be at least 4 inches above the pile, to allow ventilation. Weight down the roof with concrete blocks or other materials (at the rate of 60 pounds or more per square foot) or wire the roof securely to the pile.

Figure 9. Good seasoning practices include a level, well-drained open area that is not subject to flooding. Foundations should hold the lumber at least 15 inches above the ground and a fastened roof or cover to protect wood from rain. Orient stacks to reduce sun exposure and increase air flow, usually north to south stacks.

Table 5. Tendency to check[a] and warp[b] for various hardwoods.

Low		***Intermediate***		***High***	
Checks	*Warp*	*Checks*	*Warp*	*Checks*	*Warp*
American Elm	Birch	Ash	Ash	Beech	American Elm
Basswood	Black Walnut	Birch	Basswood	Oaks	Beech
Cherry	Butternut	Butternut	Hackberry	Sycamore	Cottonwood
Cottonwood	Cherry	Hackberry	Hickory		Sweetgum
Red Maple	Yellow-poplar	Hickory	Maples *(Red and Sugar)*		Sycamore
Yellow-poplar		Pecan	Oak		Tupelo-Gum
Tupelo-gum		Rock Elm	Pecan		
		Sugar (Hard) Maple	Rock Elm		
		Sweetgum			
		Black Walnut			

[a]Check: Face check, end check and heart check or honeycomb.
[b]Warp: four kinds of warp are defined as follows:
1. Cup - Deviation from a straight line across the with of the lumber.
2. Bow - Lumber deviates from flatness lengthwise, but not across the faces.
3. Crook - Lumber deviates edgewise from a straight line from end to end.
4. Twist - The four corners of a piece of lumber are not in the same plane.

Drying Time for Lumber

In the South, wood seasons slowly in winter and early spring, but if native lumber is carefully piled, it will season quickly during the warm months. When May, June, July and August are the seasoning periods, 1-inch lumber can be air-dried to between 15 percent and 20 percent MC, as shown in Table 4. Wood destined for interior use in the Deep South and coastal California is recommended to be dried to a moisture content of 11 percent (Figure 3). Outdoor seasoning will usually not be sufficient to dry to this low of a moisture content used for interior applications. Therefore, most interior wood is kiln or indoor dried to the target moisture content.

Table 5 shows the effective air-drying days necessary to properly air-dry various hardwoods for exterior applications (approximately 20 percent MC). The species listed as fast drying, such as basswood and cottonwood, are less dense than the slower drying species, such as the oaks and hickory. The drying rate of a species depends largely on the density and thickness of the wood. In short, a denser wood will by definition of density contain more mass per unit volume than a less dense wood. A species like oak is a dense wood because it contains more wood per unit volume than air space per unit volume. As the amount of wood per unit volume increases, so do the binding sites for water to attach itself to the wood. Less dense species contain larger amounts of air space per unit volume than denser woods, so these species cannot hold as much water.

Table 6. Effective air-drying days needed to season various hardwoods (1-inch thick lumber) to 20 percent moisture content.

Species	***Estimated Time*** *(Effective Air Drying Days)*
Fast drying:	**40-75**
Basswood, Cottonwood, Hackberry, Sycamore and Yellow-poplar	
Medium drying:	**45-80**
Ash, Beech, Cherry, Gum and Walnut	
Slow drying:	**50-90**
Birch, Elm, Hickory, Red Oak, White Oak and Pecan	

Note: Drying times for 2-inch thick lumber are three to four times as long as those for 1-inch lumber.

Indoor Seasoning

Outdoor air-drying by itself is often insufficient to season most lumber intended for interior uses, but "finishing lumber" can be effectively prepared by further drying in heated or dehumidified spaces such as a basement, garage, shed or homemade solar dryer.

A dry kiln is a chamber in which the air temperature and the RH can be regulated. With the controlled environment, lumber can be dried at an optimum rate: slowly enough to prevent warping and cracking, but fast enough to get rid of the water economically and prevent wood decay and stain. Unfortunately, the cost of a dry kiln can be prohibitive for a small lumber producer or hobbyist. The suggestions that follow are alternative ways a small lumber producer or wood hobbyist can dry wood at home.

In a Home or Farm Building

Indoor seasoning in your home or farm buildings is straightforward. Typically a hobbyist will purchase green lumber from a sawmill early in spring and pile the material properly in the back yard for the remainder of the spring and summer. The hobbyist will then transfer the stack to a heated barn, garage or basement, leaving it there during the next heating season. The storage area is humid at first, but gradually becomes dry in late fall when temperatures drop below the temperature of the heated indoor area. Early in February, the humidity of the storage area will reach a minimum, and the MC of the wood surface (or shell) will be very low while the still-moist core continues to dry. In March the RH gradually increases, and the shell will reabsorb some water vapor from the surrounding air.

By the end of spring the boards will be uniformly dried to below 10 percent MC (Table 7). To prevent slow-drying hardwood species (listed in Table 6) from drying too fast during the first heating season, cover the stack with a polyethylene sheet, or keep it in an unheated garage or basement.

As a general rule, air-dried hardwood lumber and wood for carving, bowls or gun stock blanks should be coated on all end grains. Change the storage conditions by moving the wood from damp areas to successively drier areas. For example, this lumber may be stored for a while in the garage or barn. It can then be moved to a cool room in the basement, to the furnace room and finally to the work room or the area where the finished products will be used. If the wood is not prepared in advance for its final destination, it will change dimension after it is in manufactured form.

In a Homemade Solar Kiln

For hobby use, a small homemade solar kiln can be built to dry small quantities of native lumber for private use. Solar drying can be two to three times faster than outdoor air drying and the method will dry hardwood to the 7 percent to 8 percent MC required for interior applications. Specific plans for constructing a solar kiln are available from the Louisiana Cooperative Extension Service.

In the solar kiln, the sun's heat is collected by single thickness windows on the south-facing wall of the kiln. A total of about 48 square feet of glass surface serves as the solar collector. Four heat collectors are fabricated from black sheet metal fastened to a hardboard backing. The heat collectors are attached near the top of the sash. This allows warm air to flow from the heat collector into the dryer (Figure 10 and 11).

Figure 10. The front south side view of a solar-heated lumber dryer. (Photo courtesy of USDA Forest Products Laboratory).

Figure 11. East side of solar lumber dryer showing principal loading and unloading door and the small access to collector area. (Photo courtesy of USDA Forest Products Laboratory).

Table 7. Resulting indoor relative humidity and wood moisture content when outdoor air at 80 percent relative humidity and various temperatures is brought into an unhumidified room and heated to 68 degrees Fahrenheit.

Outdoor Air Temperature at 80 percent RH (degrees Fahrenheit)	*Indoor Relative Humidity (%)*	*Wood Moisture Content (%)*
65	74	14.1
60	60	11.0
55	54	10.1
50	48	8.8
45	36	7.4

Outdoor Air Temperature at 80 percent RH	Indoor Condition at 68 degrees Fahrenheit	
(degrees Fahrenheit)	*Indoor Relative Humidity (%)*	*Wood Moisture Content (%)*
40	29	6.2
35	24	5.0
30	19	4.5
25	16	3.6
20	13	3.0
15	10	2.5
10	7	2.0
5	5	1.5
0	3	1.0

An electric motor drives a fan, but only when the temperature is above 85 degrees Fahrenheit. The air is forced down into a central flue, then passes horizontally through the lumber pile. It takes about 70 clear days or 400 hours of sunshine to dry green, 1-inch thick hardwood lumber to 10 percent MC. It takes a little longer to dry the same materials from 10 percent to 7 percent or 8 percent MC.

In the Home Freezer and Heated Room

A third alternative to the expensive industrial dry kiln is freeze-drying wood for home uses.

Food has been freeze-dried commercially for many years, and some tests have been made with hardwood lumber. The species of lumber studied were white ash, red oak, white oak and hard maple, all with boards having the dimensions of 2 x 7 x 30. The initial moisture contents were 43, 137, 77 and 47 percent, respectively.

For the first 104 days of the drying period, the ash and red oak were stored in a food freezer of 12 cubic feet capacity at -12 degrees Fahrenheit. During the next 60 days, the boards were kept in a room where the temperature was about 79 degrees Fahrenheit and the RH was about 30 percent. The white oak and hard maple were seasoned in the freezer for 132 days and in the heated room for 32 days. All boards reached a moisture content of 7 percent to 11 percent except the white oak, which still had an MC of 35 percent (Table 8).

Table 8. Moisture content of lumber dried in the freezer and heated room.

Seasoning time, days	*Moisture Content (Percent)*			
	Ash	White Oak	Red Oak	Hard Maple
0	43	137	77	47
5	42	135	74	43
13	41	133	71	39
19	40	131	70	38
26	39	130	67	37
36	39	128	66	35
41	37	128	64	34
48	36	127	63	33
61	35	125	59	31
75	34	123	57	29
90	32	122	55	27
104	31*	120	53*	24
132	17	118*	20	24*
164	9	35	11	7

Note: Asterisk (*) indicates point at which lumber was moved from freezer to heated room.
Source: (Walters 1975).

Freeze-drying removed the moisture from the wood slowly, so there were no cracks or checks as would have occurred had the freshly cut lumber been put directly in the warm room but evidently the wood loses enough moisture in the freezer.

The "freezer/heated room" combination dried the ash, red oak and hard maple to an MC of less than 12 percent, dry enough for hobbyists and some regional, interior applications. Apparently the white oak needed a longer drying time in the heated room. Lumber with 35 percent moisture content is too wet for bowls, furniture and other products of the home shop. To repeat, lumber destined for interior use should have no more than 12 percent moisture content. Always consider the region of the country in which the wood will be placed in service, however (Figure 3).

The freezing of green wood, followed by thawing before the start of indoor air-drying, increases the permeability of wood, thus increasing the drying rate and decreasing shrinkage and seasoning defect in high-value, thick-dimension lumber such as turning squares and gun stocks.

In the Home Microwave

Wood can also be dried in the home microwave or commercially in microwave kilns. The three main advantages of this method are high drying speed, reduction of drying defects and high quality drying (in terms of uniform moisture distribution and stress relaxation). Microwave energy is an attractive option in wood processing and drying of lumber, blocks, veneer, chips, paper and wood-based composite materials. During microwave drying, gradients in temperature, pressure and moisture allow for fast drying of the wood. The most humid points in the wood absorb most energy, while less humid points absorb less energy. Therefore, during drying, a uniform moisture content is achieved throughout the wood. Additionally, a temperature increase in one zone of the material leads to less energy being absorbed there. Consequently, temperature is evened out in the drying process. These two factors enhance drying quality and reduce the probability of checking and warping of the timber. The problems of commercial microwave drying include difficulties in uniform energy distribution in drying installations, complicated equipment for microwave energy generation and expensive equipment. For hobbyists, microwave drying may be ideal for small, expensive pieces of wood that need to be dried with very minimal defects for crafts and novelty items.

Troubleshooting Seasoning Defects

Quality drying of lumber depends on numerous factors. This section describes some of the simpler aspects of stacking that can be more readily implemented and will yield immediate results.

Sticker Thickness

A common sticker thickness is 3/4 inch. The typical thickness for stickers in industry can vary from 5/8 inch to 1 inch thick. It is unfortunate, however, that some individual kilns will have even more variation. While variation in sticker thickness at an operation isn't a problem by itself, it becomes a problem when the stickers of various thickness appear in the same lumber course or same kiln charge. The easiest way to avoid this problem is to have only one sticker thickness and as near to 3/4 inch thick as possible. By keeping only one sticker thickness, it is impossible for stickers of various thickness to get mixed.

Sticker thickness is important because uniformly thick stickers will block airflow during drying and result in warp and nonuniform drying. Thick stickers can be resurfaced to the target thickness, and thin stickers are best used at the next hot dog and marshmallow roast, if there is no wood-fired boiler. A stack of stickers is shown in Figure 8.

Sticker Straightness

Crook and kink in stickers can often cause problems in sticker feeding automatic stackers and also in sticker alignment in semiautomatic or hand stacking. Discard stickers with more than 3 inches of crook or kink or 3 inches shorter than the width of the stack.

Figure 12. This lumber has experienced severe bow because these stickers and braces have been placed too far apart.

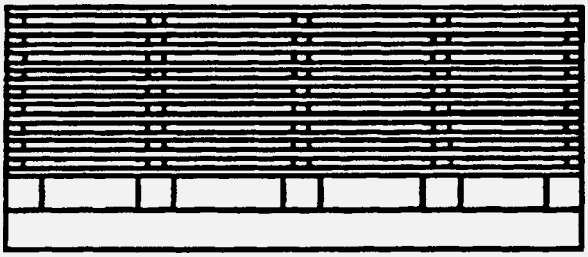

Figure 13. A properly stacked pile of lumber has stickers of equal thickness that are vertically aligned. The normal distance between stickers and braces is 18-24 inches.

Bolster Thickness

Another common source of problems when stacking lumber are the bolsters used between lumber stacks. As was the case with sticker thickness, the chances also increase for the lumber to warp if bolsters are of uneven thickness. The uneven thickness of the bolsters can block airflow in adjacent lumber stacks in a kiln. Some kilns that have experienced airflow blockage have solved the problem by using bolsters that are the same thickness in both directions. It is important that the bolsters be nearly the same length of the lumber stack, but a problem arises when the rectangular bolsters are of uneven dimension in the other two directions. Therefore, if a bolster is turned the wrong way, this will have a similar effect as thick and thin bolsters.

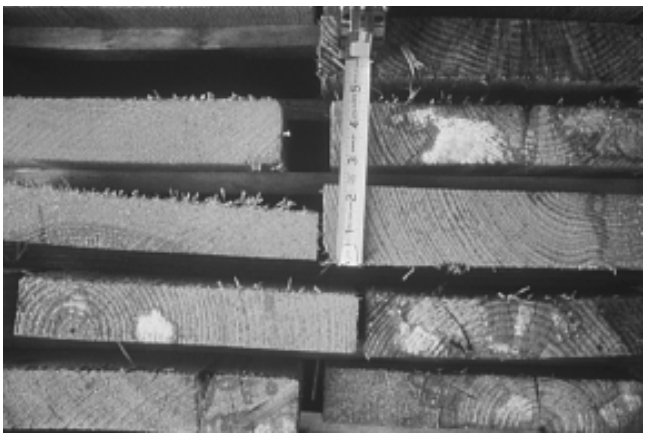

Figure 14. These southern pine boards are of uneven thickness. The board that is too thin was miscut and should have been culled or at least sorted out before stacking.

Sticker Placement

Stickers serve two main purposes. First, they separate the courses of lumber so air can move through to dry the lumber. Second, they distribute the weight of the lumber vertically from top to bottom—through the stickers and bolsters down to the kiln truck or load supports. Stickers out of alignment, on edge or missing can be costly to lumber quality by causing kink, twist, ski-tipped ends and other forms of warp. Sticker alignment is seldom perfect, especially with manual sticker placement. The ideal is to have all stickers vertically aligned in a column. The stickers should at least be placed so they overlap the ones above and below.

If a sticker is missing, the courses above the space will sag down into the open space. The weight of the wood above bearing down on the unsupported board will place a very large bending force on the board, causing it and several boards above to warp. Stickers placed on edge will have the same effect as thick stickers. The board above will tend to warp or, in softer species, the sticker may actually indent the board above and below the turned sticker.

Stickers should be within one sticker width of the end of the stack. One primary purpose of the stickers is to hold the boards flat. If either end sticker is significantly removed from the pile end, there will be no support on the lumber ends. This can lead to warp, twist, cup and splitting of the unsupported ends. It is commonly stated that an end split will extend up to the first point of good sticker contact.

Board Placement in Packages

Providing adequate sticker contact and board control at the ends of a package is critical to good drying as discussed. Even ends on all packages are needed to provide optimum sticker placement and sticker contact on board ends. Most hardwood lumber is manufactured and sold random length, and many mills do not double-end trim. A method of stacking called "box piling" can provide even-end packages. Unfortunately, stacking machines do not box pile. Instead, most even end at one end of the stack, letting the other end take up all the uneven lengths.

The maximum length lumber to be stacked will determine the pile length. Full-length boards are selected for the edges of each course. Boards in between are alternately pulled to each end. Consideration must be given to the best mix of package lengths relative to kiln size when the pile lengths are established. Failure to consider the kiln dimensions could lead to mixes of packages that will not fit in the kiln without leaving open areas.

Preventing Stain and Mildew

1. Good outdoor and indoor ground sanitation and drying practices will keep sources of infection to a minimum.

2. Rapid stacking and air-drying of green lumber in a dry location will reduce both chemical and fungal stains.

3. A roof over the outdoor pile will prevent rain from wetting the lumber and improve drying.

4. Dipping or spraying green lumber with a fungicidal solution can protect it against attack by fungi.

5. Light surface stains and mildew on the wood surface may be removed with 1 quart of liquid bleach, 1/3 cup liquid detergent and 3 quarts warm water.

6. Remember: Fungi cannot grow at a temperature above 130 degrees Fahrenheit or below 32 degrees Fahrenheit. They cannot grow in wood if the MC is below 20 percent or supersaturated with water, such as under a sprinkler or under water.

Preventing End Checks and Splits

1. Coating freshly cut ends with moisture-resistant substances, such as paraffin, will retard the drying of the ends and reduce the tendency to check or split. Coatings such as roofing cement paste, wax emulsions, hot pitch, asphalt, paraffin or oil paint should be used.

2. Material to be carved or made into bowls or gun stock blanks must be coated or dipped at both ends, using a highly water-resistant coating with a high softening point.

3. Wide, overhanging end stickers or sun shields at the ends of the lumber pile can reduce end-check.

Figure 15. Checks and separation occurred in unprotected ends of this hardwood log during storage in the log yard at the sawmill before milling. End checks can be reduced by end coatings and prompt sawing.

Figure 16. End checks in cants caused by rapid drying and sun exposure. End checks that develop in logs will also be present in the lumber that is sawn.

Preventing Surface Checks

1. Place piles of lumber closer together to reduce the rate of drying but allow sufficient air circulation to prevent surface stains.

2. Build a wide lumber stack.

3. Protect the pile with shields over the pile sides and with roofing at the top to reduce the effects of high wind, sunshine and rain.

4. Reduce the thickness of the stickers to 25/32 inches.

5. Pre-surface the wood of check-prone species (Table 5) before air-seasoning.

Preventing Warp

1. Firm and straight foundations with supporting members directly beneath the sticker tiers are necessary for the lumber pile.

2. A crooked or uneven supporting surface will cause twist, bow, cup or crook in the lumber. (Figure 5).

3. Properly placed stickers with uniform thickness are most important. Broken or distorted stickers can increase warp.

4. Closer sticker spacing (as close as 16 inches) may help, and good sticker alignment is essential.

5. Planing both faces (pre-surfacing) of green lumber to a uniform thickness before stacking, or improved thickness control in sawing, reduces the amount of warp.

6. Clamping or superimposed loading may be a practical remedy for warp-prone species (Table 5).

7. Quarter sawn (edge grain) lumber has fewer warp and surface problems.

Storage of Dried Lumber

Proper storage helps maintain dimensional stability before use. It is a safeguard against warp, nail popping and baseboard pull-away. All result from alternate wetting and drying.

Air-seasoned Lumber

1. Outdoor storage

Lumber can be bulk-piled in a dry building if its MC is 20 percent or less. The pile should be covered with a rain-tight roof or tarpaulin. Waterproof paper can also be used to wrap bulk-piled lumber. If the lumber is at an MC higher than 20 percent, air-seasoning should be continued in place. Lumber should never be in direct contact with the ground. Do not seal piles airtight.

2. Indoor storage

Provided the MC of lumber is below 20 percent, air-seasoned wood may be bulk-piled (as described above) in a shed or other building. If the shed is not floored, foundations are required to provide ground clearance. In closed sheds, circulate air with a fan. Humidity control may be needed for heated buildings (Table 6.).

Indoor-dried Lumber

Low MC wood should be stored in closed, unheated buildings or heated, indoor areas. Well-seasoned lumber, destined for furniture, novelty or other high-grade interior uses, will lose its dimensional stability if exposed to humid air for long periods. In summer, a closed unheated building is satisfactory. Lumber in a closed shed will have only one-third the moisture pickup of lumber in an open shed.

Figure 17. Dried lumber is stored commercially on stickers stored in large storage sheds. Smaller operators will receive similar results in a garage at home or a shed on the farm.

A heated indoor area is always satisfactory, and wood can be stored for years indoors with little change in moisture content. In winter, heated indoor storage is necessary for well-dried wood. Indoor wood storage can be improved by using a small fan to assure uniform humidity throughout the area. During very humid summer weather, you may need a dehumidifier to maintain the desired MC (Table 6).

Occasional checks for insects should be made. Look for borings or wood powder on or under lumber. Ambrosia beetles (powder post) and longhorn borers (grubs) are common, especially in air-dried materials. A solution of borax, dursban or lindane will usually control insect problems.

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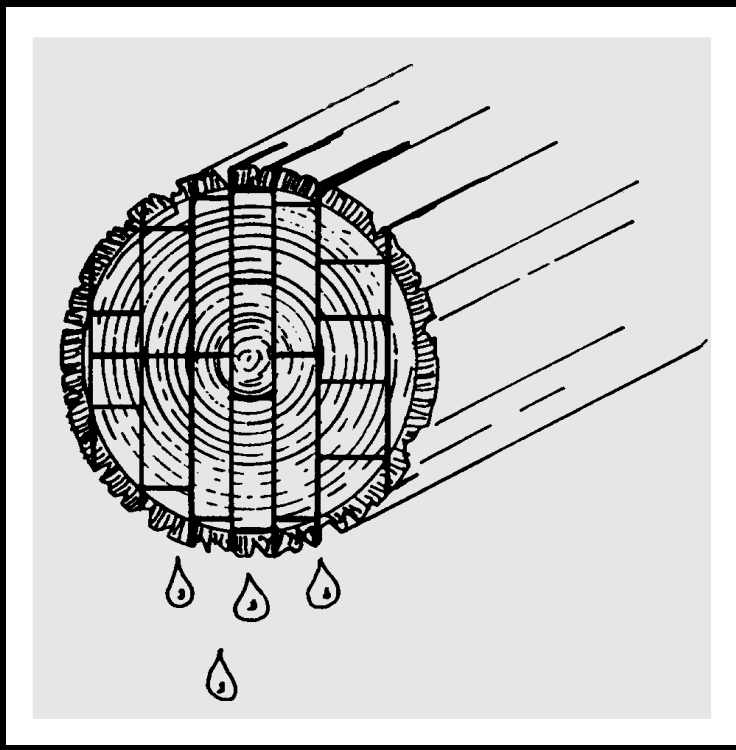

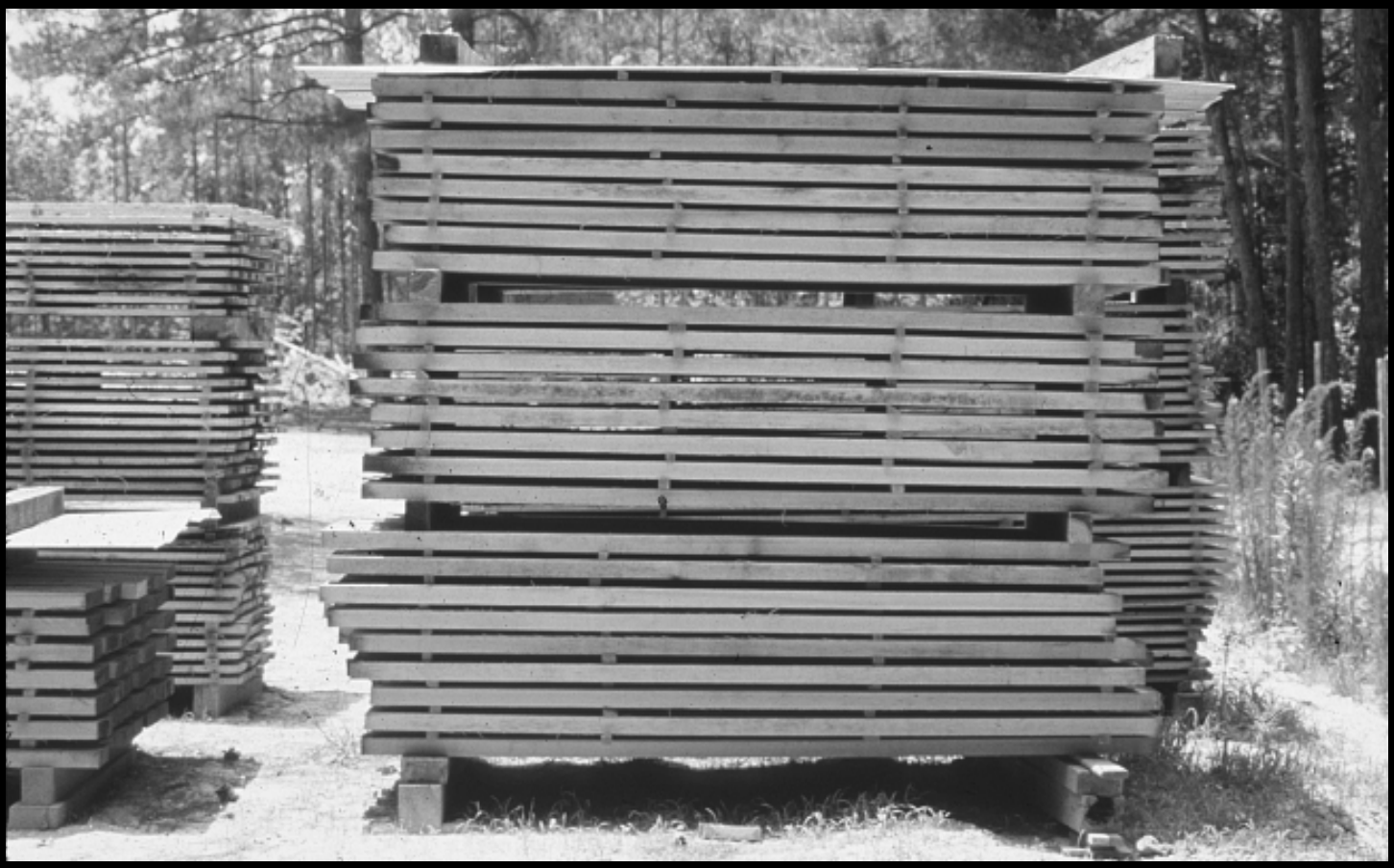

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