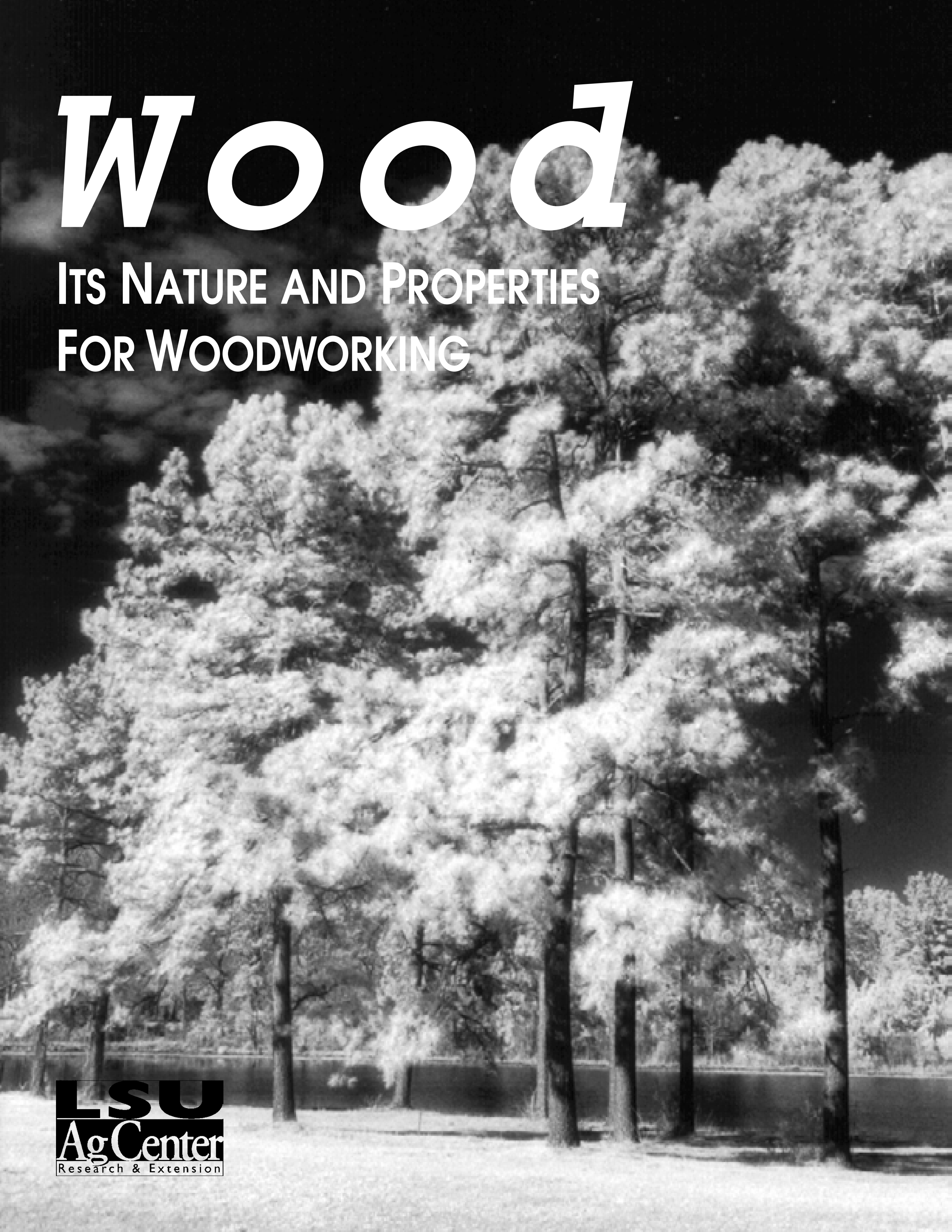
Wood

Its Nature and Properties For Woodworking



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Introduction

For most cabinetmakers and furniture makers, wood is the raw material of choice. Wood has thousands of uses. Although wood may appear to be a relatively simple substance, closer examination shows that wood is one of the most complicated and unusual natural materials. The more you know about wood and its properties, the more valuable wood can become to you.

Wood is made up of many tiny tubular cells which are held together by the wood's own cement, lignin. These tubular cells are similar to a bundle of drinking straws (see Figure 1). These cells carry the supply of necessary nutrients and water which nourish the life processes of the tree. The walls of these cells also provide support and strength to the tree. These cells run up and down the tree, and produce grain that is visible on the cut surfaces and edges of lumber.

Each of the cells is very narrow and rather long. These cells consist of a cell wall and a cell cavity (lumen) inside the cell wall (see Figure 2). Most of the cells in a tree are dead. The only living cells in a tree are the recent growth produced by the cambium (how the tree grows in width) and some cells in the sapwood.

When the wood is sawn, the openings in the cells are exposed, forming openings on all the wood surfaces. These openings are small pores, and the quantity of pores is called porosity. This porosity is quite extensive. This structure of open space and cell walls gives wood its strength and its properties.

Figure 1. A small block of wood with the surfaces of each individual axis represented. (Courtesy of the United States Forest Service Forest Products Laboratory, USDA, Madison, WI.)

Figure 2. A wood cell from the earlywood and the latewood, showing the difference in size of the cell opening (lumen) and the cell wall thickness.

Hardwoods and Softwoods

The terms hardwood and softwood are botanical terms and do not indicate the actual hardness or softness of the wood. Some hardwoods are softer than some softwoods, and vice versa. Hardwoods are actually broadleaf trees. Some examples of hardwoods include walnut, oak, ash, maple, cherry and mahogany. Softwoods come from conifers, which are actually trees that bear cones or have needle-like leaves. Some examples of softwoods are the southern yellow pines, white pines, fir, cedar and redwood. Figure 3 compares the softwoods and hardwoods.

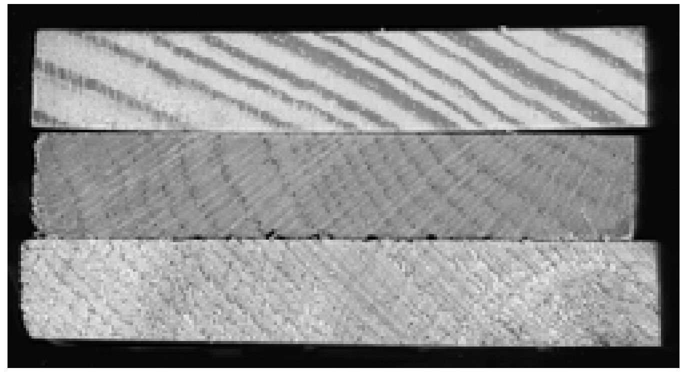


Figure 3. Comparison of a softwood (top), a dense hardwood (middle) and a soft hardwood (bottom).

Growth rings

The growth ring is often used in reference to the annual growth of a tree. The rings are not always as easy to see as the ones shown in Figure 4. Some woods do not show any visible indications of annual growth. Some species have quite distinct growth rings; others are not easily visible.

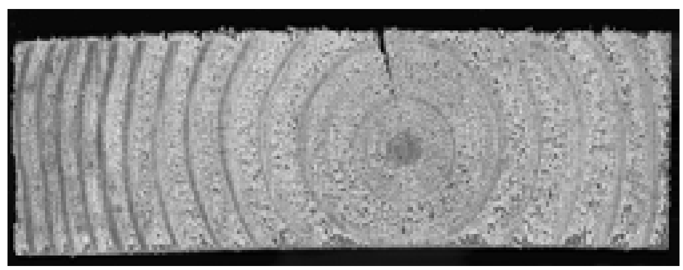


Figure 4. Southern yellow pine board showing how easily the growth rings can be distinguished for some species.

The growth rings of wood are made of springwood and summerwood. The portion of the growth ring formed early in the growing season is called the springwood or early wood. That which forms later in the season is called the summerwood or late wood. Generally, the springwood has larger cell cavities and thinner walls, and is less dense than the late wood (see Figure 2).

Hardwoods are classified into three groups, based on the pattern of growth of the annual rings:

Ring-porous species have springwood cells that are wide and distinct, usually several cells wide. The summerwood cells are small, indistinct and thick-walled, making the rings very distinct. Some examples are oak and ash. Figure 5 illustrates a ring-porous wood, red oak.

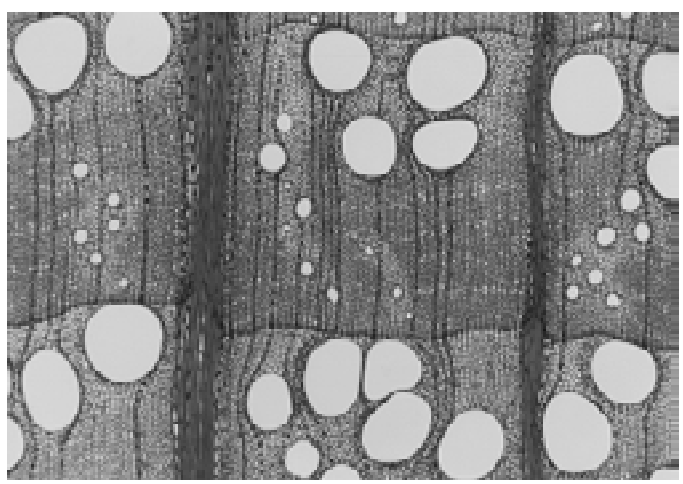


Figure 5. A ring-porous wood. This wood is red oak.

Semi-ring porous (semi-diffuse porous) species have fairly distinct springwood cells, but are not

as wide and obvious as the ring-porous wood. The summerwood, which comprises most of the annual growth ring, has distinct, thick cell walls. Some examples are black walnut and pecan. Figure 6 shows a semi-ring porous wood, black walnut.

Diffuse porous species have no distinct difference between the springwood and summerwood and no distinct ring or annual grain patterns. Some examples of diffuse porous woods are birch, poplar, basswood, maple and cherry. Figure 7 shows a diffuse porous wood, maple.

Structural arrangement of wood

Wood needs to be considered in terms of three dimensions, because it grows in a somewhat layered pattern with varying orientation of the cells. The properties of wood differ in all three directions. This phenomenon is called anisotropic. Figure 1 shows the three different directions in a block of wood. (Steel and metal alloys have similar properties in all three directions. This is termed isotropic).

The plane perpendicular to the axis of the stem is called the transverse or cross-sectional plane. This is the portion of the tree which is seen on the stump. In Figure 1, this plane is labeled **X**, and represents the X-axis of a three-dimensional cube.

Because trees grow in a rough form of a circle, if a line is drawn from the center of the tree to the outside, it forms a radial plane or surface. This plane is shown in Figure 1 as the **R**-surface.

If a plane is passed through the tree perpendicular to the growth rings, it is tangent to the growth rings. This surface is called the tangential surface, and is denoted as a **T** in Figure 1. The tangential surface is not a true tangential surface since the growth rings are not perfectly true circles. The tangential surface is, however, an ideally tangential surface to the radial plane of the tree.

Physical Characteristics and Properties of Wood

Density is the weight per unit volume of a substance. Wood density is typically measured in

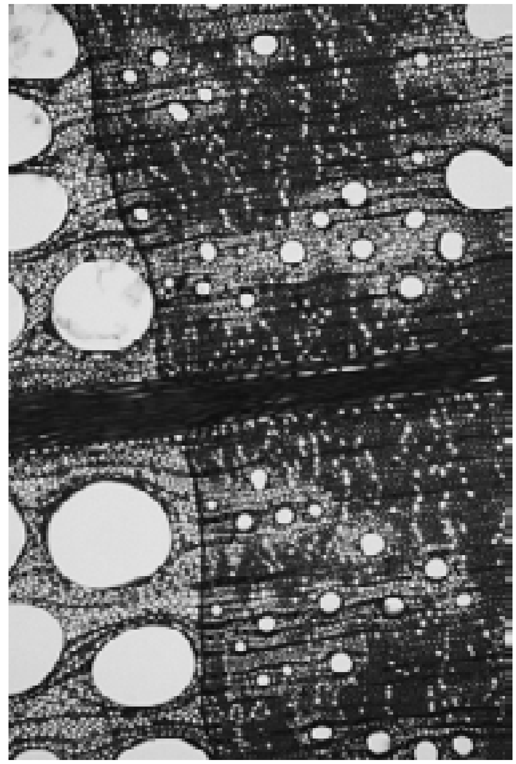


Figure 6. A semi-ring porous wood. This wood is black walnut.

Figure 7. A diffuse porous wood. This wood is soft maple.

terms of grams per cubic centimeter (g/cm^3). As the density increases, the strength and hardness of the wood increase. The density of the wood substance which makes up the cell wall is about the same for all species, but porosity and cell wall thickness make the density vary within species and individual logs.

Specific gravity (SG) is an easy way to estimate the density of most substances. SG is expressed as a ratio between the wood's density in relation to the density of an equal volume of water at 4 degrees Celsius (39 degrees F). As an example, the SG of black cherry is 0.50, exactly half the weight of an equal volume of water. Cottonwood, a lighter weight wood, has an SG of 0.37. Pecan, a much heavier wood, has an SG of 0.60.

Specific gravity is an indicator of the hardness, strength and other physical and mechanical properties of wood. In general, as the SG increases, so does the strength.

Hardness is how well wood resists being compressed or dented. The measure of hardness is done by dropping a heavy round ball onto a piece of wood and measuring how deeply the ball dents the wood. Cell wall thickness and the size of the cell lumens (openings of the cells) are important to the hardness. As the thickness increases and the lumen size decreases, the hardness increases. Hardness is a very important characteristic to fine furniture woods.

Moisture content (MC) is a measure of how much water is in a given piece of wood at a given time. Because of the porous nature of wood, it absorbs moisture from the atmosphere. The MC of wood is defined as the weight of water in wood expressed as a fraction, typically in percent, of the weight of ovendry wood. The MC is directly related to all of the strength properties of wood.

The MC ranges from 30 percent to more than 200 percent in living trees. The sapwood in softwoods generally has a higher MC than the heartwood. In hardwoods, however, no general statements can be made about the MC. In some species MC is higher in the sapwood, although there is very little difference in others. The MC varies greatly within a species and even within one tree.

Louisiana is blessed with an excellent timber resource that provides excellent raw material for manufacturing wood products by industry and hobbyists.

When wood stays in an environment for an extended time, it will reach the *equilibrium moisture content* (EMC). The EMC is defined as the point at which wood is neither gaining or losing moisture under the same conditions; it has reached an equilibrium. The EMC changes as the temperature and relative humidity in an environment change. Table 1 lists the EMC for a given relative humidity and temperature.

The EMC changes are usually gradual, and they depend on the surrounding air conditions. Short-term changes generally influence only the surface of the wood, but long-term changes can influence the entire piece. Changes in the EMC can be retarded, but not completely stopped, by using protective coatings like varnish, lacquer, paint or polyurethane. It is highly recommended that wood be brought to the average environmental conditions where it will be put into service during its manufacture. This will help reduce the uptake of moisture from the air, which will reduce the shrinkage and swelling of the wood, making the product more stable and less likely to crack, distort or split.

Table 2 lists some cities in the United States and their average outside EMC for each month. It is always a good idea to know the EMC of the area where your products will go, since the outside environment will ultimately be the EMC of your product.

Attention Louisiana citizens!

Contact your local Louisiana Cooperative Extension Service parish office to obtain additional forest products educational information.Your local county agent can keep you updated on newsletters, workshops and publications on all aspects of forest products.

Table 1. Moisture content of wood in equilibrium (EMC) with stated temperature and relative humidity.[1]

Temp °F	*Relative Humidity (%)* 5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	98
30	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3	26.9
40	1.4	2.6	3.7	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.4	11.3	12.3	13.5	14.9	16.5	18.5	21.0	24.3	26.9
50	1.4	2.6	3.6	4.6	5.5	6.3	7.1	7.9	8.7	9.5	10.3	11.2	12.3	13.4	14.8	16.4	18.4	20.9	24.3	26.9
60	1.3	2.5	3.6	4.6	5.4	6.2	7.00	7.8	8.6	9.4	10.2	11.1	12.1	13.3	14.6	16.2	18.2	20.7	24.1	26.8
70	1.3	2.5	3.6	4.6	5.4	6.2	6.9	7.7	8.5	9.2	10.1	11.0	12.0	13.1	14.4	16.0	17.9	20.5	23.9	26.6
80	1.3	2.4	3.5	4.4	5.3	6.1	6.8	7.6	8.3	9.1	9.9	10.8	11.7	12.9	14.2	15.7	17.7	20.2	23.6	26.6
90	1.2	2.3	3.4	4.3	5.1	5.9	6.7	7.4	8.1	8.9	9.7	10.5	11.5	12.6	13.9	15.4	17.3	19.8	23.3	26.3
100	1.2	2.3	3.3	4.2	5.1	5.8	6.5	7.2	7.9	8.7	9.5	10.3	11.2	12.3	13.6	15.1	17.0	19.5	22.9	26.0

[1]Table taken from Wood Handbook, by permission of US Forest Products Laboratory, USDA Forest Service, Madison, WI.

Table 2. Equilibrium moisture content of wood, exposed to outdoor atmosphere, in the United States.

Equilibrium moisture content in different months (%)

City	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*
Albuquerque, NM	9.2	8.1	8.0	6.9	6.3	5.7	7.9	7.7	7.1	6.9	10.5	11.1
Boise, ID	15.8	14.3	12.1	10.3	10.9	10.5	7.3	7.3	7.6	8.6	10.3	18.0
Boston, MA	13.0	12.3	12.3	12.0	12.3	10.9	11.7	12.6	12.9	12.7	13.0	11.9
Bridgeport, CT	14.8	12.3	13.4	12.9	13.0	12.6	13.2	14.1	14.3	13.6	14.5	13.2
Casper, WY	11.0	12.3	11.5	10.3	11.2	8.4	8.6	8.1	7.0	8.2	11.0	12.8
Charleston, WV	14.3	12.1	12.0	11.9	12.7	13.8	14.1	13.8	12.6	11.7	12.2	13.4
Chicago, IL	16.1	13.7	14.2	11.8	12.4	11.9	11.9	12.5	11.6	10.9	10.3	15.2
Denver, CO	8.4	8.3	9.3	10.3	9.8	7.6	8.2	8.9	6.9	7.2	9.9	10.4
Detroit, MI	17.5	14.3	15.2	12.2	12.2	11.4	11.5	12.4	12.5	11.9	14.0	15.8
Galveston, TX	18.2	18.2	18.1	15.8	16.9	15.7	15.4	15.7	15.5	14.2	16.6	15.9
Huron,SD	17.0	18.0	16.0	12.7	12.1	13.0	11.8	12.2	10.1	10.2	13.4	17.6
Jackson, MS	14.7	14.5	12.6	12.7	13.5	11.9	12.7	12.5	11.4	10.3	11.5	13.9
Juneau, AK	19.8	20.2	17.9	15.8	16.3	14.8	16.2	18.2	21.4	----	22.0	18.6
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, AR	15.7	13.6	12.7	12.5	13.6	11.7	12.0	12.5	11.2	10.6	11.8	13.7
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
Milwaukee, WI	15.8	14.8	14.9	12.4	13.0	13.7	13.2	14.2	13.0	11.8	13.2	15.8
Mobile, AL	15.8	16.2	14.6	13.3	15.0	14.2	15.4	16.7	14.3	12.0	13.0	14.9
Nashville, TN	15.4	14.0	12.9	12.1	12.3	11.4	11.8	11.9	11.8	11.7	12.0	14.8
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
New York, NY	13.7	11.7	12.7	11.7	12.6	11.2	11.3	12.2	12.0	11.9	12.6	12.5
Omaha, NE	18.0	15.5	15.2	12.2	12.6	11.3	12.1	12.9	11.3	10.4	12.4	15.7
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
Portland, ME	16.9	15.5	15.8	14.8	15.0	13.4	13.9	15.5	17.2	15.4	16.3	14.9
Portland, OR	19.6	16.8	14.7	13.0	14.1	14.5	12.1	13.4	13.1	15.9	18.5	20.0
Reno, NV	13.2	11.3	11.0	9.4	9.0	8.6	8.0	7.8	8.9	9.6	11.3	13.4
Salt Lake City, UT	14.3	12.5	12.4	10.8	9.3	7.8	7.8	7.4	7.5	9.1	12.1	15.8
San Francisco, CA	18.5	14.8	14.7	16.0	14.7	15.6	15.8	16.6	15.5	15.9	16.0	16.3
Tulsa, OK	14.0	12.2	12.2	12.6	12.6	11.0	12.4	11.2	9.7	9.7	12.0	12.7
Tucson, AZ	8.8	7.0	7.9	6.8	5.3	4.6	8.1	8.0	5.2	5.2	7.7	8.0

Table adapted from Wood Handbook, by permission of US Forest Products Laboratory, USDA Forest Service, Madison, WI.

Shrinkage is the term used to define the movement of wood as moisture is removed from it. The opposite of shrinkage, *swelling*, denotes how wood size increases when moisture is added to it. When wood is above 30 percent MC (referred to commonly as fiber saturation point--FSP--is defined roughly as 30 percent), wood is dimensionally stable. That is, wood does not shrink or swell above the FSP when water is lost from the wood The water is lost from the lumens of the cells. Below the FSP, water is being removed from the cell walls, and the wood shrinks. Figure 8 illustrates this shrinkage and swelling.

As stated earlier, wood is an anisotropic material. This is especially true with regard to its shrinkage properties. Wood shrinks most in the tangential direction (see Figure 1), on average about 7 percent. In the radial direction, shrinkage is about half that of tangential shrinkage, or about 5 percent. In the longitudinal direction (parallel to the grain, or across the grain), the shrinkage is minimal, about 0.1 percent to 0.2 percent. With the radial and tangential shrinkage effects combined, the shape of the wood can be distorted after the wood is dried. Figure 9 shows how radial and tangential shrinkage can affect a glued-up panel if care is not used in its manufacture. Figure 10 shows the major types of distortion caused by shrinkage.

Wood shrinkage is affected by a number of variables. Generally, a higher density wood has a higher shrinkage. The shape and size of wood can also affect shrinkage, as can the temperature and drying rate.

Appearance Characteristics ofWood

Color in wood is determined by different chemicals in the cell walls. The heartwood is denser, contains more of these chemicals than does the sapwood, and therefore, it is generally the darker portion of the wood. Some woods are highly variable in color, particularly highly prized woods, like walnut and rosewood. As wood ages, it generally darkens because of exposure to oxygen (this darkening is called oxidation). Typically, sealing wood retards this process, but does not completely stop the darkening process.

Figure 8. How wood shrinks and swells. When the wood is wet, as on the left, the wood swells as water forces the wood fibers farther apart. On the right, when the wood is dry, the lack of water in the fibers pulls the fibers closer together. (Courtesy of Mark Gibson, Louisiana Tech University)

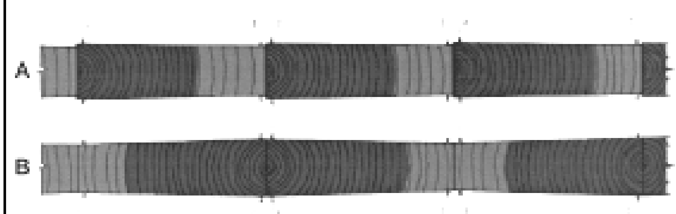


Figure 9. When care is exercised by aligning radial to radial and tangential to tangential, as shown on the bottom, swelling and shrinkage are minimized.

Wood grain is a term which describes the arrangement of fibers on longitudinal pieces, from end to end. When the cells are parallel to the center of the tree, the grain pattern is termed straight (see Figure 11). Knots and other defects typically cause the wood tissue to grow in an unusual manner. This is termed *irregular grain*. When the fibers in the cells are distorted, a curly appearance can result in *curly grain*. When the wood fibers form a spiral shape around the tree trunk, *spiral grain* is the resulting grain. When the elements of the growth ring twist in opposite directions, the grain is said to be *interlocked* (as is the case with sycamore).

The *texture* of wood describes the relative porosity of wood or the uniformity of wood tissues. It refers to the smoothness of the wood structures. Finishers typically refer to different woods as open grained or closed grain, which reflects the size of the pores and whether or not some type of filler is needed on the surface. (Although the word grain is used here, it denotes the texture of the wood, not the grain direction.) Generally, three classifications of texture exist: fine, medium and coarse. Fine texture (close grained) means that the pore size is very small; a coarse-textured wood (open grained) would have fairly large pores. Medium-textured woods are between very small and fairly large pore sizes.

Figure is typically used to denote some distinctive markings or special characteristics associated with some piece of wood. This characteristic is usually found on the longitudinal grain of the wood. Figure results from a number of different natural occurrences. It could be any one or some combination of the following: the wood's anatomical features, the cutting method used to cut the lumber or veneer, a burl on the tree, knots, bird peck, insect damage or fungal attacks on the tree. Other factors can cause different figures, but this publication lists only some of the major contributors.

Cutting Practices

The different methods of cutting lumber or veneer from a log can influence the appearance of the wood. In most cases of special methods of cutting lumber, a specific intended use of the material is requested. Generally, there are two ways to cut lumber from logs--plain-sawed and quarter-sawed.

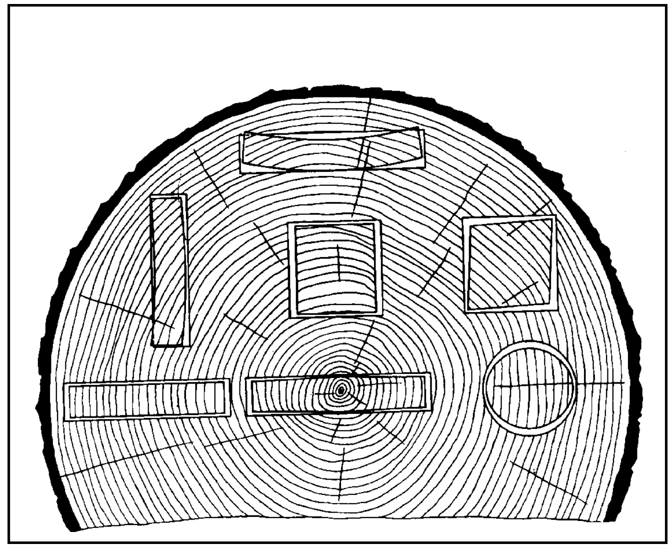


Figure 10. Different types of shrinkage are found throughout a log. This shrinkage can cause different kinds of distortion as shown here. Tangential shrinkage is about twice that of radial, causing the distortions shown. (Courtesy of the United States Forest Service Forest Products Laboratory, USDA, Madison, WI.)

Figure 11. Hickory, a very straight-grained species.

Plain-sawed lumber is produced when the log is cut tangent to the growth rings (see Figure 12). Typically, in the industry, if the growth rings form an angle from 0° to 45° with the wide surface of the board, the board is considered plain-sawed. For hardwood lumber, the term plain-sawed is used. In softwoods, the terms flat-grain and slash-grain are typically used.

Quarter-sawed lumber is produced by cutting radially to the growth rings or parallel to the rays. Commercially, lumber with rings at angles between 45° and 90° with the wide surface are considered quarter-sawed (Figure 12 shows a typical quarter-sawed board). The term quarter-sawed is used in hardwood lumber. Edge-grained or vertical-grained describes the same pattern in the softwoods.

Hardwood lumber with a grain angle of between 30° to 60° with the wide face is sometimes referred to as bastard-sawed.

Typically, quarter-sawed lumber commands a higher price than plain-sawed lumber. But for many purposes, either board may be used. Each type has its own advantages for particular use. Some of these advantages are listed in Table 3, p. 18.

Defects in lumber

A defect is defined as some problem or characteristic which detracts from the beauty or value of something. In lumber and forest products manufacturing, a characteristic of the lumber might be a defect to one company, but be highly prized by another. Take, for example, the knots on white pine (ponderosa pine). To a millwork manufacturer, these knots have to be removed. To a Colonial furniture maker, these knots add character to the wood and ultimately the final product.

A grade is assigned to each piece of lumber based on either the appearance or the strength of the board. The lumber grader has to know which defects detract from the grades and which do not. The manufacturer must be able to identify which of these defects can be used in his products, and which cannot, so the lumber selected will produce the pieces which are required. Defects can be grouped

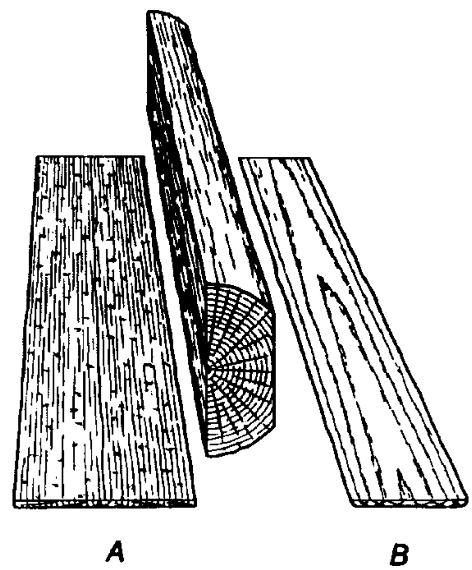


Figure 12. Quarter-sawed (A) and plain-sawed (B) lumber. (Courtesy of the United States Forest Service Forest Products Laboratory, USDA, Madison, WI.)

into four categories: natural, improper conditioning or storage, sawing method and machining.

Natural defects are those defects inherent to the nature of the tree. Things like knots, bark pockets, pith, peck and wane are natural defects. These defects are present no matter how carefully the lumber is handled.

A *knot* is a portion of a branch or limb that occurs in the tree, and hence in the lumber. There are numerous kinds of knots. Sound knots (or intergrown knots) are solid and cannot be knocked loose, and they are partially or completely intergrown with the growth rings. Unsound knots (or loose knots) are knots which fall out of the lumber when pushed or sometimes have already fallen out. Encased knots are those which are not intergrown with the surrounding wood. A knothole is a hole left where the knot has been knocked out (typically an encased knot). Figure 13 shows some different types of knots.

Bark pockets are formed when a small piece of the bark extrudes into the lumber. Generally, the area where the bark pocket occurs is considered unsound.

Pith is the center core of the living tree. The wood around the pith is typically very weak and is prone to other defects caused by seasoning and machining.

Pecky rot or peck is a small concentrated area of decay that was in the living tree. It is common in some cedars and cypress. The decay ceases to grow after the tree has been cut.

Wane is the presence of bark on the edges of a board. This is considered wane whether or not any bark is actually present. The absence of wood and bark is still considered wane.

Other types of *pockets* exist. These pockets can contain pitch and are generally just a well-defined opening between the growth rings.

Figures 14 A-E show the other natural defects discussed here.

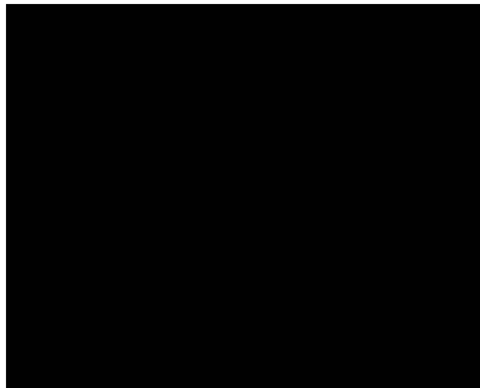
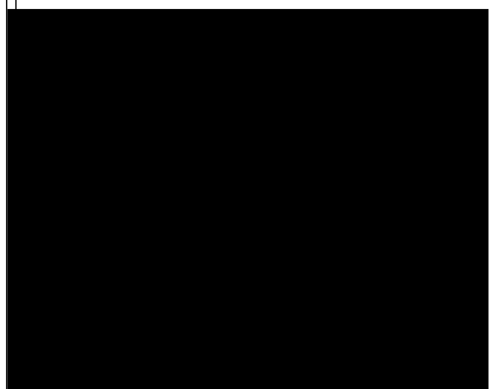
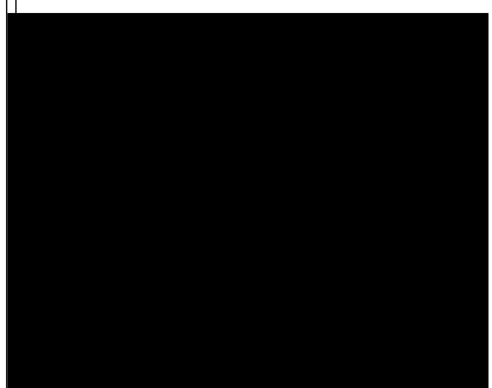


Figure 13. Different kinds of knots: A) sound

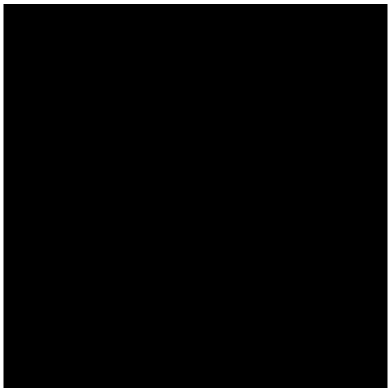


B) unsound



C) encased

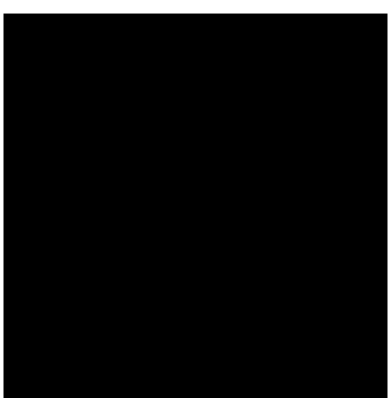
Figure 14. Other naturally occurring defects in wood:



A) bark pocket

B) pith

C) pecky rot



D) wane

E) pitch pocket.

Figure 15. Defects caused by improper seasoning and storage of lumber:

A) checks

B) decay

C) "spalted" wood

Defects that arise from improper conditioning and storage are generally avoidable. These defects are caused generally by a lack of attention to the proper procedures of drying and storage. Some will occur because of wood itself, but many are avoidable.

Checks are small separations in the wood. They occur across the growth rings and are usually caused by poor or improper drying processes.

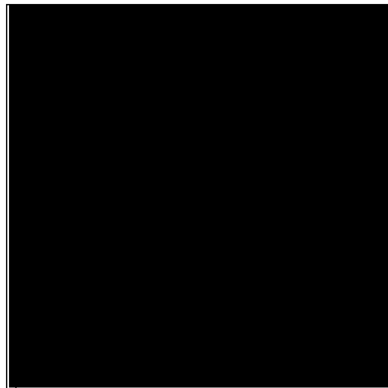
Decay is an area where some fungus has attacked the wood, and the resulting wood is generally weaker or of a different color than is typical for that species. Decay can usually be prevented by processing the logs into lumber earlier, or by dipping, stacking and drying the lumber as soon as it is cut. There is one type of decay which is highly prized. Some of the white rots during their early stages of development form what is commercially termed "spalted wood." This wood has a unique color and figure, and craftsmen highly prize it.

Dry rot is a term applied to many types of decay, but especially to that which, during its advanced stages, causes the wood to be easily crushed to a dry powder. All fungi require three things: a host (in this case, wood), moisture and a certain temperature (usually above 40° F). The dry rot fungi must have moisture or it cannot grow. The name dry rot does not mean no moisture is present. But, during the last stages of fungal growth, the fungus has destroyed the cell walls. These cell walls form the dry powder when they are crushed.

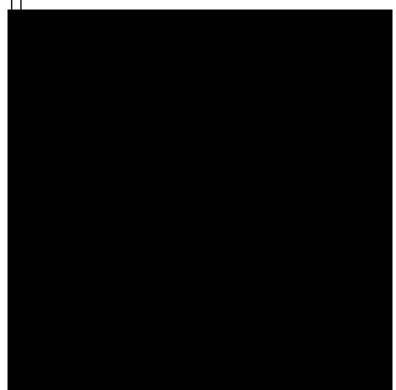
Stains are caused by a variety of conditions. They are defined as a marked difference in the natural color of the wood. A number of non-wood destroying fungi can cause stains. Other stains can indicate a decay is present. Some stains can be prevented by proper dipping, storing and drying.

Shake is a lengthwise separation of the wood. It usually occurs between the growth rings. Although this is also a naturally occurring defect, it can be caused by poor harvesting practices. Poor wood drying practices can also cause shake.

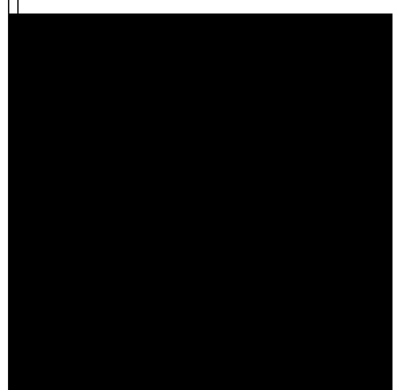
Split is a lengthwise separation of the wood caused by the wood cells being torn. This can gen-



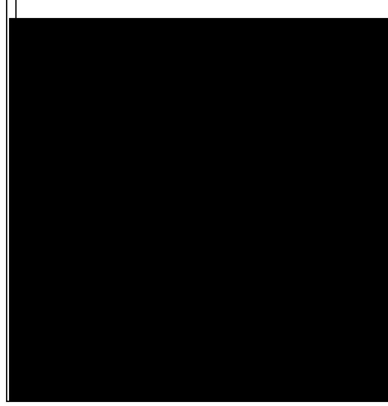
D) dry rot



E) stain



F) shake



G) split

erally be minimized by proper drying, storing and handling.

Worm holes and holes are caused by insects which feed on the sap of the tree and by birds trying to catch these insects. They can range from very tiny (<1/32-inch) to large (>1-inch).

Figures 15 A-H show these defects.

Warp is a term given to any of the defects caused by a variation from the true shape of the lumber. Included in this classification are bow, crook, cup, twist and any other combination of these. *Bow* occurs when the board does not lay flat lengthwise, but remains flat across the width. *Crook* occurs when the edges do not form a straight line from end to end. *Cup* occurs when the board is no longer flat across its width. *Twist* is when the board turns or winds at one end so that all four corners of the board are not in the same plane. *Kink* occurs when a knot on the board causes stresses immediately around the knot, causing one side of the board to "pull" up. Figure 16 depicts all five of these warp defects.

<ins>Slicing or sawing defects</ins> are caused during the manufacture of lumber or veneer. Some of these defects are difficult to minimize and must be accepted because of the nature of wood. Other defects can be reduced and even eliminated by good maintenance and care of the tools used in manufacturing. Also, it requires some skill on the part of the operator to prevent these defects.

Spike knots are limbs which have been cut across or cut lengthwise, showing the endwise or lengthwise section of the limb or knot. These knots generally have splits and severe grain deviations near them.

Loosened or raised grain is caused when the wood fibers have been loosened or raised but not torn. It is caused by the separation and curling of the tips of growth rings on flat-grained lumber. This defect resembles small splinters on the wood's surface. Typically, it is caused by a pounding action of the equipment, rather than a cutting action.

Other *variations in sawing* are any unintended deviation from the line of cut, whether outside or inside the line of cut.

H) worm holes.

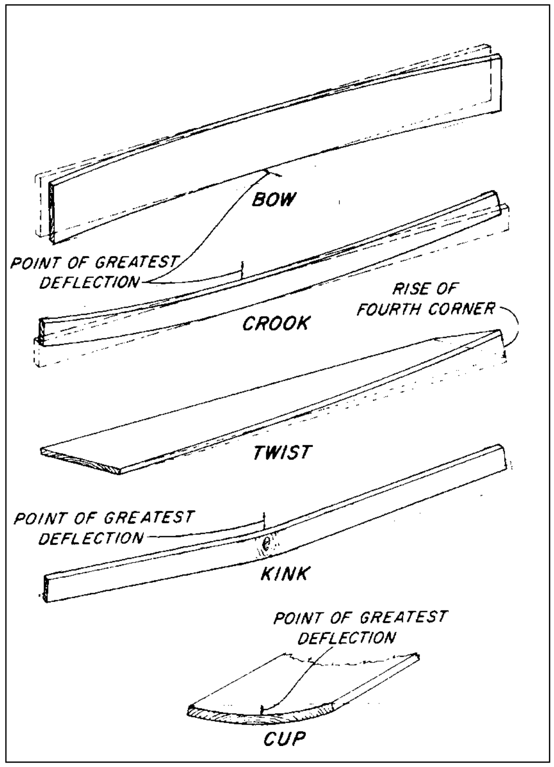


Figure 16. The five types of warp defects: bow, crook, twist, kink and cup. (Courtesy of the United States Forest Service Forest Products Laboratory, USDA, Madison, WI.)

Figure 17 shows some typical slicing and sawing defects.

Defects caused by machining can be nearly completely eliminated by keeping knives and saw blades sharp, and keeping the equipment well maintained. The operator must be able to recognize when the equipment needs maintaining or when blades or knives need changing.

Loosened grain can occur during machining, just as it does during the sawing or slicing operations.

Fuzzy grain is caused by the wood fibers becoming loosened on the board's surface. It is typically brought about by abrasion or planing, and sometimes brought on by swelling action caused by staining or humidity. It is a problem because it creates difficulties in getting a smooth surface.

Chipped grain, or torn grain, is caused by the scooping out of small pieces of wood by some cutting tools. It is typically caused by dull knives, incorrect knife settings or too fast a feed speed. Moisture contents below 5 percent are more subject to tearing and chipping than at higher MC's. Chipping can be minimized by reversing the travel direction of a board through the knives (sometimes called climb cutting).

Raised grain is actually anything that gives the wood a corrugated feel. Typically this is caused by the harder summerwood rising above the softer springwood in the growth ring. The growth rings do not separate. It is also more evident when machining wood whose moisture content is greater than 12 percent. The compressed latewood swells more than the earlywood, so the latewood actually rises above the earlywood.

Chip marks are caused by shavings or fiber bundles that fold over the knife edge and are impacted into the surface of the board being surfaced. These marks can be caused when a blower or exhaust system is inadequate, and the chips are picked up by the tool and dragged across the surface.

Snipe results when the outfeed table is not long enough to handle the piece being surfaced. The

Figure 17. Slicing and sawing defects:
A) spike knots

B) loosened grain.

end of the piece is nicked, because the free end drops as the board moves through the planer. This can be prevented by using extension rollers or tables to hold the stock at the same height.

Tool burn is caused when the tooling stays in contact with any given location on the wood. Tool burn can result from forcing the stock through the cutterhead or a sawblade, or by stopping the feeding of the stock during routing or shaping. It actually is the burning of the wood caused by the tool overheating.

Figures 18 A-F show examples of machining defects.

Summary

When using wood as a raw material, the woodworker must know the material as best he can. When the properties of the raw material are known, a lot of potential problems and possible later recuts can be avoided. New and improved techniques and equipment are being developed every day for better and more efficient usage of wood as a raw material. By keeping current on research and new processes, the woodworker can improve the efficiency of his shop and increase the profit margins.

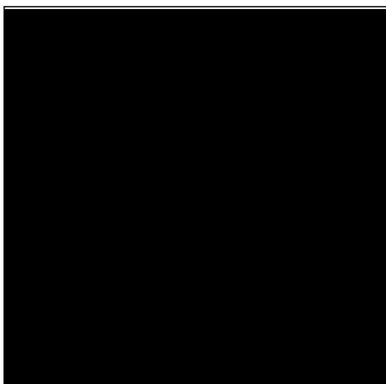
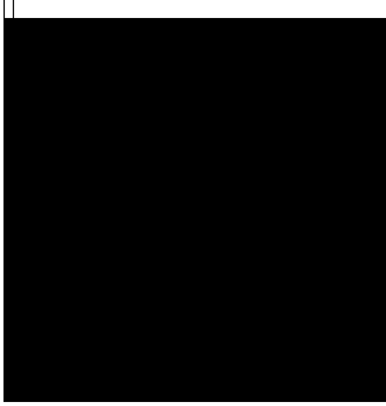
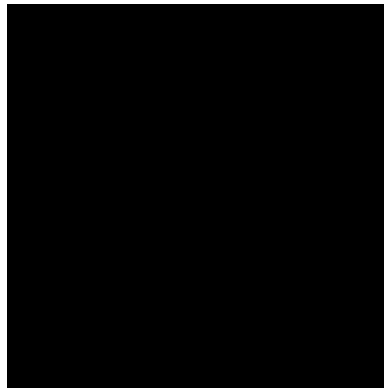


Figure 18. Machining defects:

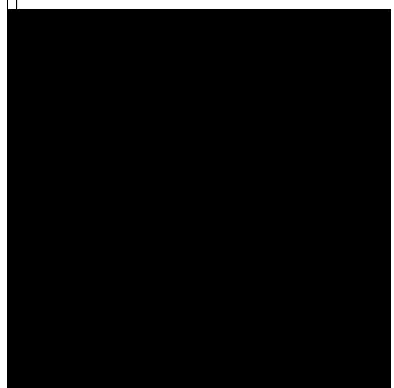
A) fuzzy grain



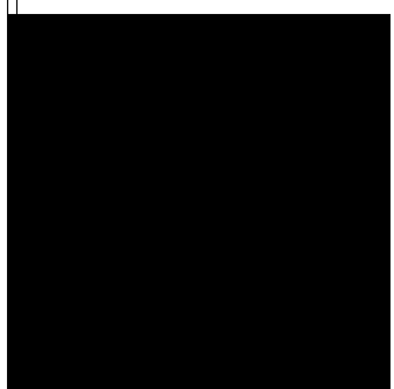
B) chipped or torn grain



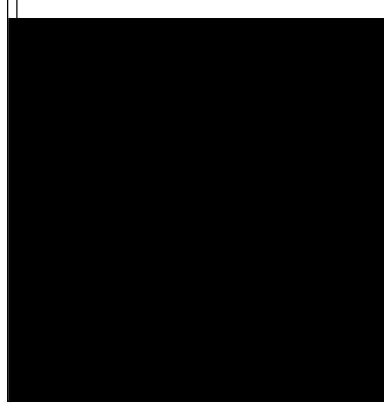
C) raised grain and fuzzy grain



D) chip marks



E) snipe



F) tool burn.

(Photos A, B and C are courtesy of the United States Forest Service Forest Products Laboratory, USDA, Madison, WI.)

Table 3. Some advantages of plain-sawed and quarter-sawed lumber.

Plain-sawed	*Quarter-sawed*
Figure patterns resulting from the annual rings and some other types of figure are brought out more conspicuously by plain-sawing.	Shrinks and swells less in width.
Round or oval knots that may occur in plain-sawed boards affect the surface appearance less than spike knots that may occur in quarter-sawed boards. Also, a board with a round or oval knot is not as weak as a board with a spike knot.	Twists and cups less.
Shake and pitch pockets, when present, extend through fewer boards.	Surface-checks and splits less in seasoning and use.
It is less susceptible to collapse during drying.	Raised grain caused by separation of annual rings does not become so pronounced.
Shrinks and swells less in thickness.	Wears more evenly.
May cost less because it is easier to obtain.	Types of figure caused by pronounced rays, interlocked grain and wavy grain are brought out more conspicuously.
	Does not allow liquids to pass into or readily through it in some species.
	Holds paint better in some species.
	Sapwood appearing in boards is at the edge, and its width is limited according to the width of the sapwood in the log.

Table taken from Wood Handbook, by permission of US Forest Products Laboratory, USDA Forest Service , Madison, WI.

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