SECTION III

INSPECTION OF LUMBER FOR PALLETS

By

Forest Products Laboratory,[1] Forest Service
U. S. Department of Agriculture

FOREWORD

This section was prepared by the Forest Products Laboratory at the request of the U. S. Naval Supply Research and Development Facility, Naval Supply Depot, Bayonne, N. J. Staff members of the Forest Products Laboratory who assisted in planning and preparing the material for this manual are:

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Purpose and Scope

This publication has been prepared to aid inspectors of pallet lumber for the Armed Forces by presenting fundamental information about wood upon which grading and inspection rules are based. Understanding of such grading rules, and their application to pallet lumber, depends to a great extent upon the inspector's basic knowledge of wood properties, characteristics, and growth variables.

The grades of lumber used in pallet manufacture may be characterized by the grosser kinds and sizes of defects, such as knots, checks, and decay, and thorough inspection becomes essential if serviceable pallets are to be obtained. Lower grades of lumber are economical for pallets because much short-length material suitable for pallets is obtainable by judicious cutting and by positioning of pallet members, so that defects are either eliminated or so placed in the finished pallets that they do not critically impair strength and serviceability.

The information in this publication was assembled for the purpose of giving inspectors the background information needed to determine whether lumber has been properly cut and assembled to assure a strong, serviceable pallet. The species commonly used for pallets are listed and their important characteristics outlined. Defects that affect strength and service life are described. The important wood properties are treated briefly, and the effects of moisture and shrinkage are explained.

3. Nature of Wood

3.1 General Structure

Wood consists mainly of hollow fibers built up of interconnected cellulose chains arranged spirally in the long direction of the fibers. In the walls of the fibers and other cells is a material called lignin, which also binds the cells together so firmly that wood breaks usually within the fiber walls rather than in the bond between the fibers. Therefore, for mechanical purposes wood may be considered as made up of tubes of indefinite length firmly welded together rather than separable fibers of varying lengths.

Unlike metals, which have generally uniform strength in all directions and whose every cubic inch is identical, wood has not, for instance, the same strength across the grain as parallel to the grain; that is, its tensile strength may vary as much as 40 to 1, its crushing strength 7 to 1, and its modulus of elasticity 150 to 1. Not only do different species of wood differ in their properties, but trees of the same species and even parts of the same tree may vary, depending on the growth conditions prevailing when the wood was formed.

3.2 Heartwood and Sapwood

In most wood, three regions are readily discernible in the end surface of the log: (1) The bark; (2) the light-colored sapwood next to the bark; and (3) the heartwood, which is usually darker than the sapwood (Fig. 56). In the structural center of the tree trunk there is a small, soft core--the pith.

Fig. 56. - Cross section of white ash log, showing irregular-shaped heartwood (dark) at center, wide sapwood (light), and bark (black outer-most layer). (M6919F)

In the sapwood many of the cells (parenchyma) are alive and serve mainly in the transfer and storage of food, which accounts in part for the greater susceptibility of sapwood to attack by certain fungi and insects. Most of the cells, however, are dead and serve only as channels for the movement of sap and to strengthen the tree trunk. In the heartwood all of the cells are dead and function mainly to strengthen the trunk.

In some woods there is little or no difference in color between heartwood and sapwood. Spruce (except Sitka spruce), hemlock, the true firs, Port-Orford-cedar, basswood, cottonwood, and beech are examples of this class. In other woods, such as pine, Douglas-fir, baldcypress, ash, oak, maple, birch, and sweetgum, there is a well-marked contrast between sapwood and heartwood.

Although sapwood is, as a rule, light-colored, it may be discolored by sap stain, wood-destroying and other fungi, chemical stains within the wood, and color leached from the bark. The heartwood may be uniform in color or streaked or variegated, as is often the case in sweetgum. Heartwood infected with decay may be discolored in various ways.

Light-colored zones, known as internal sapwood, are occasionally found in the heartwood of Douglas-fir, Sitka spruce, western redcedar, western larch, and other species.

The thickness of the sapwood layer varies considerably in different species. In black ash, black cherry, northern white-cedar, western redcedar, Douglas-fir, and spruce, it is usually less than 1-1/2 inches and consequently constitutes a relatively small part of the lumber cut from these species. In white ash, birch, maple, and hickory, the sapwood is so thick that it often comprises more than one-half of the lumber produced.

Heartwood is not fundamentally weaker or stronger than sapwood, but there are some changes in physical characteristics, besides change in color, that accompany heartwood formation. After the timber is cut, the heartwood usually is more resistant to the attack of certain insects and to decay, stain, and mold than the sapwood. In the living tree the sapwood is usually less subject to attack, whereas specific fungi often infect the heartwood. Heartwood is less permeable to liquids, as a rule, which is an advantage in many uses but a disadvantage in the injection of preservatives. Because it is less permeable, heartwood seasons at a slower rate than the sapwood. In resinous species, such as the yellow pines, the heartwood usually contains more resin than the sapwood.

3.3 Annual Rings

In timber grown in temperate climates, well-defined concentric layers of wood can be seen on the cross section. These layers correspond closely to yearly increments of growth, and for that reason are called annual rings (Fig. 57). The width of the annual rings varies with the environmental conditions, such as stand density and soil moisture, under which the trees grew.

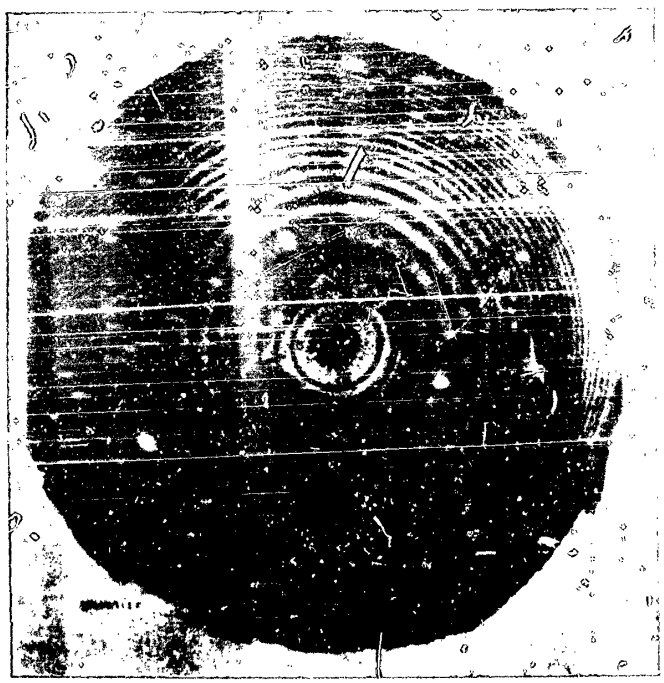

Fig. 57. - Cross section of a southern yellow pine log, showing annual growth rings. Each light ring is springwood. Each dark ring is summerwood. The dark spot at the center is the pith. (ZM10712F)

Springwood is the wood formed on the inner side of the annual ring during the early part of each growing season. It is usually more porous, softer, weaker, and, especially in the conifers (softwoods), lighter in color than the summerwood, which is formed in the outer part of the annual ring during the later part of the growing season. Segments of annual rings in a cross section of Douglas-fir, magnified 20 diameters, are shown in

Fig. 58. Springwood and sapwood may be fairly sharply differentiated from each other within each annual ring, as in Douglas-fir and oak, or the transition may be gradual, as in walnut. In some woods (for example, yellow-poplar, birch, maple, basswood, cottonwood, and sweetgum) the transition from springwood to summerwood within the annual ring is not clear, although the division between rings is distinct.

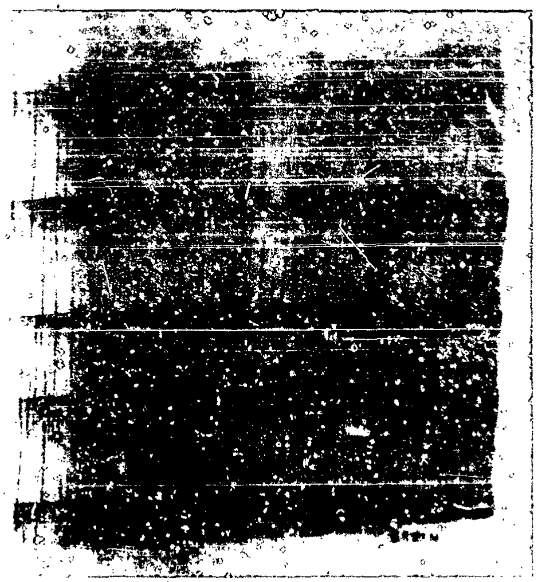

Fig. 58. - Cross section of Douglas-fir magnified 20 diameters. (2281M)

The width of the summerwood and the percentage that it occupies in the total width of the annual rings varies considerably in some species, such as yellow pines, Douglas-fir, oaks, ashes, and hickories, according to the vigor of the tree at the time the rings were formed.

3.4 Plain-sawed and Quarter-sawed Lumber

Wood can be cut in three distinct planes with respect to the annual growth rings: (1) Crosswise, exposing the transverse or end-grain surface; (2) lengthwise along any of the radii of the annual rings, exposing the radial or so-called quarter-sawed, edge-grain, or vertical-grain surface; and (3) lengthwise tangent to any of the annual rings, exposing the tangential or so-called plain-sawed or flat-grain surface. Quarter-sawed and plain-sawed boards are shown in Fig. 59.

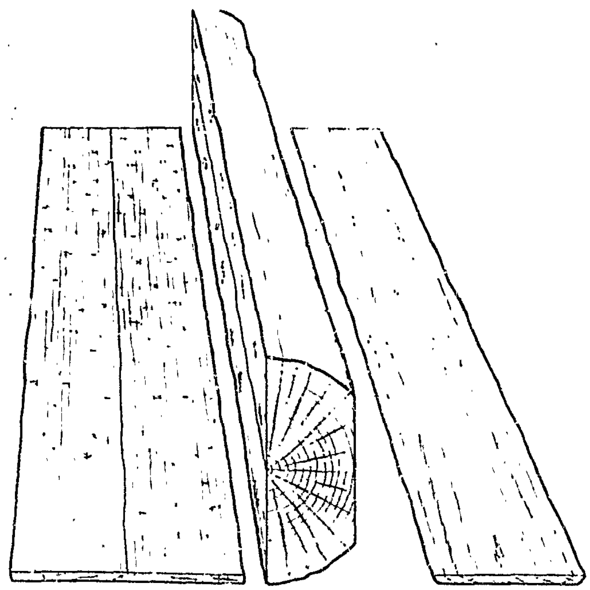

Fig. 59. - Quarter-sawed (A) and plain-sawed (B) boards cut from log. (ZM554F)

Quarter-sawed lumber shrinks and swells less in width and twists, cups, slivers, surface checks, and casehardens in seasoning less than plain-sawed lumber. On the other hand, plain-sawed lumber is cheaper to produce and does not "collapse" so easily in drying; also, any knots that are present are round or oval instead of long spike knots.

The annual rings often run diagonally across the end of a board so that it cannot be said to be either strictly plain-sawed or quarter-sawed. Squared dimension stock may show two plain-sawed and two quarter-sawed faces, or four faces of an intermediate form.

3.5 Grain and Texture

The terms "grain" and "texture" are used rather loosely in connection with lumber. "Grain" is used in referring (1) to the annual rings, as coarse, fine, even, edge, and flat grain; (2) to the direction in which the fibers run, as straight, spiral, interlocked, wavy, and curly grain; and (3) to the relative size of the pores and the fibers, as open grain and close grain.

"Texture" is often used synonymously with grain. More specifically, it is used to designate woods having small and closely spaced pores as fine-textured woods or woods having large pores as coarse-textured woods.

3.6 Weight of Wood

Table 1 shows the average weights of the more important woods used for pallets. Tabulated weights of green wood include the moisture present in the trees as felled. The weights for air-dry wood were determined at a moisture content of 12 percent, representing the moisture condition reached by lumber in unheated covered sheds in the North Central States.

In any lot of air-dry lumber of a given species, at 12 percent moisture content, the weight per cubic foot will rarely vary more than 10 percent from the figure shown in table 1. In green lumber, on the other hand, the variation may occasionally be as great as 20 percent, owing to wide differences in moisture content. Particularly in species that have a high moisture content in the sapwood, large variations in weight when green may occur, depending on the proportion of sapwood. Since young softwood trees contain a larger proportion of sapwood than old trees, their wood averages heavier when green.

3.7 Decay Resistance

Wood kept constantly dry, at a moisture content of less than 20 percent, does not decay, regardless of species or of the presence of sapwood. Therefore, when pallets are used for protected storage, where they will remain dry, decay resistance of the wood is not an important consideration. With unprotected outdoor storage, however, decay resistance is a significant factor in pallet serviceability. When exposed to conditions that favor decay, as in a warm, wet climate, woods of low decay resistance may last less than a year, but the heartwood of highly resistant species may give several years of service, even up to 15 years. When outdoor exposure is less severe, several years of service may also be expected from the woods of low decay resistance.

In all woods, the sapwood has very low decay resistance, but the heartwood may have high or low resistance, depending on the species. The heartwood of the cedars, redwood, cypress, black locust, and black walnut has a high natural resistance to decay. The heartwood of white oak is also very resistant to decay. Other common species have heartwood of intermediate to low decay resistance.

3.8 Hardwoods and Softwoods

Native species of trees are divided into two classes--hardwoods, which have broad leaves, such as the oaks and maples, and softwoods, which have scalelike leaves, such as the cedars, or needlelike leaves, such as the pines. Hardwoods, except in the warmest regions, are deciduous; that is, they shed their leaves at the end of each growing season. Native softwoods, except cypress, tamarack and larch, are evergreen. Softwoods are known also as conifers, because all native species of softwoods bear cones of one kind or another.

The terms "hardwood" and "softwood" have no direct application to the hardness or softness of the wood of the two classes. In fact, such hardwood trees as cottonwood and aspen have softer wood than the white pines and true firs, and certain softwoods, such as longleaf pine and Douglas-fir, produce wood that is as hard as that of basswood and yellow-poplar.

Fig. 60 shows the principal types of forests in the United States and may be helpful in identifying pallet species when the locality of growth is known.

Since either softwoods or hardwoods may be used in the fabrication of pallets, it is frequently desirable to separate the two classes, depending upon specification requirements.

Although the differences between hardwoods and softwoods are quite marked when the wood is examined with a hand lens or microscope, they may not be so apparent when viewed with the naked eye. Because the number of species employed in pallets is relatively small, it is possible to distinguish between softwoods and hardwoods on the basis of the appearance of their annual rings.

In softwoods, the annual rings are made up of two more or less distinct parts: The harder, darker summerwood and the soft, lighter-colored springwood. The color difference is usually quite apparent, and the degree of hardness can readily be observed by denting with the thumbnail.

The hardwood species can be divided into two groups on the basis of their pores, which are the small, round openings visible on a cross section of the wood smoothly cut with a sharp knife. The pores are sometimes large enough to be seen by the eye, or if smaller, can be seen under a 10-power magnifying glass.

In ring-porous woods, such as the oaks and ashes, the pores are much larger in the springwood than in the summerwood. The annual rings in this group are very apparent because of the difference in the degree of porosity between the two zones making up an annual ring. In the other group of hardwoods, the pores are more or less uniform in size throughout the annual ring, and the group is called diffuse-porous. Although this group may sometimes be confused with the softwoods, it does not have the marked difference in hardness between the springwood and summerwood that is found in the softwood species. Diffuse-porous species include the maples, birches, beech, and magnolia, and in all these species the pores are not visible to the naked eye. In the majority of the diffuse-porous hardwoods, the annual rings can generally be distinguished but are not so clearly marked as they are, for example, in Douglas-fir and southern yellow pine.

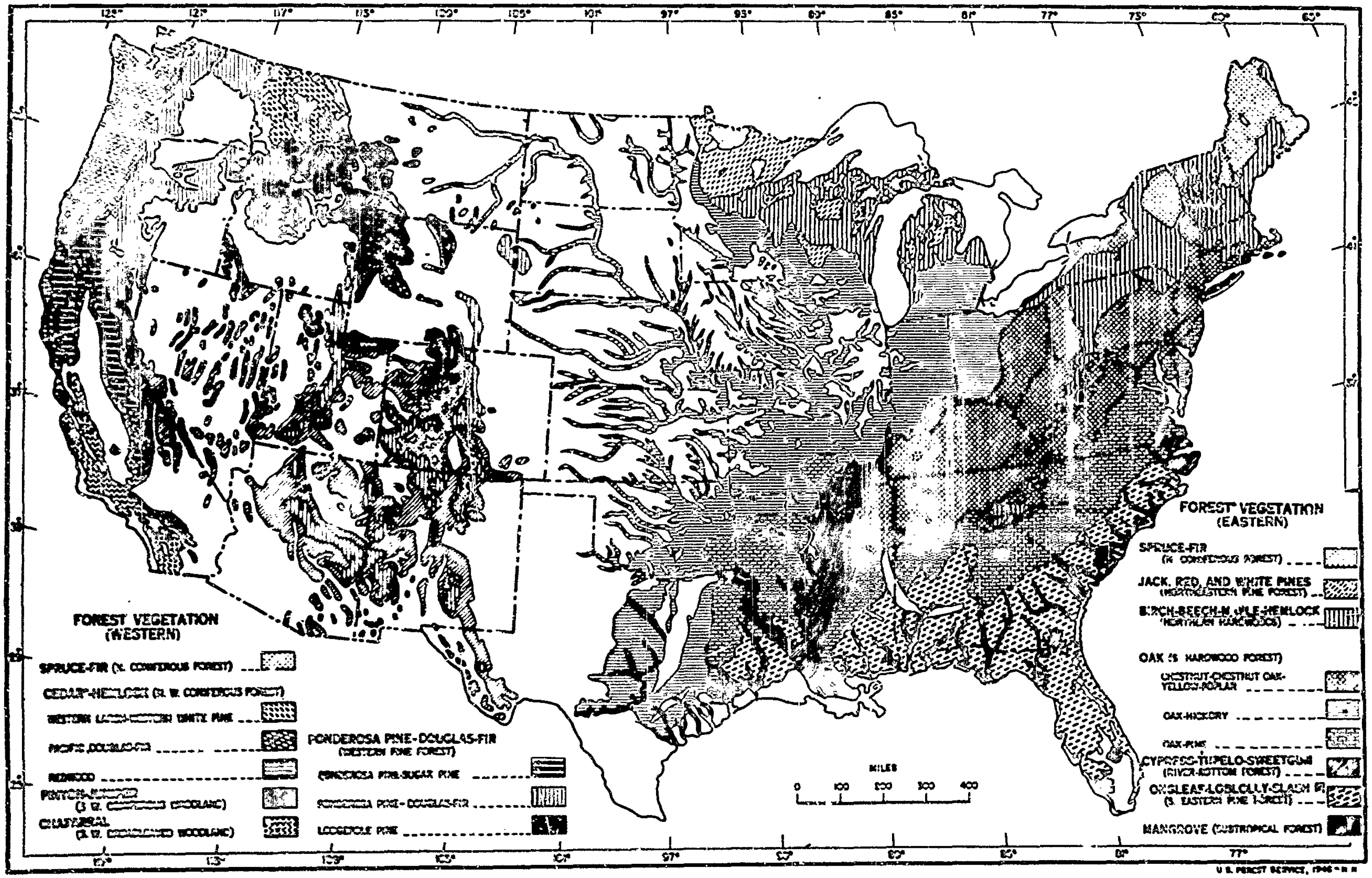

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Fig. 60. - Principal types of forest in the United States

SECTION IV

4. Principal Woods Used for Pallets

The following brief discussion of the localities of growth and properties of the principal woods used for pallets will aid in their identification and selection for specific purposes.

Hardwood Pallet Species

4.1 Ash

Important species of ash are white ash (Fraxinus americana), green ash (Fraxinus pennsylvanica), blue ash (Fraxinus quadrangulata), Biltmore ash (Fraxinus biltmoreana), black ash (Fraxinus nigra), pumpkin ash (Fraxinus profunda), and Oregon ash (Fraxinus oregona). The first six of these species grow in the eastern half of the United States. Oregon ash grows along the Pacific coast.

Commercial white ash is a group of species that consists mostly of white ash and green ash. Biltmore ash and blue ash are also included in this group.

States with the greatest production of ash are Louisiana, Pennsylvania, Wisconsin, Michigan, Ohio, and Tennessee. All States east of the Great Plains produce some ash lumber.

Heartwood of commercial white ash is brown; the sapwood is light-colored or nearly white. Second-growth trees have a large proportion of sapwood. Old-growth trees with little sapwood are scarce. Heartwood of black ash is mostly dark colored.

4.2 Beech

Only one species of beech (Fagus grandifolia) is native to the United States. The terms "red beech" or "red-heart beech" are applied to the darker-colored heartwood and "white beech" or "white-heart beech" to the lighter-colored heartwood.

Beech grows in the eastern one-third of the United States and adjacent Canadian provinces. Greatest production of beech lumber is in the Central and Middle Atlantic States. The Southern States contribute over one-fifth of the total production and lesser amounts come from Michigan and the New England States.

Beech wood varies in color from nearly white sapwood to reddish-brown heartwood in some trees. Sometimes there is no clear line of demarcation between heartwood and sapwood. Sapwood may be 3 to 5 inches thick. Growth rings are usually distinct but not conspicuous. The wood has little figure and is of close, uniform texture. It has no characteristic taste or odor.

The wood of beech is classed as heavy, hard, strong, high in resistance to shock, and highly adaptable for steam bending. Beech has large shrinkage and requires careful drying. It machines smoothly, wears well, and is rather easily treated with preservatives. Beech is low in decay resistance.

4.3 Birch

The important species of birch are yellow birch (*Betula alleghaniensis*), sweet birch (*Betula lenta*), and paper birch (*Betula papyrifera*). Other birches of some commercial importance are river birch (*Betula nigra*), gray birch (*Betula populifolia*), and western paper birch (*Betula papyrifera* var. *occidentalis*).

Yellow birch, sweet birch, and paper birch grow principally in the Northeastern States and Lake States. Yellow and sweet birches also grow along the Appalachian Mountains to northern Georgia. They are the sources of most birch lumber and veneer. Production of birch lumber is highest in the Lake States, followed by the New England and Middle Atlantic States.

Yellow birch has white sapwood and light reddish-brown heartwood. Sweet birch has light-colored sapwood and dark-brown heartwood tinged with red. Wood of yellow birch and sweet birch is heavy, hard, strong, and has good shock-resisting ability. The wood is fine and uniform in texture. Paper birch is lower in weight, softer, and lower in strength than yellow and sweet birch. Birch shrinks considerably during drying and is low in natural resistance to decay.

4.4 Elm

There are six species of elm in the United States: American elm (Ulmus americana), slippery elm (Ulmus rubra), rock elm (Ulmus thomasii), winged elm (Ulmus alata), cedar elm (Ulmus crassifolia), and September elm (Ulmus serotina). American elm is also known as white elm, water elm, and gray elm; slippery elm as red elm; rock elm as cork elm or hickory elm; winged elm as Wahoo; cedar elm as red elm or basket elm; and September elm as red elm.

American elm grows throughout the eastern half of the United States, except in higher elevations of the Appalachian Mountains. Slippery elm, occupies about the same area, excepting the Atlantic Coastal Plain, most of Florida, and along the Gulf coast. Rock elm occurs from New Hampshire to northern Tennessee and Nebraska. Winged elm grows from the Ohio Valley southward to the Gulf, except in southern Florida, and westward to eastern Texas. Cedar elm extends from southern Arkansas and eastern Mississippi into Texas. Slippery elm is most abundant in the central Mississippi Valley.

The sapwood of the elms is nearly white and generally quite thick, except in slippery elm where it rarely exceeds one-half inch in thickness. The heartwood of elm is light brown, often tinged with red. The elms may be divided into two general classes, hard elm and soft elm, based on the weight and strength of the wood. Hard elm includes rock elm, winged elm, cedar elm, and September elm. American elm and slippery elm are the soft elms. Soft elm is moderately heavy, has a high degree of shock-resisting ability, and is moderately hard and stiff. Hard elm species are somewhat heavier than soft elm. Elm is moderately resistant to decay and requires care in drying. It has excellent bending qualities.

4.5 Hackberry

Hackberry (Celtis occidentalis) and sugarberry (Celtis laevigata) supply the lumber known in the trade as hackberry. Hackberry grows east of the Great Plains from Alabama, Georgia, Arkansas, and Oklahoma northward, except along the Canadian boundary. Sugarberry overlaps the southern part of the range of hackberry and grows throughout the Southern and South Atlantic States. The wood of the two species is similar and is not separated in the trade.

The sapwood of both species is 3 or more inches wide and varies from pale yellow to greenish or grayish yellow. Heartwood is commonly darker in color. Growth rings are distinct. The wood resembles elm in structure.

Wood of hackberry is moderately heavy, moderately strong in bending, moderately weak in compression parallel to the grain, moderately hard to hard, high in shock resistance, but low in stiffness. It has moderately large to large shrinkage but keeps its shape well during seasoning.

4.6 Hickory, True and Pecan

True hickories are found throughout most of the eastern half of the United States. The species most important commercially are shagbark (Carya ovata), pignut (Carya glabra), shellbark (Carya laciniosa), mockernut (Carya tomentosa), and red hickory (Carya ovalis).

Species of the pecan group include bitternut hickory (Carya cordiformis), pecan (Carya illinoensis), water hickory (Carya aquatica), and nutmeg hickory (Carya myristicaeformis). Bitternut hickory grows throughout the eastern half of the United States. Pecan hickory grows from central Texas and Missouri and Indiana. Water hickory grows from Texas to South Carolina. Nutmeg hickory occurs principally in Texas and Louisiana.

The greatest commercial production of the true hickories is in the Middle Atlantic and Central States. The Southern and South Atlantic States produce nearly half of all hickory lumber, which includes lumber from pecan hickories as well as from true hickories.

Sapwood of true hickory is white and usually quite thick, except in old, slowly growing trees. Heartwood is reddish. From the standpoint of strength, no distinction should be made between sapwood and heartwood having the same weight.

The wood of true hickory is very tough, heavy, hard, and strong, a combination not found in any other native commercial wood. Hickory is low in natural resistance to decay and shrinks considerably in drying. Because of its hardness, hickory does not nail easily when thoroughly dry.

The wood of pecan hickory resembles that of true hickory. It has white or nearly white sapwood, which is relatively wide, and somewhat darker heartwood. Like true hickory, it is typically ring porous. The wood is heavy to very heavy and sometimes has very large shrinkage. Heavy pecan hickory overlaps the lowest true hickory in weight and in many strength properties.

4.7 Maple

Commercial species of maple in the United States include sugar maple (*Acer saccharum*), black maple (*Acer nigrum*), silver maple (*Acer saccharinum*), red maple (*Acer rubrum*), boxelder (*Acer negundo*), and bigleaf maple (*Acer macrophyllum*). Sugar maple is also known as hard maple, rock maple, sugar tree, and black maple; black maple as hard maple, black sugar maple, and sugar maple; silver maple as white maple, river maple, water maple, and swamp maple; red maple as soft maple, water maple, scarlet maple, white maple, and swamp maple; boxelder as ash-leaved maple, three-leaved maple, and cut-leaved maple; and bigleaf maple as Oregon maple.

Sugar maple grows from Maine to Minnesota and southward to northern Georgia, Alabama, Louisiana, and Texas. Black maple occupies mainly a belt from New York through southern Michigan, southward to Kentucky and westward through Iowa. Silver maple grows through most of the eastern United States, except the southern Atlantic and Gulf coasts. Red maple grows east of the Great Plains and south to the Gulf of Mexico, except for the southern tip of Florida. Boxelder grows from Minnesota to Texas, and eastward to the Middle Atlantic States. Bigleaf maple grows along the Pacific coast.

Maple lumber comes principally from the Middle Atlantic and Lake States, which together account for about two-thirds of the production. A considerable amount of maple is cut in New England and some in the South Atlantic and Southern States. Production in the New England, Middle Atlantic, and Lake States is principally hard maple.

The wood of sugar maple and black maple is known as hard maple; that of silver maple, red maple, and boxelder as soft maple. The sapwood of the maples is commonly white with a slight reddish-brown tinge. It is from 3 to 5 or more inches thick. Heartwood is usually light reddish brown but sometimes is considerably darker. Hard maple has a fine, uniform texture. It is heavy, strong, stiff, hard, resistant to shock, but has large shrinkage. It is generally straight-grained, but some trees are characterized by curly, wavy, or bird's-eye grain. Soft maple has considerably wider sapwood and lighter-colored heartwood than hard maple, and is not so heavy as hard maple. Bigleaf maple is intermediate between soft maple and hard maple in strength properties.

4.8 Oak, Red

Among the numerous species of red oaks in the United States, 10 have considerable commercial importance.

(1) Northern red oak (Que cus rubra), also known as eastern red oak, grows in the eastern half of the United States, to the lower Mississippi Valley, Florida, and the Atlantic Coastal Plain. It is the most important lumber tree of the red oak group.

(2) Scarlet oak (Quercus coccinea) grows in the eastern third of the United States, except the southern border States and the northern-most portions of New York, Vermont, New Hampshire, and Maine.

(3) Shumard oak (Quercus shumardii), also known as Schneck oak, Texas oak, and southern red oak, grows chiefly along the Atlantic and Gulf coasts, and in the Mississippi Valley.

(4) Pin oak (Quercus palustris), also known as swamp oak, grows principally in the central Mississippi Valley, and eastward to the Atlantic coast.

(5) Nuttall oak (Quercus nuttalli) grows in the lower Mississippi Valley region from Missouri southward, and from Alabama to Texas.

(6) Black oak (Quercus velutina), also known as yellow oak, grows in the eastern half of the United States.

(7) Southern red oak (Quercus falcata) grows in southeastern United States from New Jersey to Missouri, Arkansas, and Texas.

(8) Water oak (Quercus nigra) grows in the South Atlantic and Gulf States from Maryland to Texas.

(9) Laurel oak (Quercus laurifolia) grows in the South Atlantic and Gulf Coastal Plains from Maryland to Louisiana.

(10) Willow oak (Quercus phellos) grows along the Atlantic and Gulf coasts and in the lower Mississippi Valley.

Most red oak lumber comes from the Southern States, the southern mountain regions, and the Atlantic Coastal Plain.

Sapwood is nearly white in color and from 1 to 2 or more inches thick. Heartwood is brown with a tinge of red. Red oaks are all ring porous and have distinct growth rings. Sawed lumber of the various species of red oak cannot be separated on the basis of the characteristics of the wood alone. Red oak lumber can be separated from white oak, however, by the absence of the froth-like growth known as tyloses in the pores, and by the larger size of the summerwood pores. If these pores are plainly visible as minute, round openings and can be readily counted under a hand lens, the wood belongs to the red oak group. Quarter-sawed lumber of the oaks is distinguished by the broad and conspicuous rays, which add to its attractiveness.

Wood of the red oaks is heavy. Rapidly grown second-growth oak is generally harder and tougher than finer-textured old-growth timber. The red oaks have fairly large shrinkage in drying.

4.9 Oak, White

There are nine commercially important species of the white oak group, and all grow mainly in the eastern United States.

(1) White oak (Quercus alba) grows throughout the eastern half of the United States and adjacent Canada, except in the Florida Peninsula and the Mississippi River Delta. It is the most important lumber tree of the white oak group.

(2) Chestnut oak (Quercus prinus), also known as rock chestnut oak or rock oak, grows from southern Vermont and New Hampshire, southward along the Appalachian Mountains to central Georgia and Alabama.

(3) Post oak (Quercus stellata) grows throughout the eastern half of the United States from southern New England southward to the Great Plains.

(4) Overcup oak (Quercus lyrata), also known as swamp white oak, grows in the Atlantic Coastal States and westward to Texas through southern Illinois and Indiana.

(5) Swamp chestnut oak (Quercus michauxii), also known as basket oak and cow oak, grows along the Atlantic coast and westward to Texas through southern Illinois and Indiana.

(6) Bur oak (Quercus macrocarpa) grows mainly from New York to Montana and southward through Kentucky to Texas.

(7) Chinkapin oak (Quercus muehlenbergii) grows from New York, southern Michigan, and southern Minnesota southward to the Gulf of Mexico, except for the Atlantic Coastal Plain and Florida.

(8) Swamp white oak (Quercus bicolor) grows from southern Maine through the Central States to the Great Plains.

(9) Live oak (Quercus virginiana) is limited to the Atlantic Coastal Plain, Florida, and the Gulf Coast, extending across the southern portion of Texas.

White oak lumber comes chiefly from the South, South Atlantic, and Central States, including the southern Appalachian area.

The heartwood of the white oaks is generally grayish brown, and the sapwood, which is from 1 to 2 or more inches thick, is nearly white. The pores of the heartwood of white oaks are usually plugged with a froth-like growth known as tyloses, which tend to make the wood impenetrable to liquids. Chestnut oak lacks tyloses in many of its pores.

To distinguish between white oak and red oak, cut the end grain of the wood smoothly with a sharp knife across several growth rings of average width and with a hand lens examine the small pores in the dense summerwood. If the pores in the summerwood are very small, somewhat angular, and so numerous that it would be exceedingly difficult to count them, the wood belongs to the white oak group.

The wood of white oak is heavy, averaging somewhat heavier than that of red oak. The heartwood of white oak is considered to be somewhat more decay resistant than that of red oak.

4.10 Sweetgum

Sweetgum (Liquidambar styraciflua) is frequently called red gum, star-leaved gum, or merely gum. Lumber from sweetgum is usually divided into two classes--sap gum, the light-colored wood from the sapwood, and red gum, which is cut from the heartwood.

Sweetgum grows from southwestern Connecticut westward into Missouri and southward to the Gulf. Lumber production is almost entirely from the Southern and South Atlantic States.

The wide sapwood of sweetgum is white, tinged with pink. The heartwood is reddish brown. The annual rings are inconspicuous, and the wood is uniform in texture. It has interlocked grain, a form of cross grain, and must be carefully dried. The interlocked grain causes a ribbon stripe. Sweetgum is rated as moderately heavy and hard. It is moderately strong, moderately stiff, and moderately high in shock resistance. Sweetgum is classed with wood of intermediate decay resistance.

4.11 Sycamore, American

American sycamore (Platanus occidentalis) is also known as sycamore, and sometimes as button-wood, button-ball tree, and plane-tree. Sycamore grows from Maine to Nebraska, Texas, and northern Florida. In the production of sycamore lumber, the Central States rank first, followed by the Southern States and the South Atlantic States.

The heartwood of sycamore is reddish brown; sapwood is lighter in color and from 1-1/2 to 3 inches thick. In quarter-sawed lumber, the rays are very conspicuous and, though smaller, resemble those in quarter-sawed oak. The wood has a fine texture and interlocked grain. It shrinks moderately in drying and requires careful seasoning. Sycamore wood is moderately heavy, moderately hard, moderately stiff, moderately strong, and has good resistance to shock.

4.12 Tupelo

The tupelo group includes water tupelo (Nyssa aquatica), also known as tupelo gum, swamp tupelo, and gum; black tupelo (Nyssa sylvatica), also known as blackgum, and sour gum; swamp tupelo (Nyssa sylvatica var. bilfora), also known as swamp blackgum, blackgum, tupelo gum, and sour gum; and ogeechee tupelo (Nyssa ogeche), also known as sour tupelo, gopher plum, tupelo, and ogeechee plum.

All except black tupelo grow principally in the southeastern United States. Black tupelo grows in the eastern United States from Maine to Texas and Missouri. About two-thirds of the production of tupelo lumber is from the Southern States and nearly another one-third from the South Atlantic States. The small amount from the Middle Atlantic and Central States is largely black tupelo.

Wood of the different tupelos is quite similar in appearance and properties. Heartwood is light brownish gray and merges gradually into the lighter-colored sapwood, which is generally several inches wide. Annual rings are indistinct and frequently very difficult to count. The wood has fine uniform texture and interlocked grain, which prevents splintering and makes the wood difficult to split. Tupelo wood is rated as moderately heavy. It is moderately strong, moderately hard and stiff, and moderately high in shock resistance. Because of interlocked grain, tupelo lumber requires care in drying.

Softwood Pallet Species

4.13 Baldcypress

Baldcypress (Taxodium distichum) is commonly known as cypress, also as southern cypress, red cypress, yellow cypress, and white cypress. Commercially, the terms "tidewater red cypress," "gulf cypress," "red cypress (coast type)," and "yellow cypress (inland type)" are frequently used.

Cypress grows along the Atlantic Coastal Plain from Delaware to Florida, westward through the Gulf Coast region to the Mexican border in Texas, and up the Mississippi Valley to southern Indiana. About one-half of the cypress lumber production comes from the Southern States and one-fourth from the South Atlantic States.

Sapwood of cypress is narrow and nearly white. The color of the heartwood varies widely, ranging from light yellowish brown to dark brownish red, brown, or chocolate. The wood of cypress is moderately heavy, moderately strong, and moderately hard, and its heartwood is one of our most decay-resistant woods. Shrinkage is moderately small, somewhat greater than that of cedar, but less than that of southern yellow pine.

Frequently the wood of certain cypress trees contains pockets or localized areas that have been attacked by a fungus. Such wood is known as "pecky" cypress. The decay caused by this fungus is arrested when the wood is cut into lumber and dried. Pecky cypress therefore is durable and useful where appearance is not important and watertightness is unnecessary.

4.14 Douglas-fir

Douglas-fir (Pseudotsuga taxifolia) is also known locally as red fir, Douglas spruce, yellow fir, and Oregon pine.

The range of Douglas-fir extends from the Rocky Mountains to the Pacific Coast and from Mexico to central British Columbia. Most of the Douglas-fir production comes from the coast States of Oregon, Washington, and California, principally Oregon, and some from Idaho and Montana.

Sapwood of Douglas-fir is narrow in old-growth trees but may be as much as 3 inches wide in second-growth trees of commercial size. Fairly young trees of moderate to rapid growth have reddish heartwood and are called red fir. Very narrow-ringed wood of old trees may be yellowish brown in color and is known on the market as yellow fir.

The wood of Douglas-fir varies widely in weight and strength. The heaviest wood of Douglas-fir frequently has from 12 to 16 growth rings per inch. Douglas-fir wood splits easily. It is intermediate in decay resistance.

4.15 Firs, true

Eight commercial species make up the group of true firs: Balsam fir (Abies balsamea), California red fir (Abies magnifica), Fraser fir (Abies fraseri), grand fir (Abies grandis), noble fir (Abies procera), Pacific silver fir (Abies amabilis), subalpine fir (Abies lasiocarpa), and white fir (Abies concolor). Of these, all but balsam and Frazer fir are often marketed together as commercial white fir. Balsam fir and Fraser fir grow in the east, the other six in the west.

In the United States, balsam fir grows principally in New England, New York, Pennsylvania, and the Lake States. Fraser fir grows in the Appalachian Mountains of Virginia, North Carolina, and Tennessee. White fir grows from the Rocky Mountains to the Pacific Coast. Subalpine fir grows at high altitudes in the Rocky Mountain region and the Cascade Mountains of Oregon and Washington. Pacific silver fir is found in Oregon and Washington.

Grand fir's range is western Montana, northern Idaho, northeastern Oregon, and along the coast from Washington to northern California. Noble fir grows in the mountains of northwestern Washington, western Oregon, and northern California. California red fir is limited to the mountains of southwestern Oregon and northern and eastern California. The western true firs (commercial white fir) are cut for lumber primarily in Oregon and Washington. The rest comes from California and Rocky Mountain areas.

The wood of the true firs is creamy white to pale brown. Heartwood and sapwood are generally indistinguishable. Because of their similarity of structure, wood of the true firs cannot be separated from an examination of the wood alone. Balsam fir is rated as light in weight, low in bending and compressive strength, moderately limber, soft, and low in resistance to shock. The western firs, except grand fir, have somewhat higher strength properties than balsam fir. Shrinkage of the wood is rated from small to moderately large; noble fir and California red fir shrink most. The wood of the true firs is low in decay resistance.

4.16 Hemlock, Eastern

Eastern hemlock (*Tsuga canadensis*) grows from New England southward along the Appalachian Mountains to northern Alabama and Georgia, and in the Lake States. Other names are Canadian hemlock and hemlock spruce.

The production of hemlock lumber is divided fairly evenly between the New England States, the Middle Atlantic States, and the Lake States. North Carolina, South Carolina, and Virginia also produce considerable amounts.

The heartwood of eastern hemlock is pale brown with a reddish hue. Sapwood is not distinctly separated from the heartwood, but may be lighter in color. Growth rings are distinct. The wood is coarse and uneven in texture and inclined to splinter; old trees tend to have considerable shake. The wood is low in decay resistance. It is moderately light in weight, moderately hard, moderately weak, moderately limber, and moderately low in shock-resisting ability. It requires care in seasoning.

4.17 Hemlock, Western

Western hemlock (Tsuga heterophylla) is also known by several other names, including west coast hemlock, hemlock spruce, western hemlock spruce, western hemlock fir, Prince Albert fir, gray fir, silver fir, and Alaska pine.

The heartwood and sapwood of western hemlock are almost white with a purplish tinge. Sapwood, which is sometimes lighter in color, is generally not over 1 inch thick. Growth rings are distinct. The wood contains small, sound, black knots that are usually tight and stay in place. Dark streaks often found in the lumber are caused by hemlock bark maggots.

Western hemlock is moderately light in weight and moderately low in strength. It is moderately hard, moderately stiff, and moderately low in shock resistance. The wood is not highly resistant to decay. It has moderately large shrinkage, about the same as Douglas-fir. Green hemlock lumber contains considerably more water than Douglas-fir, but it is comparatively easy to kiln dry.

4.18 Larch, Western

Western larch (Larix occidentalis) grows in western Montana, northern Idaho, northeastern Oregon, and on the eastern slope of the Cascade Mountains in Washington. It is found at elevations of 2,000 to 7,000 feet. About two-thirds of the lumber of this species is produced in Idaho and Montana and one-third in Oregon and Washington.

The heartwood of western larch is yellowish brown and the sapwood yellowish white. Sapwood is generally not more than 1 inch thick. Growth rings are distinct; they are generally quite uniform and range from 15 to 30 per radial inch. The wood is moderately strong, stiff, moderately hard, moderately high in shock resistance, and moderately heavy. It has moderately large shrinkage. The wood is usually straight-grained, splits easily, and is subject to ring shake. It has about the same decay resistance as Douglas-fir. Knots are common but small and tight. If proper drying schedules are used, western larch can be seasoned satisfactorily.

4.19 Pine, Eastern White

Eastern white pine (Pinus strobus) grows in the United States from Maine southward along the Appalachian Mountains to northern Georgia and Alabama, and in the Lake States. It is also known as white pine, northern white pine, Weymouth pine, and soft pine.

Lumber production of eastern white pine is confined principally to the New England States, which produce about one-half of the total. About one-third comes from the Lake States and most of the remainder from the Middle Atlantic and South Atlantic States.

The heartwood of eastern white pine is light brown, often with a reddish tinge. It turns considerably darker on exposure. Growth rings are distinct. The wood has comparatively uniform texture, and is straight-grained. It is easily kiln dried, has small shrinkage, and ranks high in ability to stay in place. It is also easy to work and can be readily glued. Eastern white pine is light in weight, moderately soft, moderately weak, and low in resistance to shock. The heartwood is rated as intermediate in decay resistance.

4.20 Pine, Lodgepole

Lodgepole pine (Pinus contorta) grows in the Rocky Mountain and Pacific Coast regions and is cut largely in the Central Rocky Mountain States.

The heartwood of lodgepole pine varies from light yellow to light yellow-brown. The sapwood is yellow or nearly white. The wood is generally straight-grained with narrow growth rings.

The wood is moderately light in weight, fairly easy to work, and has moderately large shrinkage. In strength properties, lodgepole pine rates as moderately weak, moderately stiff, moderately soft, and moderately low in shock resistance. It is low in decay resistance.

4.21 Pine, Ponderosa

Ponderosa pine (Pinus ponderosa) grows in every state west of the Great Plains; major producing areas are in California, Oregon, Washington, Idaho, and Montana.

Although ponderosa pine belongs to the yellow pine group, much of its wood is similar in appearance and properties to that of the white pines. Heartwood is light reddish brown, and the wide sapwood is nearly white to pale yellow. Growth rings are generally distinct when not exceedingly narrow.

The wood of the outer portions of ponderosa pine of saw-timber size is generally moderately light in weight. It is moderately low in strength, moderately stiff, moderately soft, and moderately low in shock resistance. It is generally straight-grained and has moderately small shrinkage. It is quite uniform in texture and has little tendency to warp and twist. Wood in young trees and in the heartwood of older trees is sometimes heavier, harder, and stronger than that in the outer portion of the older trees.

4.22 Pine, Red

Red pine (Pinus resinosa) is frequently called Norway pine. It is occasionally known as hard pine and pitch pine. Red pine grows in the New England States, New York, Pennsylvania, and the Lake States. In the past, lumber from red pine has been marketed with white pine without distinction as to species.

The heartwood of red pine varies in color from pale red to a reddish brown. The sapwood is nearly white with a yellowish tinge and is generally from 2 to 4 inches wide. The wood resembles the lighter-weight wood of southern yellow pine. Summerwood is distinct in the growth rings. Red pine is moderately heavy, moderately strong and stiff, moderately soft, and moderately high in shock resistance. It is generally straight-grained, not so uniform in texture as eastern white pine, and somewhat resinous. The wood has moderately large shrinkage, but is not difficult to dry and stays in place well when seasoned. It is low in decay resistance.

4.23 Pine, Southern Yellow

There are a number of species included in the group marketed as southern yellow pine lumber. The most important and their growth ranges are:

(1) Longleaf pine (Pinus palustris), which grows from eastern North Carolina south into Florida, and westward into eastern Texas.

(2) Shortleaf pine (Pinus echinata), which grows from southeastern New York and New Jersey southward to northern Florida and westward into eastern Texas and Oklahoma. Northern limits of growth are the Ohio Valley and southern Missouri.

(3) Loblolly pine (Pinus taeda), which grows from Maryland southward through the Atlantic Coastal Plain and Piedmont Plateau into Florida and westward into eastern Texas. The northern limit of growth west of the Appalachian Mountains is near the southern Tennessee border.

(4) Slash pine (Pinus eliottii), which grows in Florida and the southern parts of South Carolina, Georgia, Alabama, Mississippi, and Louisiana east of the Mississippi River.

Other southern yellow pines of less commercial importance include Virginia pine (Pinus virginiana), pond pine (Pinus rigida serotina), and spruce pine (Pinus glabra).

Many names are applied to the lumber and trees of the various species of southern yellow pine. Longleaf is known also as pitch pine in export trade and as Georgia pine, Florida pine, Texas yellow pine, and hard pine. Slash pine may be called Cuban pine, yellow slash pine, swamp pine, and pitch pine. Shortleaf pine may be called yellow pine, Arkansas shortleaf pine, North Carolina pine, and Rosemary pine. Loblolly pine is known as oldfield pine, North Carolina pine, sap pine, and shortleaf pine.

Southern yellow pine lumber comes principally from the Southern and South Atlantic States. States that lead in production are Georgia, Alabama, North Carolina, and Texas.

The wood of the various southern yellow pines is quite similar in appearance. The sapwood is yellowish white (usually white in second-growth stands), and the heartwood is reddish brown. Heartwood begins to form when the tree is about 20 years old. In old, slow-growth trees, sapwood may be only 1 or 2 inches in width. Growth rings in the southern yellow pines are usually prominent, each made up of a band of dark-colored summerwood and a band of light-colored springwood. Width of the annual rings varies greatly, depending upon the conditions under which the trees have grown. Rings may be as much as 1 inch in width in young trees in old-field stands or extremely narrow in the outer part of old-growth trees.

Longleaf and slash pines are classed as heavy, strong, stiff, hard, and moderately high in shock resistance. Shortleaf and loblolly pine are usually somewhat lighter in weight than longleaf. The other less important species of southern yellow pine have properties similar to shortleaf and loblolly pine.

In order to obtain heavy, strong wood of the southern yellow pines for structural purposes, a "density rule" has been written that specifies certain visual characteristics for structural timbers.

Heartwood of the southern yellow pines is intermediate in decay resistance. The sapwood can be readily treated with preservatives to improve its decay resistance. Southern yellow pine lumber can be satisfactorily seasoned either by air drying or by kiln drying. All the southern yellow pines have moderately large shrinkage but stay in place well when properly seasoned.

4.24 Pine, Sugar

Most of the lumber from sugar pine (Pinus lambertiana) is produced in California and the remainder in southwestern Oregon.

The heartwood of sugar pine is buff or light brown, sometimes tinged with red. Sapwood is creamy white. Sugar pine contains resin canals, which show on cross sections or tangential faces as small, dark-colored dots or as thin, dark-colored streaks. During seasoning the wood frequently becomes discolored because of the action of blue stain fungi or a chemical reaction resulting in brown stain. These stains do not affect the strength properties of the wood but do affect its appearance. The wood is straight-grained, fairly uniform in texture, and easy to work with tools. It has very small shrinkage, is readily seasoned without warping or checking, and stays in place well. Sugar pine is light in weight, moderately weak, moderately soft, low in shock resistance, and low in stiffness. It is rated as intermediate in decay resistance.

4.25 Spruce, Eastern

The term "eastern spruce" includes three species, red (Picea rubens), white (Picea glauca), and black spruce (Picea mariana). White spruce and black spruce grow principally in the Lake States and New England, and red spruce in New England and the Appalachian Mountains. All three species have about the same properties, and in commerce no distinction is made between them. The wood dries easily, stays in place well, is moderately light in weight and easily worked, has moderate shrinkage, and is moderately strong, stiff, tough, and hard. The wood is light in color, and there is little difference between the heartwood and softwood.

4.26 Spruce, Engelmann

Engelmann spruce (Picea engelmannii) grows at high elevations in the Rocky Mountain regions of the United States. About two-thirds of the lumber is produced in the southern Rocky Mountain States. Most of the remainder comes from the northern Rocky Mountain States and Oregon.

The heartwood of Engelmann spruce is nearly white with a slight tinge of red. The sapwood varies from 3/4 inch to 2 inches in width and is often difficult to distinguish from heartwood. The wood has medium to fine texture and is generally straight-grained. Engelmann spruce is rated as light in weight and has low strength as a beam or post. It is limber, soft, low in shock resistance, and has moderately small shrinkage. The lumber contains small knots.

4.27 Spruce, Sitka

Sitka spruce (Picea sitchensis) is a tree of large size growing along the northwestern coast of North America from California to Alaska. About two-thirds of the production of Sitka spruce lumber comes from Washington and one-third from Oregon. Small amounts are produced in California.

The heartwood of Sitka spruce is a light pinkish brown. Sapwood is creamy white and shades gradually into the heartwood. Sapwood may be 3 to 6 inches wide or even wider in young trees. The wood has a comparatively fine, uniform texture, and is generally straight-grained. It is moderately light in weight, moderately low in bending and compressive strength, moderately stiff, moderately soft, and moderately low in resistance to shock. It has moderately small shrinkage. On the basis of weight, it rates high in strength properties, and can be obtained in clear, straight-grained pieces of large size.

SECTION V

5. Moisture Relations in Wood

5.1 Moisture Content of Green Wood

In living trees, the sapwood generally contains more water than the heartwood. This is particularly true of the softwoods, in which there is often considerably more water in the sapwood than in the heartwood. On the other hand, in many of the hardwoods the moisture content of heartwood and sapwood is more uniform.

The sapwood of living trees often contains more than 100 percent of moisture, and trees have been found in which the moisture content was over 300 percent of the dry weight. In such cases the cell walls are fully saturated, and the cell cavities are almost filled with water. In the heartwood of some green softwoods, the moisture content is as low as 30 percent.

5.2 Relation of Moisture Content of Wood, Relative Humidity, and Temperature

When wood is exposed to a constant temperature and relative humidity, it will in time come to a definite moisture content that balances the amount of moisture in the surrounding air. This moisture content is called the equilibrium moisture content. The relationship between the moisture content of wood and the surrounding atmospheric conditions is shown in Fig. 61. Under constant temperature conditions the moisture content increases as the relative humidity increases; under constant relative humidity conditions the moisture content decreases as the temperature increases.

In general, the relative humidity of the atmosphere is lower in the spring and summer than during the autumn and winter, and seasoned wood exposed to these changes in relative humidity will absorb or lose moisture accordingly in order to reach an equilibrium moisture content.

Relative humidity also varies in different parts of the country as affected by altitude, proximity to the ocean, precipitation, or

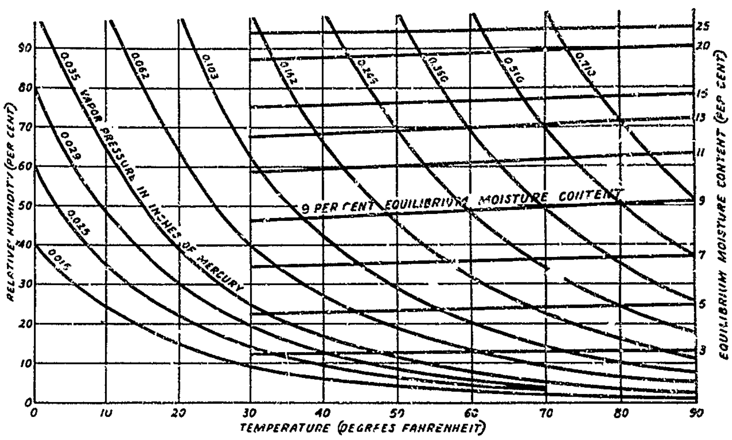
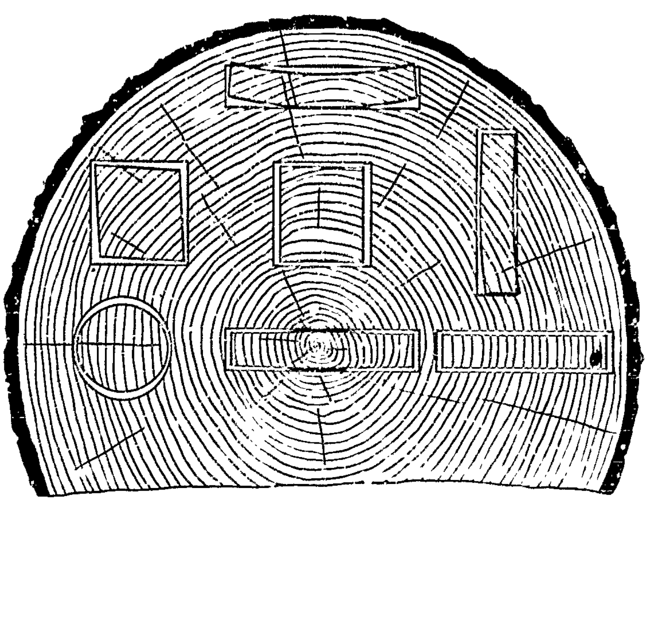


Fig. 61. - Relationship of relative humidity, vapor pressure, equilibrium moisture content, and temperature. (ZM17222F)

Fig. 62. - Effects of radial and tangential shrinkage on the shape of various sections in drying from the green condition. (ZM12494F)



other local conditions. Table 2 shows the average relative humidity for a number of widely separated cities in the United States at different times of the year. Similar seasonal variations occur in other parts of the world. In tropical and subtropical areas, where long rainy seasons are followed by long dry spells, the spread of equilibrium moisture content between seasons may be considerable. Low equilibrium moisture content conditions may be expected in desert areas. In Europe generally the average equilibrium moisture content would be as high as, or higher than, that along the northeastern coast of the United States.

The approximate equilibrium moisture content for wood can be estimated for any section of the country and for any season by noting the relative humidity given in table 2 and reading the corresponding moisture content from Fig. 61 at the particular temperature under consideration. Moisture content variations in wood in service can be minimized by fabricating or installing the wood at a moisture content corresponding to the average atmosphere conditions to which it will be exposed.

5.3 Shrinkage of Wood

Wood shrinks as it loses moisture and swells as it absorbs moisture.

Wood from the tree may contain from 30 to 250 percent of water, based on the weight of the oven-dry wood. This water is held in the wood in two ways--imbibed water in the walls of the wood cells and free water in the cell cavities. When wood begins to dry, the free water leaves first, followed by the imbibed water. The fiber-saturation point is that condition in which all the free water has been removed but all the imbibed water remains; for most species this point is approximately 30 percent moisture content.

Wood shrinks only if its moisture content is reduced below the fiber-saturation point. In seasoning green wood, however, the surface dries more rapidly than the interior and reaches the fiber-saturation point first; shrinkage may therefore start while the average moisture content is considerably above the fiber-saturation point. Wood shrinks most in the direction of the annual growth rings (tangentially), about one-half to two-thirds as much across these rings (radially), and very little, as a rule, along the grain (longitudinally). The combined effects of radial and tangential shrinkage on the shape of various sections in drying from the green condition are illustrated in Fig. 62. Greater shortening occurs in a cross-grained board than would occur in a straight-grained piece.

Shrinkage is usually expressed as a percentage of the green dimensions, which represent the natural size of the piece. Table 4 gives the range in shrinkage in different directions for most of the commercially important native species.

Shrinkage in drying is proportional to the moisture lost below the fiber-saturation point. Approximately one-half the total shrinkage possible has occurred in wood seasoned to an air-dry condition (12 to 15 percent moisture content) and about three-fourths in lumber kiln dried to a moisture content of about 7 percent. Hence, if wood is properly seasoned, manufactured, and installed at a moisture content in accord with its service conditions, there is every prospect of satisfactory performance without serious changes in size or distortion.

In general, the heavier species of wood shrink more across the grain than the lighter ones. Heavier pieces also shrink more than lighter pieces of the same species. When shrinkage is more of a factor than hardness or strength, a lightweight species should be chosen. When both hardness or strength and low shrinkage are very important, then an exceptional species, such as black locust, should be chosen.

5.4 Moisture Content of Seasoned Lumber

The trade terms "green," "shipping dry," "air dry," and "kiln dried," although widely used, have no specific or agreed meaning with respect to moisture content except in a few instances where lumber association rules define moisture content limits for kiln-dried and air-dried lumber. The wide limitations of these terms as ordinarily used are covered in the following statements, which, however, are not to be construed as exact definitions:

"Green lumber"--lumber that may be freshly cut or partially seasoned but which has not yet reached a shipping-dry or air-dry condition. The term may also be applied to lumber that has a higher moisture content than is acceptable for manufacture into finished products.

"Shipping-dry lumber"--lumber that has been partially dried, either in a kiln or by air drying, to reduce weight and freight charges, and which may have a moisture content of 30 percent or more.

"Air-dry lumber"--lumber that has been exposed to the air for any length of time. If exposed for a sufficient time, it may have a moisture content ranging from 6 percent, as in summer in the arid Southwest, to 24 percent, as in winter in the Pacific Northwest. For the United States as a whole, the minimum moisture content range for thoroughly air-dry lumber is 12 to 15 percent in the summer, and the average is somewhat higher. Sometimes such terms as "90 days on sticks" or "4 months in the yard" are used instead of "air-dry" to denote the length of time the lumber remained in the yard piles. Since lumber seasons slowly in cold weather, less drying would take place during the winter than during the summer, and a given period in the yard would not mean the same degree of seasoning in cold or wet months as would occur in summer or dry months (table 3).

"Kiln-dried lumber"--lumber that has been kiln dried for any length of time. The term applies to lumber dried to "shipping dry," as defined previously, as well as to stock dried to a final moisture content of 8 to 12 percent. Specifications covering kiln-dried lumber intended for immediate processing into a finished product should state the average moisture content, tolerance of individual pieces above and below the average, and moisture distribution between surface and center.

5.5 Moisture Content Determination

Two methods of determining the moisture content of wood are recognized: (1) Drying of a sample in an oven, and (2) using an electric moisture meter. They are not interchangeable but complement one another, since each has a distinct field of usefulness not covered by the other. Since the moisture content will vary between pieces in a given log or shipment, with either method a number of tests must be made to obtain an average. Intelligent selection of test pieces and a suitable number of samples to represent the total lot will minimize error.

5.6 Oven-dry method.--The moisture content of a test section of wood can be determined accurately by the oven-dry method, regardless of original moisture content, moisture distribution, size, species, density, or temperature of the wood being tested. On the other hand, this method necessitates cutting into and wasting part of the original board or plank and requires 24 hours or more. The moisture content of wood is determined by the oven-dry method as follows:

(1) Select a representative sample. A good sample from a pallet board is a cross section 1 inch long, taken about 1 foot from the end of the board.

(2) Immediately after sawing the sample, remove all loose splinters from it and accurately weigh it.

(3) Put the sample in an oven maintained at a temperature of 212° to 221° F. (100° to 105° C.) and dry until constant weight is attained.

(4) Reweigh the sample to obtain the oven-dry weight.

(5) Divide the loss in weight by the oven-dry weight and multiply the result by 100 to get the percentage of moisture in the original sample. Thus,

$$\text{Percentage of moisture} = \frac{(W - D)}{D} \, 100$$

where $\underline{W}$ is the original weight as found under (2), and $\underline{D}$ is the oven-dry weight as found under (4).

<u>5.7 Electric moisture meters.</u>--Electric moisture meters give an instantaneous moisture content reading, based on the effect of moisture on the electrical resistance or capacity of wood. The values are affected by a number of factors, such as density, species, temperature, moisture distribution, and thickness of material. The presence of glue or paint may affect the accuracy. Many moisture meters are limited to readings covering a moisture-content range between 7 and 25 percent.

Moisture meters will not satisfactorily serve in place of kiln samples used in dry kilns for the guidance of kiln operators. These instruments are of value, however, for the control of moisture content of lumber being processed, or purchased under moisture content specifications, since they give instantaneous readings and are sufficiently accurate for this purpose. Since such lumber is generally of a single species, the necessary corrections can be made for species and for temperature. Occasionally, check readings should be made on lumber of the same shipment and species, preferably on the same test section, whose moisture content has been determined by the oven-dry method.

The moisture-meter readings may not always agree absolutely with the oven-dry determination, but when significant differences occur, the results of the oven-dry tests should take precedence over the meter readings.

The electrical-resistance type of meter generally has a range of measurement of 7 to 25 percent moisture content, although some meters have special scales extending to about 60 percent. Measurements made within the higher range are not, however, so accurate as those made at from 7 to 25 percent. Most measurements needed are between 7 and 25 percent, and the higher range is used only in special instances.

Measurements of electrical resistance with a portable meter are very difficult to make at moisture content values below 7 percent because of the high electrical resistance of dry wood.

Instruments that measure the electrical capacity of wood may also be used for determining variations in moisture content. In this instance, a high-frequency electric field is created by the instrument adjacent to the electrode. Materials introduced into this electrical field absorb energy and affect the flow of current in the circuit. This change is shown by a meter that may be calibrated for a single species or have an arbitrary scale that can be converted into moisture content readings from tables supplied by the manufacturer. Variations in the density of the wood affect the accuracy of the capacity-type instrument, so that the instrument should not be used indiscriminately on species for which it is not calibrated.

The following conditions should be observed in making moisture content tests electrically:

(1) Follow the written instructions of the manufacturer of the moisture meter.

(2) Apply corrections for species, temperature, or density when necessary.

(3) Make measurements at several points on the faces of the boards.

(4) Do not make measurements on the end of lumber.

(5) Do not assume moisture content values when calibrations have not been made.

(6) Drive needle points full depth and with the current flow parallel to the grain.

(7) Do not use plate electrodes, such as on capacity-type meters, on rough lumber.

(8) Do not make measurements on lumber that has been subjected to surface wetting, such as rain or fog.

(9) Avoid measurements above 100° F. or below 30° F., which are not recommended because satisfactory temperature-correction data is not available.

(10) If the needle points cause splitting of veneers, disregard the readings.

(11) Regard moisture content measurements with needle electrodes on plywood as approximate, since glue lines containing electrolytes are likely to show moisture-content values that are too high.

(12) If moisture meters are to be used on lumber thicker than 1 inch, drive the contact points to a depth equal to one-fifth of the lumber thickness.

(13) If a moisture meter does not function properly, return it to the manufacturer for recalibration.

SECTION VI

6. Limitation of Defects in Pallet Lumber

6.1 Knots

A knot is the base of a limb embedded in the tree trunk. Normally a knot starts at the pith and increases in diameter from the pith outward as long as the limb is alive.

When the limb is alive, its fibers interlace with those of the tree trunk, producing an intergrown knot (Fig. 63). Many of the lower limbs die after a time, however, as a result of shading or other causes, but they may not break off for many years thereafter. After the death of a limb, the wood formed in the tree trunk makes no further connection with it but grows around it, producing an encased knot, which may be either loose, so that it will drop out, or tight, so that it is held in position when the trunk is sawed into lumber (Fig. 64). When lumber dries, the knots shrink more than the surrounding wood and may check or loosen. Eventually, the dead limb breaks off, the stub heals over, and the distortion of grain in successive growth layers becomes less and less with increasing diameter of the trunk, until finally clear wood with normal grain is produced in the area covering the knot.

When a knot is cut through transversely, a round knot results, when cut obliquely an oval knot results, when cut lengthwise a spike knot results (Figs. 63 and 64). A sound, tight knot is solid across its face, fully as hard as the surrounding wood, shows no signs of decay, and is so fixed by growth or position that it will firmly retain its place in the piece.

Knots are objectionable on account of the distortion and, in encased knots, the discontinuity of the grain that they produce, thereby weakening the wood, causing irregular shrinkage, and making machining more difficult. Loose knots are likely to drop out. In resinous species pitch often exudes more freely from knots than from the clear wood, and in all species knots usually are considered as marring the appearance of the lumber unless painted.

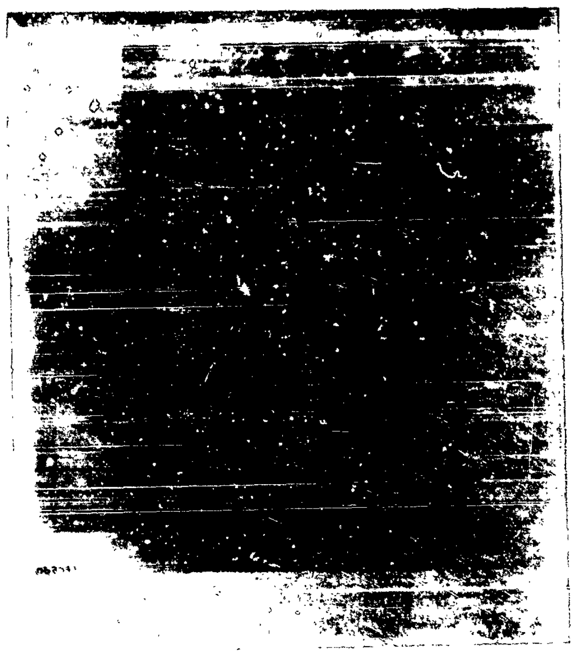


Fig. 63. - Intergrown round knots in yellow pine. (M6894F)

Fig. 64. - Left: An encased knot in hemlock. Right: A spike knot intergrown for most of its length in southern yellow pine. (M6893F)

Knots in pallet lumber are limited by their average diameter, as shown in Fig. 65.

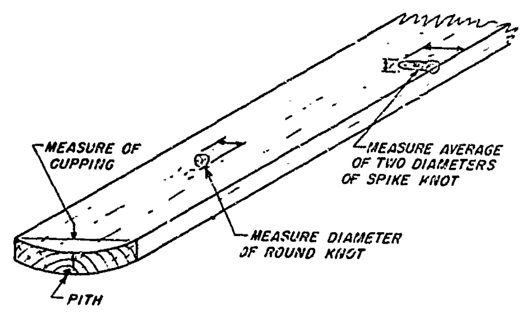


Fig. 65. - Board showing pith and methods of measuring cup and measuring round or spike knots. (M90319F)

6.2 Checks, Splits, and Shakes

A check is a longitudinal crack in wood, generally in the radial direction, or across the annual rings (Fig. 66). Checks usually result from shrinkage in seasoning. Thick lumber checks more severely than thin lumber. A split is a longitudinal crack that extends through the full thickness of a board. It often takes a radial direction and may be called a through check. Checks or splits in pallet lumber may be limited in length, which is measured as indicated in Fig. 66.

A shake is a longitudinal crack in wood between two annual rings (Fig. 66). Shakes originate in green timber but may be extended in seasoning. They indicate a weakness of bond between annual rings that extends lengthwise beyond the visible opening. For this reason shakes in pallet lumber should be limited by width as well as length (Fig. 66).

Figure 67 shows photographic views of checks and shakes in boards.

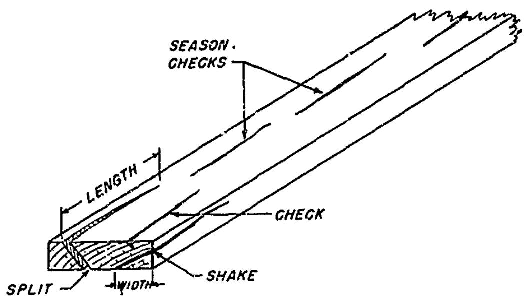
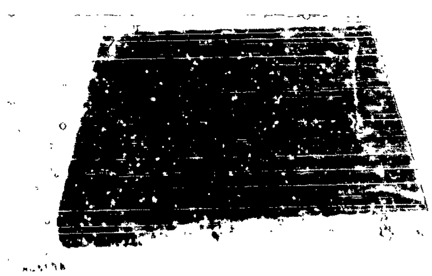
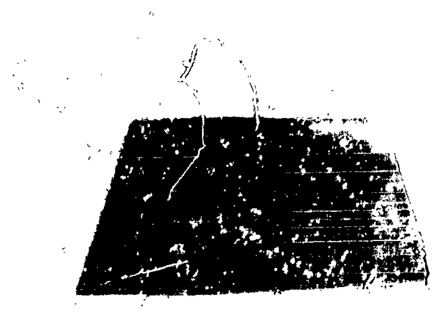


Fig. 66. - Board showing shake, split, and season checks. (M90317F)

Fig. 67. - Above: Checks in a flat-grained board. (M6889F)

Below: Shake in a flat-grained board. (M6890F)





6.3 Cross Grain

In cross-grained wood the fibers are not parallel to the length of the board. The principal types of cross grain are diagonal grain and spiral grain.

Diagonal grain results from sawing a board at an angle other than parallel with the bark. It is easily detected by noting the slope of the annual rings on an edge-grain or radial surface.

Spiral grain is caused by the fibers growing spirally around the trunk of a tree instead of in a vertical course (Fig. 68). In lumber it is not always apparent to the eye, but can often be detected by the direction of surface checks on a flat-grained (tangential) surface (Fig. 67). The direction followed by a split in the radial plane will show the slope of spiral grain.

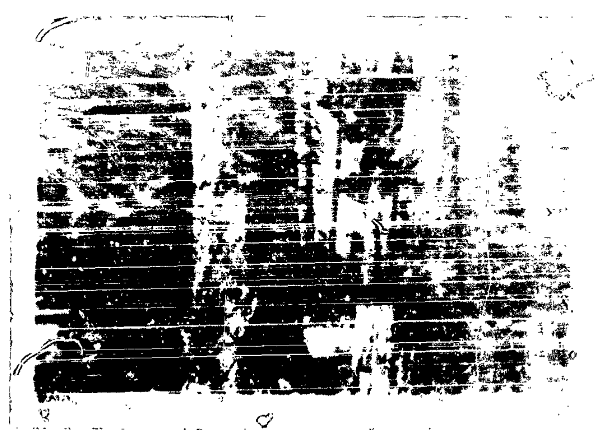


Fig. 68. - Spiral-grained and straight-grained forest trees. (M6918F)

Cross grain is usually measured as the number of inches of length in which a deviation of 1 inch from parallel occurs (Fig. 69). Small local deviations, as around knots, are disregarded. Cross grain is not usually a serious defect in pallet lumber, but boards with slope of grain steeper than 1 in 5 are greatly weakened and are likely not to stay in place well with seasoning.

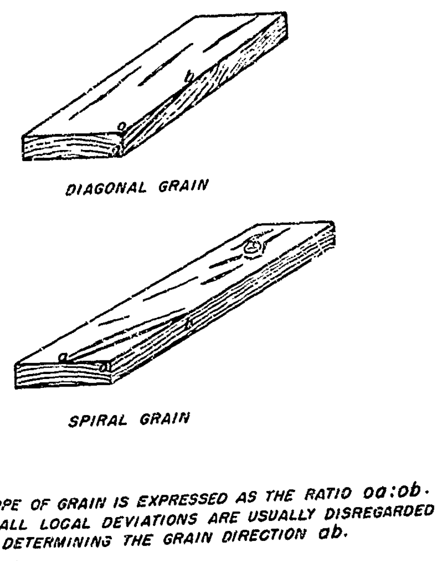


Fig. 69. - Measurement of diagonal grain and spiral grain.
(M92180F)

6.4 Pockets and Streaks

Pitch pockets are lens-shaped openings within annual rings, usually longer than they are wide. As a rule, they contain more or less free resin and, occasionally, bark. They may be from less than an inch to several inches in length. Pitch pockets normally occur only in certain conifers, namely, pine, Douglas-fir, spruce, tamarack, and larch. They are most common in southern yellow pine and Douglas-fir and least common in redwood. They are objectionable because they may weaken small members and resin may exude from them, especially when the wood becomes warm. Figure 70 shows how a pitch pocket may appear in the end and on the flat surface of a board.

A bark pocket is a patch of bark partially or wholly enclosed in the wood. There is usually some slight separation, or at least a lack of cohesion, involved that has a definite weakening effect. In appearance, bark pockets resemble pitch pockets more closely than any other defect but they are usually smaller and do not contain resin.

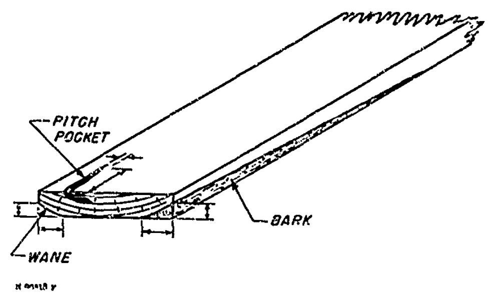


Fig. 70. - Board with pitch pocket, wane, and bark. (M90318F)

Pitch streaks are well-defined infiltrations of resin in the fibers in the form of streaks, usually extending a greater distance along than across the grain (Fig. 71). They normally occur only in pine, Douglas-fir, spruce, tamarack, and larch.

Mineral streaks are dark brown or black streaks, frequently with a green tinge, and often contain mineral matter in sufficient quantities to dull sharp-edged tools. They vary in length from less than an inch to a foot or more along the grain and at their widest portion may extend 1/8 inch to 1 inch or more across the grain (Fig. 71). Their limits may be sharply defined, or they may fade out gradually into the surrounding wood. Mineral streaks are frequently infected by fungus, and they check more easily in seasoning than normal wood. Mineral streaks are common in maple, hickory, basswood, yellow-poplar, and yellow birch, and are occasionally found in other hardwoods. Evidently they are often, if not always, due to some injury that the living tree received, such as bird pecks, mechanical abrasion, or tappings for maple sugar. They have little effect on strength or other mechanical properties, and are not considered objectionable in pallet lumber.

Fig. 71. - Above: Pitch streak. Below: Mineral streak.
(M6895F)

6.5 Stain and Decay

Many stains and all forms of decay or rot are caused by fungi that grow on and in wood. Fungi are primitive plants made up of fine threads invisible to the eye unless massed or matted together. Fruiting bodies of these fungi may appear on the surface of the wood. The fruiting bodies of the staining fungi are always small. Those of decay fungi may be very large, and take such forms as toadstools, conks, and brackets. Since they are not formed until the fungi have developed vigorously inside the wood, their presence indicates serious infection.

Lumber with a moisture content of less than 20 percent will not stain or decay.

The most common stain is the blue stain that occurs in the sapwood of many species of wood and is often known as sap stain. The sapwood is mottled or streaked with a bluish or grayish stain (Fig. 72); in advanced stages the entire sapwood becomes dark blue-gray or almost black. A stain of this type ordinarily does not have a serious effect on strength and is not considered objectionable in pallet lumber. Its presence, however, indicates exposure to conditions that are also favorable to the development of decay, and stained pieces should be carefully examined for decay.

Fig. 72. - Planed sapwood board of southern yellow pine showing dark streaks and irregular zones of blue stain. (M48578F)

Incipient decay usually appears as a discoloration, often in rather irregular streaks or elongated areas having a reddish or brownish tinge. The streaks extend lengthwise of a board but are not limited to certain annual rings as is the case with most normal color variations in wood. Decay in this stage has only moderate effects on those properties important in pallet lumber, and minor amounts may be admitted.

More advanced decay or rot results in a distinct brown color, a soft or brittle texture, a dry or "dead" appearance, and pronounced cross-cracking. Some types of decay produce discolorations in the wood known as zone lines. These are very narrow black, orange, or yellow lines of various lengths that tend to run somewhat in the direction of the grain of the wood. They are often most prevalent at or near the border of the most conspicuously discolored areas. Sometimes they border areas only slightly discolored, but their presence is certain evidence of decay. Figure 73 shows advanced decay in wood and prominent zone lines. In some instances, as with the white pocket in Douglas-fir and other species, many small white specks or pockets appear (Fig. 74).

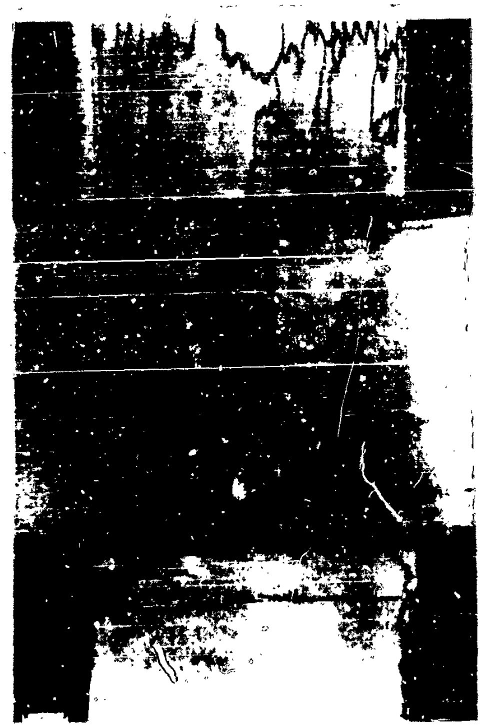


Fig. 73. - Advanced decay in wood, showing prominent zone lines. (M54327F)

Decay in the advanced stage seriously reduces the strength and toughness of wood and is generally excluded from pallet lumber. Minor amounts of white pocket (Fig. 74) may be allowed where specifications so permit. Small amounts of decay in knots (unsound knots) may be allowed if specifications permit and if the decay does not extend to adjacent areas outside the knot.

Fig. 74. - Pallet boards of Douglas-fir containing white pocket decay in comparatively light degree. (M86765F)

6.6 Manufacturing Defects

Under-size or off-size lumber may result from errors in sawing. Specifications or accompanying drawings for pallets usually indicate permissible limits on size.

Wane is the presence of bark along one or both edges of boards sawed from the outer portion of the tree trunk (Fig. 70). It is limited in terms of the proportion of thickness or width occupied (Fig. 70).

Lumber may be surfaced on one side (S1S), two sides (S2S), one edge (S1E), two edges (S2E), four sides (S4S), or some combination thereof. Some areas, where dimensions are scant, may not surface fully smooth. These areas are known as skips and may be defined and limited by area, depth, or both. A slight skip does not have measurable depth; a shallow skip is one that the planer knife failed to touch by not more than 1/32 inch and a deep skip, by not more than 1/16 inch. The term " hit and miss" describes a series of surfaced areas with skips not more than 1/16 inch deep between them.

Where areas of irregular grain occur, a part of the wood may be torn out below the general dressed surface. Torn grain up to 1/32 inch deep is classed as slight, up to 1/16 inch as medium, and up to 1/8 inch as heavy. Torn grain may also be limited to a proportional part of the face area of a board.

Lumber may become warped during seasoning or kiln drying. Figure 75 shows the kinds of warp that may occur either separately or in combination. Crook is deviation edgewise from a straight line from end to end of a piece. Bow is deviation flatwise from a straight line from end to end. Cup is a curve in a piece across the grain or width of a piece; its measurement is indicated in Fig. 75 and also in Fig. 65. Slight cup measures up to 1/4 inch, medium cup up to 3/8 inch, and deep cup up to 1/2 inch, based on a board 12 inches wide. Cup in a 6-inch board measures half as much or in like proportion for other widths. Twist is a distortion caused by the turning of the edges of a board so that the four corners of any face are no longer in the same plane. Bow or twist in pallet deck boards can usually be straightened by nailing, but cupped boards may split when the two edges are nailed.

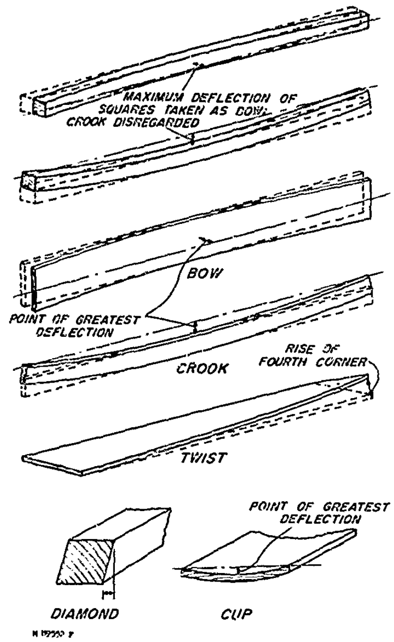


Fig. 75. - Various kinds of warp in boards. (M89552F)

Table 1.--Weights of woods used in pallets

Species	Weight per cubic foot: Green	Weight per cubic foot: Air-dry (12 percent moisture content)
	Lb.	Lb.
Ash, commercial white[1]	48	41
Baldcypress	51	32
Beech	54	45
Birch[2]	57	44
Douglas-fir (coast region)	38	34
Elm, American	54	35
Elm, rock	53	44
Fir, commercial white[3]	46	27
Hackberry	50	37
Hemlock, eastern	50	28
Hemlock, western	41	29
Hickory, pecan[4]	62	45
Hickory, true[5]	63	51
Larch, western	48	36
Maple, red	50	38
Maple, sugar	56	44
Oak, red[6]	64	44
Oak, white[7]	63	47
Pine, eastern (northern) white	36	25
Pine, red (Norway)	42	34
Pine, ponderosa	45	28
Pine, southern yellow:		
Loblolly	53	36
Longleaf	55	41
Shortleaf	52	36
Pine, sugar	52	25

(Sheet 1 of 2)

Table 1.--Weights of woods used in pallets (Cont'd)

	Lb.	Lb.
Spruce, eastern[8]	34	28
Spruce, Sitka	33	28
Sweetgum (Red gum)	50	34
Sycamore	52	34
Tupelo	56	35

[1]Average of Biltmore ash, blue ash, green ash, and white ash.

[2]Average of sweet birch and yellow birch.

[3]Average of grand fir and white fir.

[4]Average of bitternut hickory, nutmeg hickory, water hickory, and pecan.

[5]Average of mockernut hickory, pignut hickory, shagbark hickory, and shellbark hickory.

[6]Average of black oak, laurel oak, northern red oak, pin oak, scarlet oak, southern red oak, swamp red oak, water oak, and willow oak.

[7]Average of bur oak, chestnut oak, post oak, swamp chestnut oak, swamp white oak, and white oak.

[8]Average of black spruce, red spruce, and white spruce.

(Sheet 2 of 2)

Table 2.--Relative humidity at different seasons in various parts of the United States[1]

City	Mean relative humidity[1]			
	Winter	Spring	Summer	Autumn
	Percent	Percent	Percent	Percent
New York, N. Y.	73	70	74	75
Cleveland, Ohio	77	72	70	74
Spokane, Wash.	82	61	47	67
Seattle, Wash.	83	73	69	81
Phoenix, Ariz.	47	32	32	41
San Diego, Calif.	74	78	81	78
San Francisco, Calif.	79	79	84	80
Denver, Colo.	54	51	49	46
Washington, D. C.	72	69	75	76
El Paso, Tex.	45	27	41	46
Galveston, Tex.	84	82	79	78
Jacksonville, Fla.	80	74	80	83

[1]The relative humidity values given are based on daytime readings made by U.S. Weather Bureau and are not the mean average humidity for 24-hour periods. The relative humidity during the night is usually much higher than during the day, and the equilibrium moisture content will follow the mean average humidity for the 24-hour period.

Table 3.--Approximate moisture content of thoroughly air-dry 1-inch lumber by months for different regions

Forest Region[1]	Moisture content of air-dry lumber, in percent											
	January	February	March	April	May	June	July	August	September	October	November	December
California Pine	20	18	16	14	12	10	9	9	10	12	16	18
Redwood	24	25	22	20	18	16	15	15	16	17	19	21
Inland Empire[2]	20	20	18	15	14	14	12-1/2	13	14	15	20	20
Oregon and Washington	26	24	22	18	16	15	12	13	15	16	22	26
Southern Pine	20	......	.....	13	....	....	14	14	14	16	17	20

[1] In the arid Southwest during the driest portion of the year, air-dry lumber dries down to between 5 and 10 percent moisture content.

[2] Northwestern Montana, Idaho north of the Salmon River, Washington east of the Cascade Mountains, and the Northeastern tip of Oregon.

Table 4.--Range in average shrinkage of a number of native species of wood

Direction of shrinkage	From green to oven-dry condition	From green to air-dry condition (12 to 15 percent moisture content)
	Percent of green dimension	Percent of green dimension
Tangential	4.3 - 14.0	2.1 - 7.0
Radial	2.0 - 8.5	1.0 - 4.2
Longitudinal	.1 - .2	.05 - .10
Volumetric	7.0 - 21.0	3.5 - 10.5