

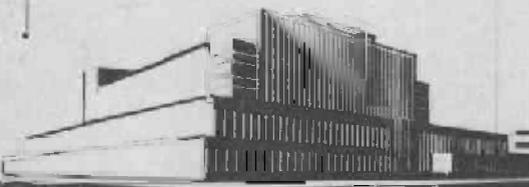
# THE ROLE OF INSPECTION IN WOOD LADDER SAFETY

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# THE ROLE OF INSPECTION IN WOOD LADDER SAFETY<sup>1</sup>

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## Introduction

There is more than a grain of truth to the old saying that "familiarity breeds contempt." Because wood ladders are such common utility devices for both indoor and outdoor use, they are prone to be taken too much for granted, both with respect to the need of inspection and maintenance, and the observance of safety requirements in use. As a result, we continue to have ladder accidents -- accidents that do not just happen, but are avoidable in that they too often result from carelessness, neglect, or lack of appreciation of the hazards. Many of us have among our acquaintances home owners who placed too much confidence in an inadequate repair of a broken side rail, or who have taken other liberties in the use of ladders, with the result that they have needlessly suffered permanent personal injury.

The price of safety is eternal vigilance. Safety begins with the responsibility of the manufacturer in furnishing a well manufactured ladder made of carefully inspected material and of proper design. To the user or owner falls the responsibility of choosing the right ladder for the job, of providing continued inspection and maintenance, and above all, of observing safety precautions in use. Dropping a ladder, using it as a scaffold plank, or storing it in contact with the ground may not only shorten its life, but actually make it unsafe for further use. It is the purpose of this paper to discuss the inspection of ladder material, as one link in the chain of ladder safety requirements.

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<sup>2</sup>Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

## Characteristics of Wood and Facility of Inspection

Among the characteristics of wood that have enabled it to serve so satisfactorily for ladders are high strength, relatively light weight, ease of fabrication, maintenance and repair, facility of inspection, and low electrical and thermal conductivity. Ladders are made of any of a number of species of wood; the parts usually are of single-piece material. Because of recent significant developments in glues and gluing techniques, we may in the future expect to see more wood ladders made of glued laminated construction. By this method structural members, such as side rails of any desired size, may be fabricated from smaller pieces, just as are laminated arches for buildings or railway bridge timbers; also, different species of wood may be combined, to afford even better strength-weight efficiency.

The basic principles of wood inspection are applicable to laminated material as well as to ladders of one-piece members. Inspection need not be difficult or complicated. Each piece of wood in reality is an open book, merely requiring a knowledge of its composition and structure and how to recognize and limit certain natural characteristics and defects to insure the selection of satisfactory stock. On the other hand, the importance of such selection should not be underestimated, nor should the possible use of special techniques that afford more efficient and thorough inspection be overlooked. As a background for proper inspection methods, let us examine the structure of wood and some of its characteristics more intimately.

### Structure of Wood in Relation to Inspection

#### Wood Formation

Wood is an organic material -- a renewable resource -- the product of the living tree. For the production of wood, nature invented chlorophyll, which, actuated by the energy of sunlight, manufactures sugar out of carbon dioxide gas and water. The green leaves, by the process of photosynthesis, break up the CO<sub>2</sub> molecule, giving back oxygen to the air. They combine carbon with water and other minerals conveyed from the root system to form sugar, starch, cellulose, and other food products. These new compounds of photosynthesis flow downward to the growing parts through the inner bark, and presumably also through the sapwood to form cells.

A tree thus grows by the formation of new cells -- myriads of new cells -- under the bark and at the tips of the branches and roots. The growing region just under the bark is known as the cambium. As the cambium cells divide they diversify, some developing on the inner side

to form wood elements, and others on the outer side to form bark elements. The cambium is hence the basic zone of tree growth. Year by year, growth thus consists of adding a new and complete layer or envelope over the entire tree structure, the thickness of the growth layer depending on the growth conditions, the species, and many other factors.

### Cell Structure and Composition

There are principally three kinds of cells, namely wood fibers, vessels or pores, and storage cells which are technically called parenchyma. The wood fibers, which are the most common cells in wood, are oriented longitudinally in the tree and give wood its great strength. They consist of essentially narrow tubes closed at both ends and in softwoods are about 1/7 inch long and about 1/100 as wide as they are long; in hardwoods the fibers are on the average much shorter. The length of the fibers, however, does not bear a definite relation to the strength of the wood. For example, the fibers of shagbark hickory, noted for its high strength and toughness, are much shorter than those of black tupelo, which is inferior to hickory in its mechanical properties. The bond between the fibers, regardless of their length, is exceedingly strong and does not constitute a principal source of weakness, as evidenced by the fact that the fibers of wood tested in tension do not commonly separate from one another but are torn. The vessels, present only in hardwoods, are shorter and wider than the fibers. They are open at the ends and thereby form the long tubes or pores through which the water absorbed by the roots is conducted to maintain the life processes of the trees. In the softwoods, the fibers conduct sap. The parenchyma cells in wood are short in length, somewhat rectangular in cross section, and closed at the ends. They serve as a medium for storage of food materials.

### Microstructure

The cell walls are made up of concentric layers -- a primary, a secondary, and sometimes a tertiary layer. The primary layer is the modified membrane of the original cell. The secondary layer is divided into a series of sleeves, varying in number from 8 to 12 (fig. 1). The layers of the cell wall may be dissected into long slender fibrils. The fibrils are arranged spirally, and are the smallest unit that becomes evident through any simple mechanical disintegration. The orientation of the fibrils, particularly in the secondary layer, affects the important properties of strength and shrinkage in wood. In typical wood fibers, such as are associated with good strength properties, the fibrils are spiraled at only small angles to the axis of the fiber. On the other hand, large fibril angles are associated with poor strength and with appreciable longitudinal shrinkage that causes serious warping. The submicroscopical structure of the fibrils is comprised of units of glucose molecules that make up the strands of cellulose, which are about two millionths of an inch in diameter.

From the standpoint of chemical composition, the wood fibers are composed of cellulose cemented to each other with a complex substance called lignin. Roughly, cellulose comprises about 60 percent of wood substance, lignin 28 percent, and sugars and extractives the remaining 12 percent.

## Growth Characteristics and Related Features

### Annual Rings

In climates where temperatures limit tree growth to the summer months, each year's growth increment is usually readily distinguishable and is called an annual ring. In tropical climates growth is more or less continuous, and concentric demarkations occur as a result of fluctuations in growth activity; such demarkations, however, should not be confused with the annual rings.

### Springwood and Summerwood

In many woods, cells formed in the spring, when tree growth is most active, are comparatively large and thin-walled, whereas those formed later in the year are smaller and relatively thick-walled. The early cells constitute the springwood and the later ones the summerwood; together they comprise one annual ring. Obviously, the thin-walled cells are weaker than the thick-walled cells, and hence summerwood is, in general, denser and stronger than springwood. In woods that exhibit a marked contrast in springwood and summerwood, such as Douglas-fir and southern yellow pine, the proportion of summerwood offers a visual basis for estimating density and strength (fig. 2).

### Sapwood and Heartwood

In the tree, certain wood elements function as living cells for a time, but eventually become inactive. As the tree gets older and bigger, more and more of the cells from the pith outward cease to function other than as mechanical support. This inner, and usually darker colored, portion of the tree is called the heartwood. The outer layers of growth, which contain the only living elements of the wood, are called sapwood. The sapwood is light in color and varies greatly in thickness among different species, among individual trees of the same species, and even among different portions of a tree.

There is a popular misconception that sapwood is stronger than heartwood, particularly in such woods as hickory. However, the change from sapwood to heartwood during the growth of the tree does not result in significant changes in strength, so that there should be no discrimination, with regard to the color of the wood, in the selection of

ladder stock. The density of the wood, regardless of whether sapwood or heartwood, is the best basis of selection for strength.

### Hardwoods and Softwoods

The terms "hardwood" and "softwood" are often confusing to those not familiar with the lumber industry. Instead of indicating the hardness or softness of wood, these terms are simply popular descriptive names in use for two great groups botanically known as angiosperms and gymnosperms, but more popularly as "trees with broad leaves" and as "conifers." Although the terms "hardwoods" and "softwoods" are the most generally accepted popular names for the two classes of trees, they are the most misleading. Oak, birch, and basswood are common "hardwood" species, while longleaf pine, spruce, and cypress are "softwoods." While it is true that many "hardwoods," such as oak, are really hard, others, such as basswood, are softer than many "softwoods" (conifers); in fact, balsa, one of the softest woods in the world, is a broad-leaved species, and falls in the so-called "hardwood" group (fig. 3).

### Density in Relation to Strength

Variability is common to all materials, but materials differ considerably in the amount of variation. The growing tree is subject to numerous changing influences that affect the wood produced, and it is not surprising that the clear wood of any species varies in density and strength properties. It should be noted in this connection that the density of wood substance itself, regardless of species, is practically constant, being about 1.53. It is thus obvious that the reason some species of wood are heavier than others, and that within a species some pieces are heavier than others, is because they contain more wood substance -- thicker cell walls and smaller cell spaces. Thus, since the denser pieces of wood contain the most wood substance, it is to be expected that the density is an index to the strength properties. For purposes involving high strength requirements it is therefore desirable that low-density pieces of a species be excluded in inspection (fig. 4).

### Moisture Content

Lumber as it comes from the saw contains a considerable amount of moisture that must be removed before the wood is suitable for the manufacture of ladders.

The moisture in green wood is in part held by the cell walls and in part within the cell cavities, much in the same manner as water is held in a container. As wood dries, the cell walls do not give off moisture until the adjacent cavities are emptied. The condition in

which the cell walls are fully saturated and the cell cavities emptied is known as the fiber saturation point. It varies from 25 to 35 per cent moisture content based on the oven-dry weight of the wood.

Increase in strength begins when the cell walls begin to lose moisture; that is, after the wood is dried to below the fiber saturation point. From this point on, most strength properties increase rapidly as drying progresses.

Shrinkage across the grain also results when wood dries below the fiber saturation point, and conversely, swelling occurs when dry or partially dry wood is soaked or when it takes on moisture from the air. Shrinking and swelling in the direction of the grain of normal wood is only a small fraction of 1 percent from the green to the oven-dry condition and is of little practical importance in most species of wood.

In the seasoning of wood, checks sometimes develop on the surface. The effect of checks is related mainly to the reduction of shearing strength and to appearance. Small surface checks are not serious from the strength standpoint.

#### Check List of Natural Characteristics

Inspection of ladder material involves recognition and identification of a number of natural characteristics and defects. Some of these are very familiar and require but little if any comment; some are prohibited entirely, while others are limited in accordance with their effect on strength. A complete list of the various items and features to be considered in the inspection of ladder material, together with a definition of each, is as follows:

##### A. Characteristics Excluded in Ladders and Ladder Material

1. Decay.--Disintegration of wood substance due to action of wood-destroying fungi. Also known as rot and rot.
2. Wane.--Bark, or the lack of wood from any cause, on the corner of a piece.
3. Honeycombing.--Checks, often not visible at the surface, that occur in the interior of a piece, usually along the wood rays.
4. Insect damage.--Insect damage consists of holes made by borers, generally classified as pin holes, grub holes, and powder-post beetle holes.

5. Shake.--A separation along the grain, the greater part of which occurs between the rings of annual growth.
6. Compression wood.--An abnormal growth occurring in softwoods and is characterized by relatively wide annual rings, usually eccentric, and a comparatively large proportion of summerwood which merges into the springwood without exhibiting a marked contrast in color.
7. Compression failure.--A deformation of the fibers due to excessive compression along the grain. This deformation takes the form of buckling of the fibers.

#### B. Characteristics Limited by Visual Inspection

1. Density.--The mass of a body per unit volume. It is an index of the amount of wood substance present in a piece, and hence an index of strength.
2. Check.--A lengthwise separation of the wood, most of which occurs across the annual growth layers.
3. Pitch pocket.--A well-defined opening between rings of annual growth, which usually contains, or has contained, more or less pitch, either solid or liquid. Bark may also be present in the pocket.
4. Knot.--A branch or limb, embedded in the tree and cut through in the process of lumber manufacture; classified according to size, quality, and occurrence. For ladders, the size of the knot is determined as the average diameter on the surface of the piece.
5. Cross grain (Slope of grain).--A deviation in direction of the wood fibers from a line parallel to the sides of the piece. Cross grain may be diagonal, or spiral, or both. Cross grain is limited in terms of its slope, which is established as the distance along the sides of the piece in which a deviation of grain of 1 inch occurs. For example, cross grain with a slope of 1 in 12 means that in a distance of 12 inches, the grain deviates 1 inch from the edge of the piece. The slope of grain is measured over a distance that will assure the determination of the general slope of the grain not influenced by short local deviations.

## Visual Inspection of Natural Characteristics

Wood defects are defined by the American Standard Safety Code for Portable Wood Ladders as irregularities in wood that lower the durability, strength, and utility of ladders. The restrictions on such natural characteristics are in accord with their effects on the strength properties. Inspection of ladders and ladder material is made by visual examination, facilitated in some instances by special tools or techniques. Some characteristics, such as knots and checks, can be readily seen and evaluated in accordance with the limits of sizes and locations specified for ladder stock. On the other hand, such defects as cross grain require more careful inspection, but their presence is indicated by certain visible characteristics of the wood when it is examined under suitable conditions.

The complete tabulation of characteristics may look formidable, but in actual practice it is on only a few features that especially close and critical inspection is required. Manufacturing control includes as routine the meeting of requirements for dimensions, seasoning, and quality of workmanship; the exclusion of material containing wane, shakes, insect damage, and decay; and inspection with respect to limitation in size of permissible characteristics. Actually, the lumber grades under which ladder stock is purchased from the lumber producer limit or exclude many of these features.

The only characteristics requiring special inspection are compression wood, compression failures, and cross grain. However, in addition to a detailed discussion of procedures and techniques on these, it appears desirable to mention briefly decay, density, and knots.

### Decay

Decay in wood is produced by plant organisms known as fungi, which live on wood substance. Wood-destroying fungi require favorable conditions for their development with respect to moisture, temperature, and air; hence if any one of these requirements is eliminated, the growth of fungi will be inhibited. Wood that is kept dry will not decay.

Different wood-destroying fungi affect wood differently. However, the presence of incipient or advanced decay can usually be readily detected by the presence of discoloration or by an easily recognized pitting of the wood. No method is known for estimating from the appearance of decayed wood the amount of reduction in strength. Consequently, in ladders where strength is an important consideration, any ladder material containing either incipient or advanced decay is excluded.

Molds and staining fungi are usually not critical with respect to their effect on strength as compared with decay organisms. However, conditions

that favor the development of molds and stains are also ideal for the growth of wood-destroying fungi. Since decay even in early stages may greatly reduce some strength properties, stained lumber should generally be excluded for ladder use.

### Density

Low-density wood is defined as that which is exceptionally light in weight for its species. As mentioned earlier, pieces of lumber with appreciably less than average density, or specific gravity, are inferior in strength properties to denser pieces of the same species. Therefore, ladder specifications require that exceptionally low-density wood be excluded.

In the ordinary handling of lumber, low-density pieces frequently are detected by their lighter weight as compared with other pieces of the same size and moisture content. Thus, unusually lightweight ladder rungs, for example, sometimes can be detected during their preparation or inspection in the finished condition for other defects. Within practical size and moisture content limitations for such finished pieces, it is considered reasonable to establish minimum weights which can be obtained on rapidly weighing scales, particularly for the pieces that have the general appearance and feel of exceptionally lightweight material.

Rate of growth, though not an infallible guide, is nevertheless helpful in inspection for density. It is generally recognized in softwood species that exceptionally low density is associated with extremely wide annual rings, particularly if the summerwood shows a thin line at the outer boundary of the rings. In general, specific gravity of the wood is directly related to the proportion of summerwood and, thereby, serves a basis for detecting low density in softwood species. On the other hand, rapid growth in hardwoods, as indicated by wide annual rings, is most frequently associated with denser material. As a general guide, material of moderate growth rate in the softwoods is to be preferred from the strength standpoint, with more critical inspection for density of exceptionally fast or exceptionally slow growth material. In the hardwoods, on the other hand, material of medium and rapid growth rate is generally indicative of higher density, and exceptionally slow growth material should be most closely inspected for density (fig. 5).

### Knots

Knots are seldom a serious problem in ladder inspection. In ladder stock, any knots present are readily visible. The effect of knots on strength is well established, and they can be easily limited in accordance with specification requirements. Knots are most serious when

located at the center of the length of side rails or steps, and when near the upper or lower edges of the rail. Knots are limited on the basis of their average diameter as measured on the face.

The holes for ladder rungs, being at the center of the side rails, do not greatly affect the strength. A knot of the same diameter similarly placed would be even less detrimental, because of the continuity of the grain around it. The maximum size of knots permitted in side rails in the present ASA safety code for ladder construction is 1/2 inch as compared to the 7/8-inch rung tenon diameter, so it is apparent that the present limitations are conservative. Knots seldom if ever have been found to contribute to ladder failures.

### Cross Grain

Cross grain, or lack of parallelism between the fiber direction of the wood and the axis of the piece, may seriously detract from the strength of a ladder part if the slope of the cross grain is steep (fig. 6).

Since strength reductions resulting from excessively steep cross grain can be so serious, extreme care in determining grain slope is important. While both diagonal and spiral grain have the effects shown in figure 6, spiral grain is generally much more difficult to evaluate and thus is the more likely to escape detection and endanger the safety of a ladder.

Specifications usually impose certain limitations, such as 1 in 12 or 1 in 15, on the general slope of grain, disregarding small local deviations. Where the local deviations of grain occupy but a small proportion of the cross section, their effect on strength may be small. In parts of small dimension, such as a step, however, the local deviation may extend entirely through the thickness of the part. In such a case, the part may be seriously weakened even though the cross grain extends over only a small portion of the length.

Because determination of slope of grain in lumber is complicated by positions of the annual rings with respect to the surface, it is necessary to recognize the several kinds of cross grain as well as the characteristics by which cross grain can be detected. Cross grain may be of three fundamentally different types, spiral grain, diagonal grain, and irregular grain. The latter comprises various types of wavy, interlocked, and curved grain. Spiral grain results from a curved or spiral rather than vertical arrangement of fibers in the tree (fig. 7). Spiral grain refers to the direction of the fibers within the annual growth layers, and its true direction is evident only on a plain or flat-sawed surface. Interlocked grain is a special form of spiral grain, varying or reversing in slope between successive layers.

Diagonal grain is the deviation caused when the lumber is sawed at an angle rather than parallel to the growth layers, either because of crooked logs, carelessness in manufacture, or the practice of sawing parallel to the pith rather than parallel to the bark in logs of large taper. Diagonal grain shows on the edge-grain or quarter-sawed face of a board.

Irregular grain applies to more or less irregular wood structure, usually accompanying knots or occasionally a series of waves in otherwise clear wood. These are usually localized deviations of grain as compared to the possible prevalence of spiral and diagonal grain throughout the piece.

The simplest method for determining the presence of cross grain of any form is by splitting a piece 4 inches or longer, both tangentially and radially. If cross grain is present, the splits will not be parallel to the edges of the piece. This method, of course, cannot be employed in inspecting finished products, such as ladders.

Fortunately, the presence of cross grain in ladder stock can be detected by certain characteristics through careful visual examination of the piece. The directions of spiral grain on tangential surfaces frequently are indicated by positions of lines of pores, resin ducts, pitch pockets, and seasoning checks with respect to the edges of a piece. Scribe marks (fig. 8) and the application of ink or dyes to smooth surfaces also indicate the slopes of spiral grain, since both the scratches and dyes tend to follow the longitudinal direction of the fibers of the wood. Spiral grain frequently is indicated by chipped radial surfaces which have been planed against the grain; in fact, chipped surfaces always are reason to suspect cross grain in a piece of lumber (fig. 9).

Slopes of diagonal grain usually are seen readily by the position of the annual rings with respect to the edges of radial or quartersawed surfaces of a piece of lumber. Diagonal grain is indicated also by frequent intersection of the annual rings with tangential surfaces of lumber. In woods in which the annual rings are not distinct, diagonal grain is indicated by lines of pores and mineral streaks or other differences in color which follow the general fiber directions in the wood. In the porous hardwoods, the so-called "short grain" is reason to suspect cross grain; that is, short pores, one-eighth to one-fifth of an inch long in contrast to two-thirds of an inch or more, are indications that the surface was cut across the fiber direction rather than approximately parallel to it.

The problems involved in the detection of cross grain are extremely complicated and therefore require good understanding of the visible characteristics that indicate cross grain. An inspector should look for the several indications of cross grain on both the surfaces and edges of the pieces which are described above. The use of scribes

and even splitting tests may be necessary in order to determine the steepness of slopes of grain which are indicated by the visible characteristics on the surfaces of ladder parts. Information on the characteristics and detection of cross grain is included in Forest Products Laboratory Report No. 1585, "Guides to Determining Slope of Grain in Lumber and Veneer," which is available without charge.

### Compression Failures

Less common than cross grain, but nevertheless as important, are compression failures. Compression failures comprise zones in which the fibers have been seriously damaged or buckled, so that strength is greatly impaired. They may be caused in the living tree by the bending that takes place in severe storms, or in logging when a tree is felled on uneven ground. Fortunately, the incidence of compression failures is not high, but regular inspection to detect them is necessary because of their hazard to safety.

Compression failures are evidenced by buckling of the fibers. Occasionally, the buckling is well defined and can be seen on surfaces of pieces without magnification; but more frequently, the compression failures are so small that special techniques are necessary to detect them. The readily visible compression failures shown in figure 10 were photographed at slight magnification with optimum conditions of lighting. The localized damage to the fiber walls is shown at a high magnification in figure 11, along with the brittle break at the upper edge of the microscopically thin section of wood.

It is possible, nevertheless, to detect the presence of the extremely small compression failures even though they are not visible with optimum lighting on planed surfaces of lumber. The presence of compression failures cause fiber breakage on sawn end-grain surfaces of lumber (fig. 12). Examination to detect roughening of end-grain surfaces is hence an effective way of inspecting for compression failures.

The technical information on compression failures has led to recommendations for practical methods of detection in ladder rails. The methods include ordinary visual inspection of ladder rails on the end grain for the fiber breakage already described and on the sides and edges for visible compression failures which are greater than microscopical sizes. Incident lighting by a reflector spot bulb that is focused at an angle of about 20° to the surface has been found to facilitate detection of visible compression failures. Slight magnification, such as can be obtained with a reading glass, aids in the detection of the visible compression failures. Compression failures frequently are made more readily visible after clear lacquer, shellac, or varnish has been added to the surfaces. The application of non-swelling liquids also makes more readily visible the small, but not

microscopic, compression failures. However, since the most commonly available nonswelling liquids are somewhat toxic or inflammable, or both, such materials should be used only in areas of good ventilation and freedom from danger of being ignited.

Figure 13 shows a convenient arrangement of suitable lighting equipment and magnifier by which to detect the presence of visible compression failures on sides and edges of ladder rails and fiber breakage on the end-grain surfaces. The fiber breakage sometimes can be seen also at the ends of pieces of rough lumber or ends of stored ladder rails that have been cut to length.

### Compression Wood

Compression wood is an abnormal type of wood growth occurring in soft-wood species, principally on the under side of leaning trees (fig. 14). It is generally denser than normal wood, and usually distinguishable by very wide and eccentric annual rings, a lack of contrast between springwood and summerwood, and with summerwood yellow in color.

Structurally, the wood fibers that constitute compression wood differ from normal wood in that the fibrils are oriented at a larger angle with the length of the fiber. Normal wood exhibits very little longitudinal shrinkage in seasoning, but compression wood because of the greater fibril angle has a very significant longitudinal shrinkage. Hence, when present with normal wood, as is commonly the case, the presence of compression wood is manifested by the bowing of the piece due to this shrinkage differential, making the lumber unsuitable for critical uses such as ladders. Naturally, much of the lumber containing compression wood is eliminated early in the inspection process because of warping, and compression wood is limited in specifications for lumber grades. Compression wood is less stiff than normal wood, and is less satisfactory and reliable where strength is important. The compression wood fibers differ in degrees of abnormality, from the borderline forms that differ only slightly to the extremely abnormal forms. Fortunately, the most extreme forms, which are the most essential to eliminate, are readily detected by ordinary visual inspection. The greater proportion of summerwood over springwood facilitates detection of compression wood.

A simple method has been developed as a guide in the detection of compression wood without the use of microscopical examinations which furnish positive evidence on the presence or absence of the abnormal structure of the fibers. Because of minute checks in the fiber walls of compression wood, thin cross sections of the abnormal summerwood are opaque while those of normal summerwood are translucent when held against a bright light (fig. 15). A box containing a bright light has been designed to facilitate examinations of 5/32-inch thick cross sections of softwood lumber in which compression wood is suspected (fig. 16).

## Safety Supervision and Maintenance of Ladders

Ladders are service equipment on which every effort should be made to exclude defects that could contribute to ladder failure and to personal injury. Because of the importance of recognizing and meeting the challenge of safety in ladder use, the owner should not overlook the possibility of checking the quality of the ladder or ladders purchased. To permit such inspection, ladders are sold unpainted; and they are usually left unpainted to facilitate subsequent periodical inspection. Many of the inspection techniques discussed can be used in the visual inspection and appraisal of finished ladders. Such inspection is to be highly recommended, because unfortunately some defects get into completed ladders, as evidenced by an analysis of ladder failures. The most common defects observed in ladder parts leading to failure have been cross grain and compression failures. By application of safety codes and other specification requirements, manufacturers seek to produce safe ladders. Nevertheless, some defects are still occasionally encountered, largely as the result of lack of understanding of the significance of cross grain and compression failures and failure to employ the most effective inspection methods.

It is, of course, obvious that, once a ladder is manufactured, there can be no subsequent change with respect to the natural characteristics present in the wood, such as knots and cross grain.

However, ladders should be inspected frequently to determine possible evidence of damage as a result of lack of reasonable care in handling, to determine whether repair is needed, or whether they have become otherwise unserviceable. Good maintenance practice requires that the joints between steps or rungs and side rails be kept tight, that hardware and fittings are securely attached, and that movable parts operate freely. Rope should be replaced when necessary, and metal bearings of locks, wheels, and pulleys should be lubricated. Attempts to repair broken side rails or rungs are to be discouraged. If a side rail is broken, either the ladder should be discarded, or a complete new side rail of proper size and quality should be installed.

### Painting Ladders

The question is often asked, should ladders and ladder equipment, including step ladders, single and extension ladders, scaffold planks, swing stages, and trestles, be painted. What are the advantages and disadvantages of painting?

It has been mentioned that new ladders, except certain specialty items, are sold in an unpainted or unfinished condition. In this condition, the ladder can readily be checked for cross grain, compression failures, and quality of wood. Many users prefer to leave the

ladders unpainted throughout their serviceable life to permit continued recurring inspections. This practice is safe in that there need be no deterioration of the wood with time or age if it is properly stored when not in use. For users who desire a finished ladder while retaining the natural features of the wood, a transparent finish such as varnish, shellac, or a clear preservative is recommended. Such a ladder can be inspected from time to time the same as an unfinished ladder. Some State safety codes require transparent finishes or that ladders be left unpainted for these reasons.

On the other hand, when adequate initial inspection has been made, some companies find it desirable to paint ladders and maintain them in a painted condition. Painting may increase serviceability and reduce splintering, as well as improve appearance. It is only to be recommended, however, after adequate initial inspection has been made by competent organizations that have thorough inspection and maintenance programs. Painting itself does not increase durability or resistance to decay.

#### Don't Test That Ladder

It may be noted that the wood ladder in this inspection procedure has not been given any test loading. There is no simple satisfactory method of proof testing wood for strength, and any test loading much beyond the design load may result in serious damage to the side rails. Sometimes a ladder is tested by supporting it horizontally on horses at the ends and having a man jump on it at the center.

Such a test method should never be used, because it subjects a ladder to more severe loads than it was ever intended or designed to carry and because, even if it does not fail, it may sustain injuries in the form of compression failures that may be the source of sudden failure and serious accident in future use. Hence, don't test that ladder, but rather give it a critical visual inspection to insure that it meets all needed requirements.

#### Strength and Design

Single or extension ladders are not designed to carry loads when stretched out full length horizontally over end supports. This is the function of scaffold ladders or scaffold planks. In ladder design, the strength is calculated on the assumption that the ladder will be used with the base moved out from the wall against which the upper end rests by a distance equal to one-fourth the length of the ladder. If the base is out farther, the loading condition is more severe than that for which the ladder was designed. If the base is too near the wall, the ladder becomes less safe because it is more unstable.

Wood ladders meeting the minimum requirements of the American Standard Safety Code for Portable Wood Ladders are designed to carry safely an assumed load of 200 pounds at the center of their length, when the load is at the center of the rungs midway between the two side rails, and when the foot of the ladder is moved out of the perpendicular by one-quarter of the length being used. These design conditions indicate the limitations that must be kept in mind in the use of a ladder.

It has been pointed out that the safety code for the correct construction and use of ladders is based on the minimum requirements to afford safety under average conditions of use. Sometimes, for heavy industrial uses where extra weight must be carried on ladders, or where there is continuous and extensive handling and hauling, it is desirable to use stronger ladders, such as may be obtained by employing rails of somewhat larger cross sections than those recommended for ordinary use. Such so-called heavy-duty ladders provide an extra margin of safety and may be important in reducing ladder accidents where circumstances indicate their need.

#### Storage of Ladders

Wood ladders, when not in use, should be stored under shelter and in a place where there is good ventilation. They should not be stored near radiators, stoves, steam pipes, or other places subjected to excessive heat or to dampness. Further, they should be supported so that the weight of the ladder is distributed, and sag will not occur. For example, if a long ladder is hung from two hooks near the end, considerable sag at the center will take place from the weight of the ladder. If so hung for an extended period the ladder may become permanently sagged. Likewise, ladders carried on vehicles should be adequately supported to avoid sag and fastened to minimize damage in transport.

#### Proper Use

Wood does not deteriorate with age, when protected from adverse exposure and decay. Hence, wood ladders properly used, cared for, and maintained will have long life and give continued service over many years.

Regardless of how strong or how perfect a ladder may be, it may still be a hazard if not properly used. Avoidable ladder accidents are still all too numerous. Some of the important safety practices that should be followed are the following:

Portable ladders should, where possible, be used at such a pitch that the horizontal distance from the top support to the foot of the ladder is one-quarter of the length of the ladder in use. Obviously, the ladder must be on a level footing and be so placed as to prevent slipping, or be lashed, or held in position.

Ladders should not be used in a horizontal position as platforms, runway, or scaffold, nor for any other purpose than that for which they were designed. To illustrate, the common household type stepladder should never be used for heavy maintenance work.

For other than short ladders, additional help is needed for safe handling, particularly under unfavorable conditions, such as uneven footing, the presence of ice or snow, or gusts of wind.

Ladders should be faced when ascending or descending them.

With the exception of special types, ladders are not designed to support more than one person, or to support heavy objects. Carrying heavy objects on a ladder is even more critical when the weight is mostly on one side, so as to be carried largely by one side rail. Failures, with resulting personal injury, have resulted from overloaded and misused ladders.

It is important also to make certain that the feet of the ladder are so placed as to avoid slipping. Special safety feet for ladders may be particularly helpful in avoiding accidents under certain conditions.

Someone has said that a little knowledge is a dangerous thing. With ladders, a lot of knowledge, mixed with care and discretion, means safety. It pays to be careful when personal safety is at stake.

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# DIAGRAM OF FIBER WALL

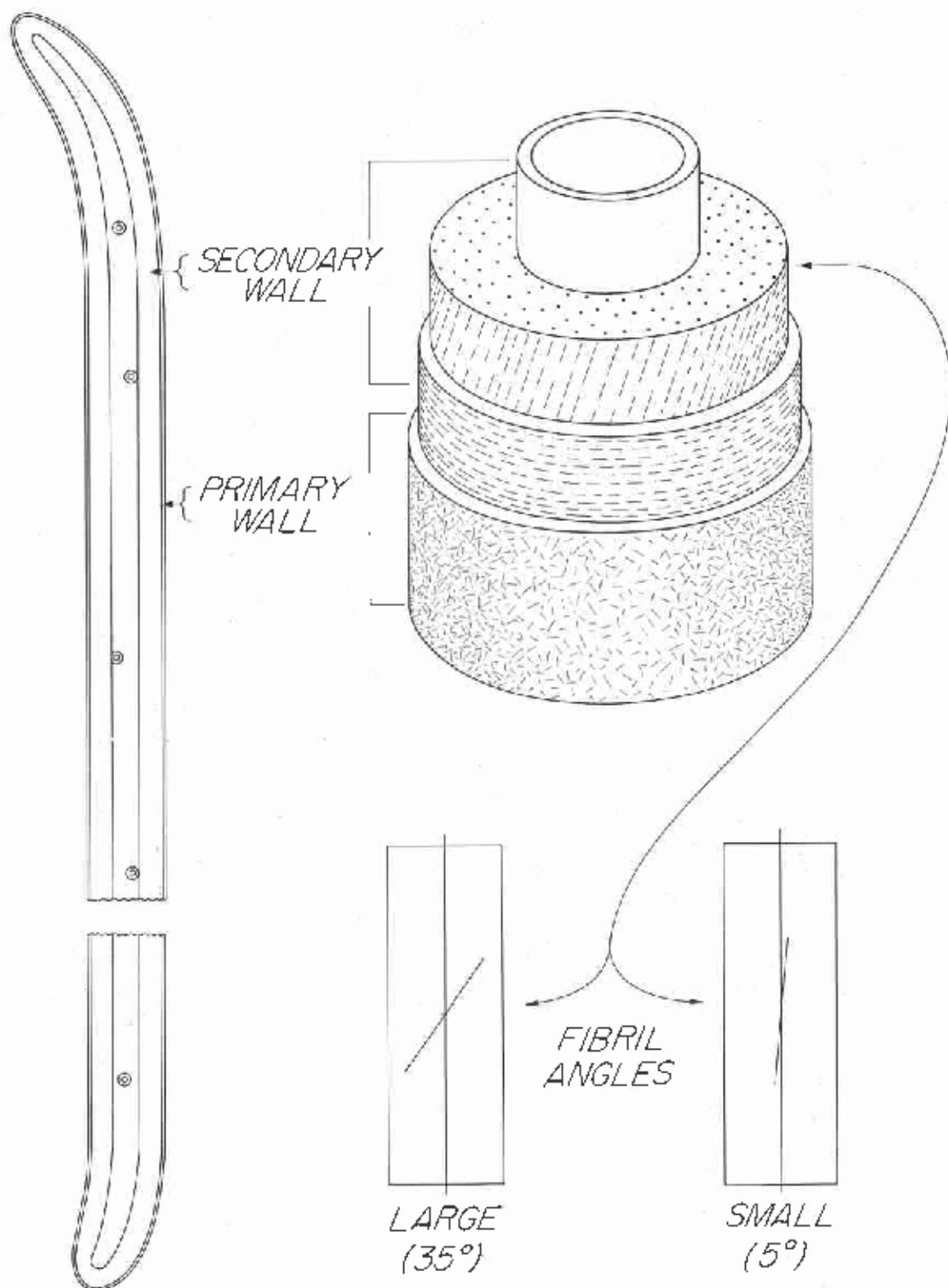


Figure 1.--Diagram of a typical wood fiber showing variations in fibril angles in the central of the secondary cell wall.

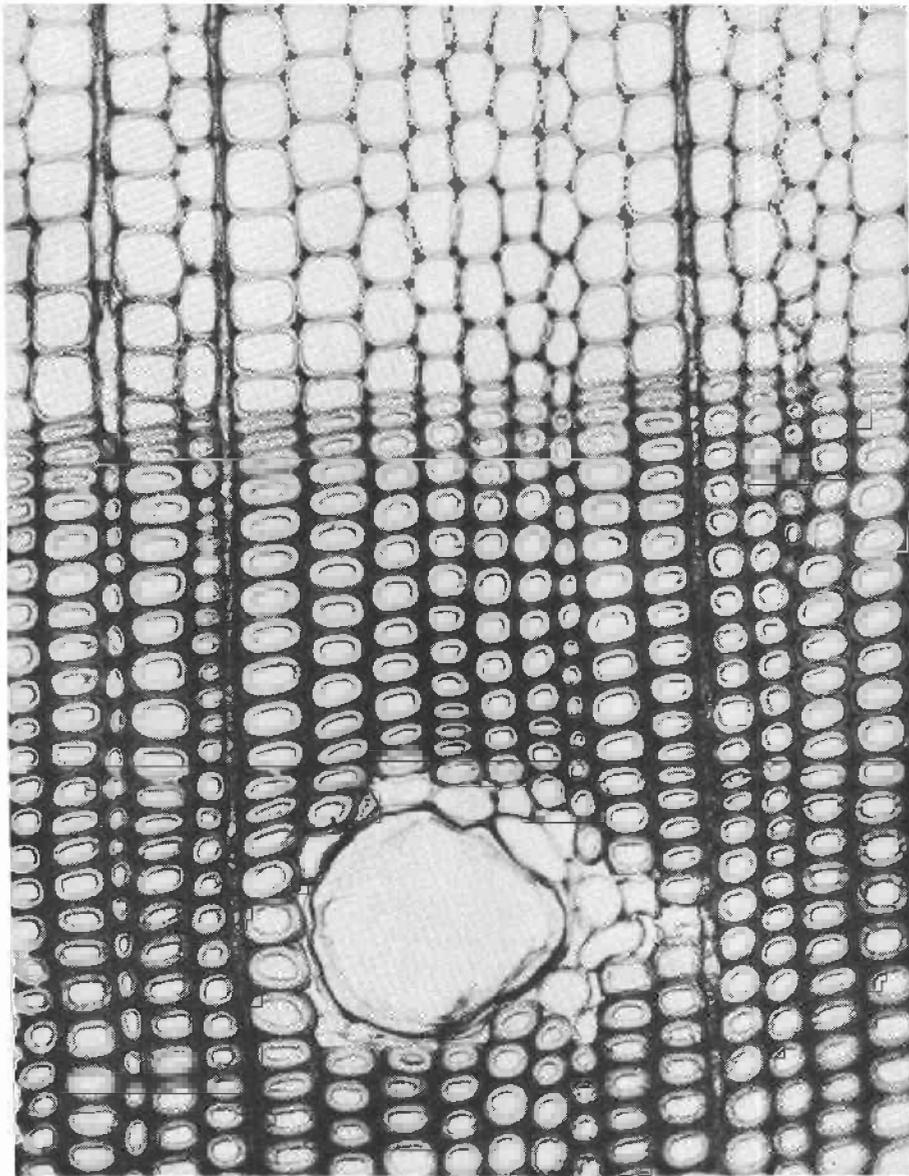


Figure 2.--Highly magnified cross section of southern yellow pine showing springwood fibers (above) and summerwood fibers (below).

Z M 9858 F

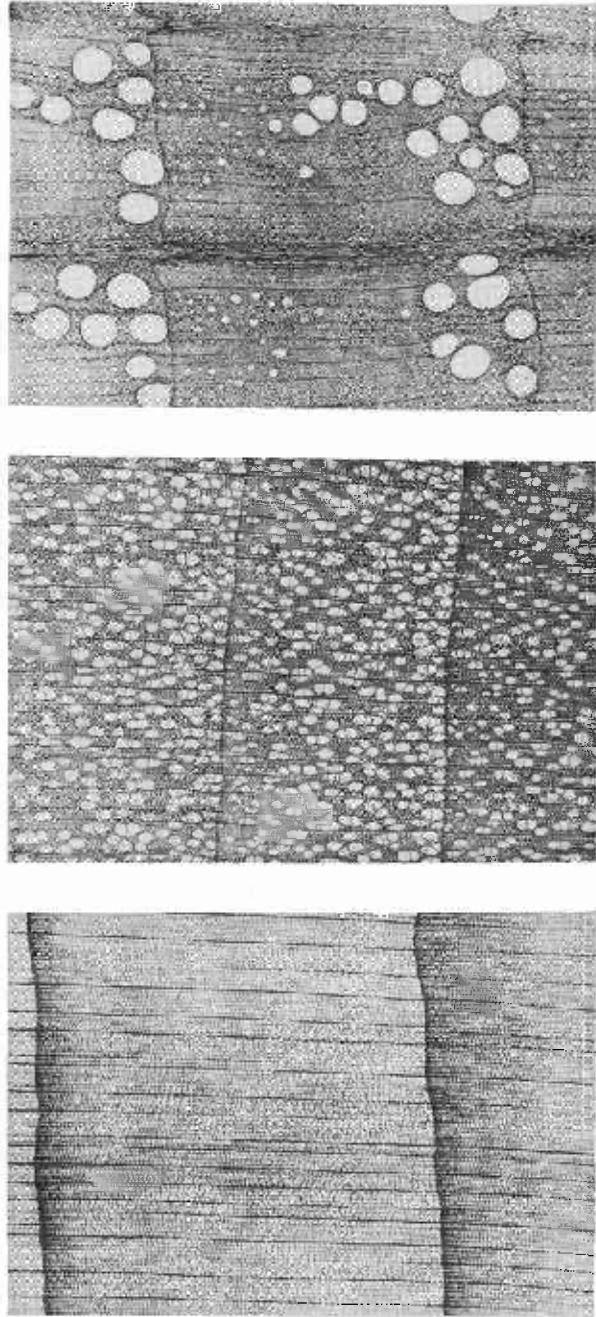
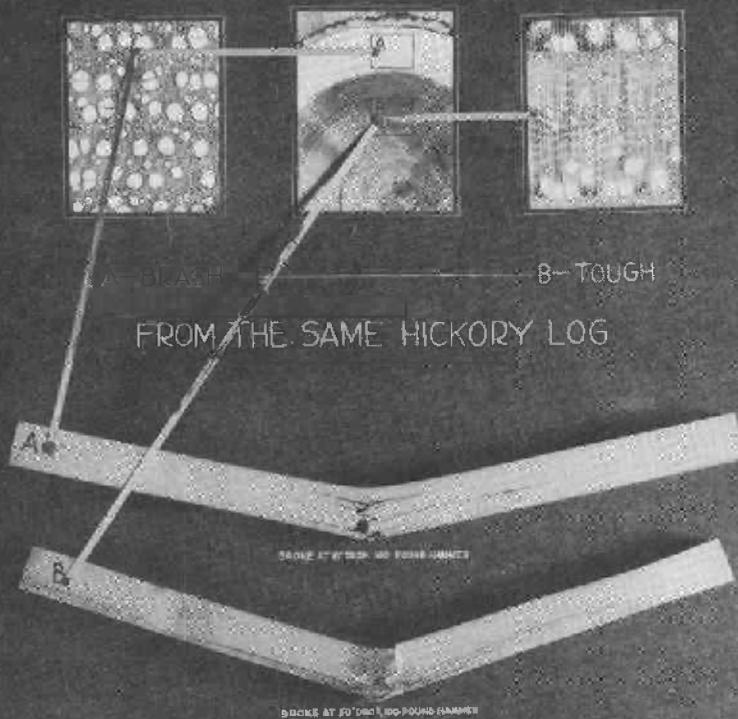


Figure 3.--Structure of wood as viewed on the end grain showing features of a nonporous softwood (left), a diffuse-porous hardwood (center), and a ring-porous hardwood (right).

Z M 3359 F

# GROWTH CONDITIONS AFFECT WEIGHT AND STRENGTH



## VARIATION IN WEIGHT OF HICKORY

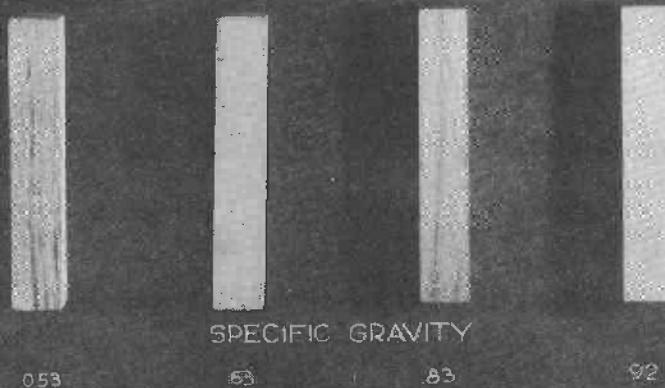


Figure 4.--Photomicrograph of dense and low density hickory, and related tough and brash failure when tested.

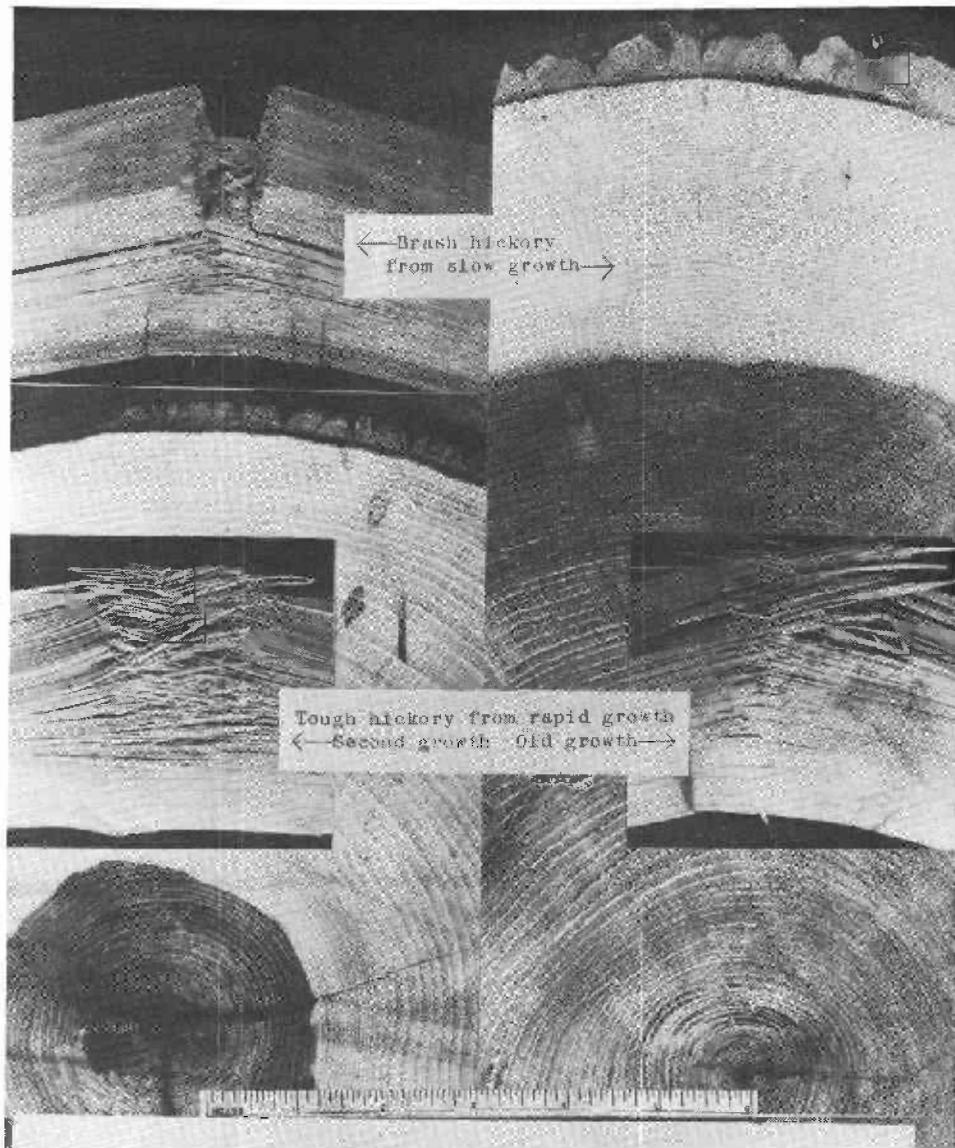


Figure 5.--Cross section of hickory logs and broken test specimens illustrating tough and brush failures in rapid growth and slow growth pieces.

Z M 73377 F

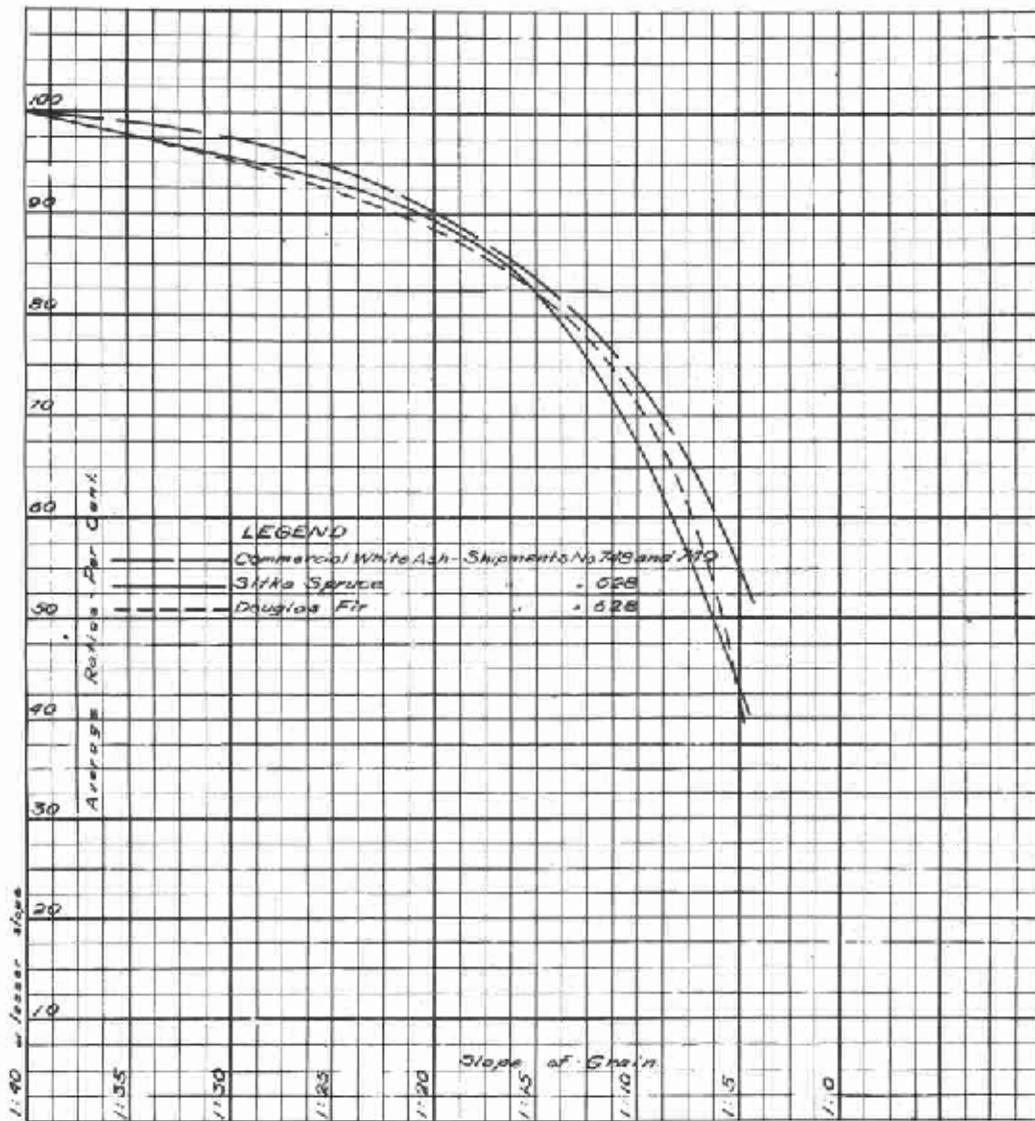


Figure 6.--Composite curves showing the effect of spiral and diagonal grain on bending strength properties in white ash, Sitka spruce, and Douglas-fir.



Figure 7.--Spiral-grained and straight-grained trees.  
Direction of grain shown by checks.

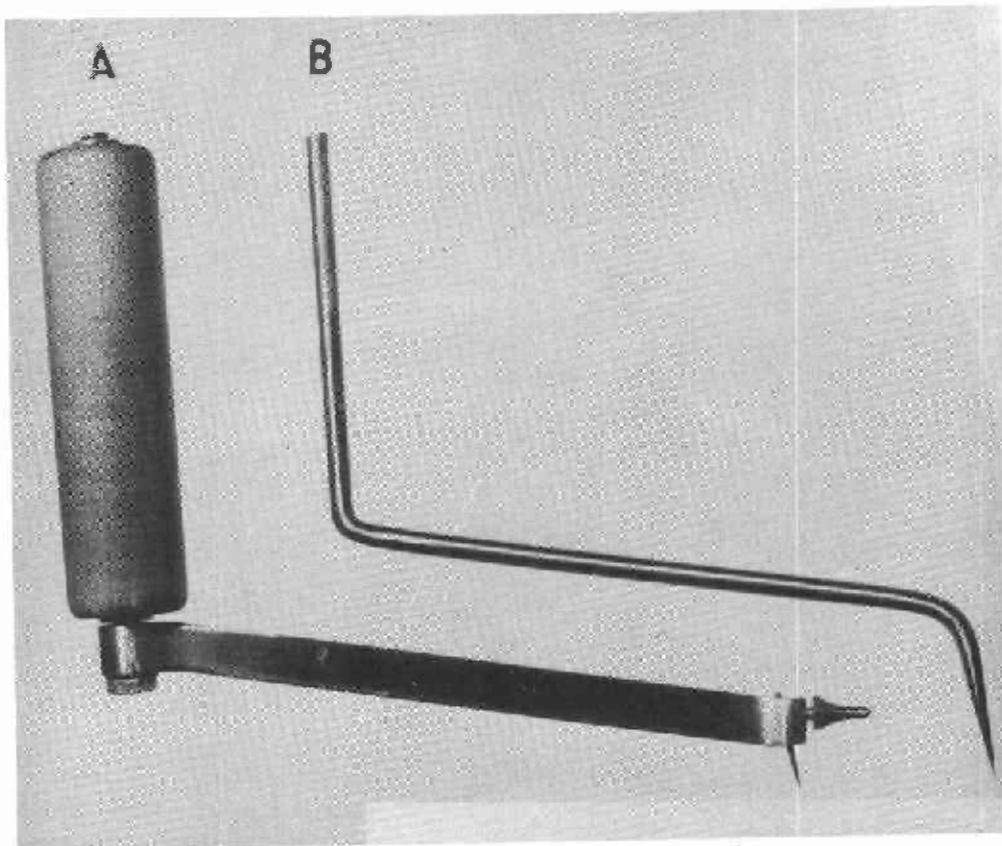


Figure 8.--Scribes for determining the slope of grain in wood.

Z M 46091 F



Figure 9.--View of Sitka spruce board showing tangential face (upper part) and chipped radial face (lower part). The chipped radial face gives a ready visual indication of the presence of spiral grain.

Z M 6901 F

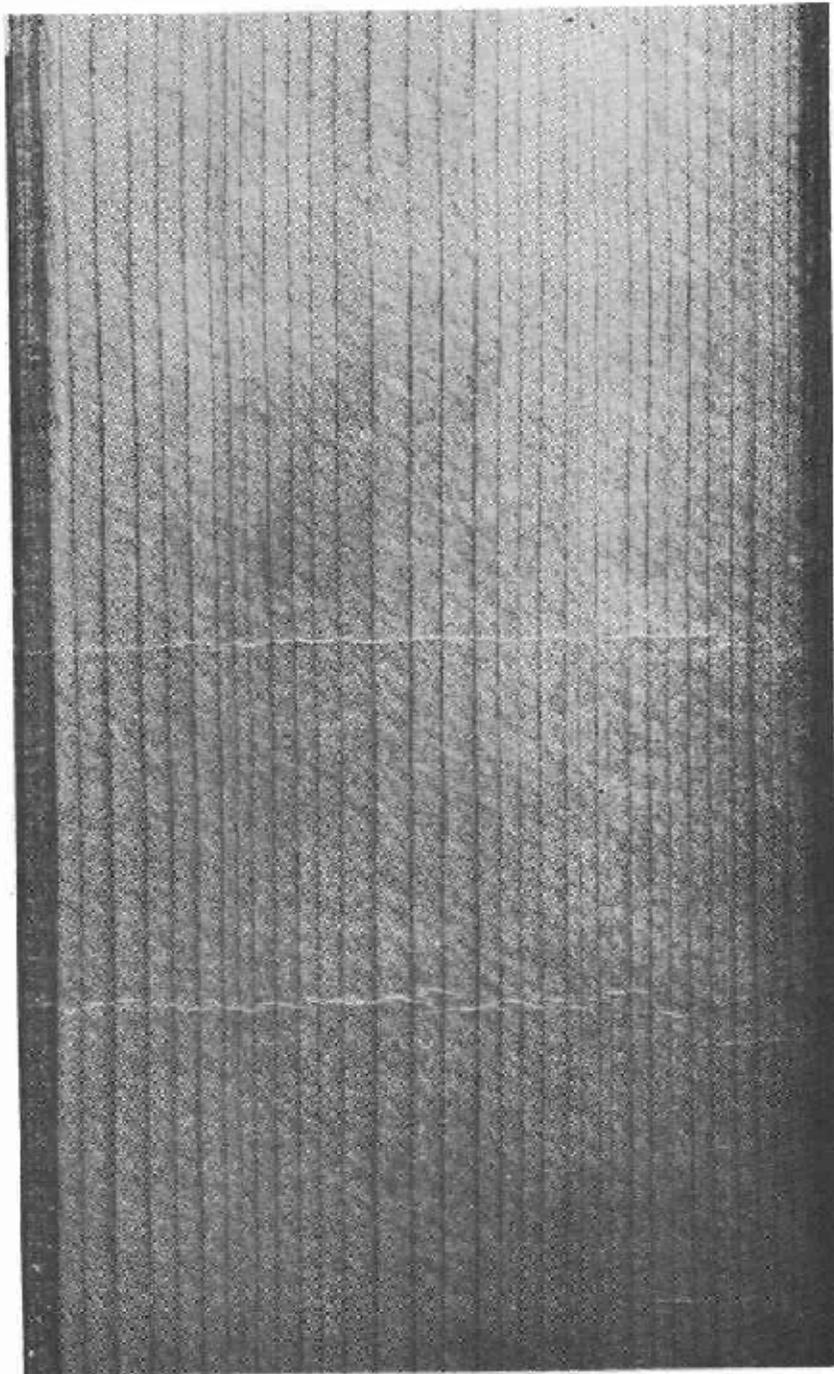


Figure 10.--Large compression failures in spruce lumber that are visible as lines across the grain. (Slightly magnified.)

Z M 80312 F

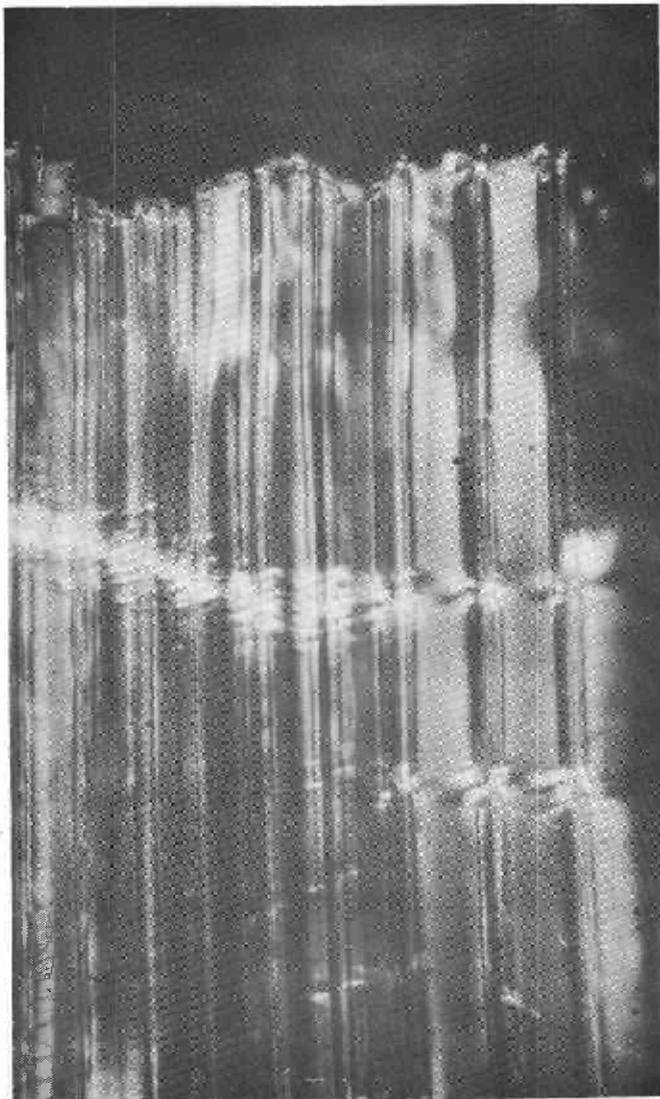


Figure 11.--Two compression failures shown as light zones across the fibers in a highly magnified microscopical section. Note brittle break at another compression failure at the top of the section.

Z M 69283 F

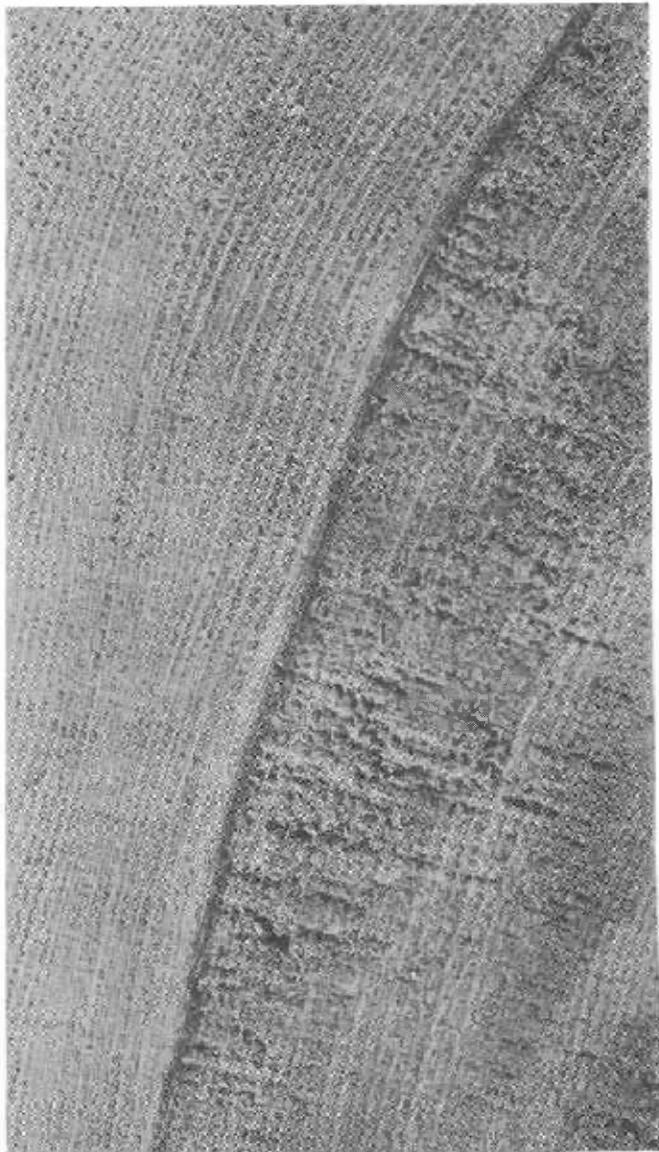


Figure 12.--End-grain surfaces of Sitka spruce lumber showing fiber breakage in the part below the black line in comparison with wood free from this characteristic above the line.

Z M 81195 F

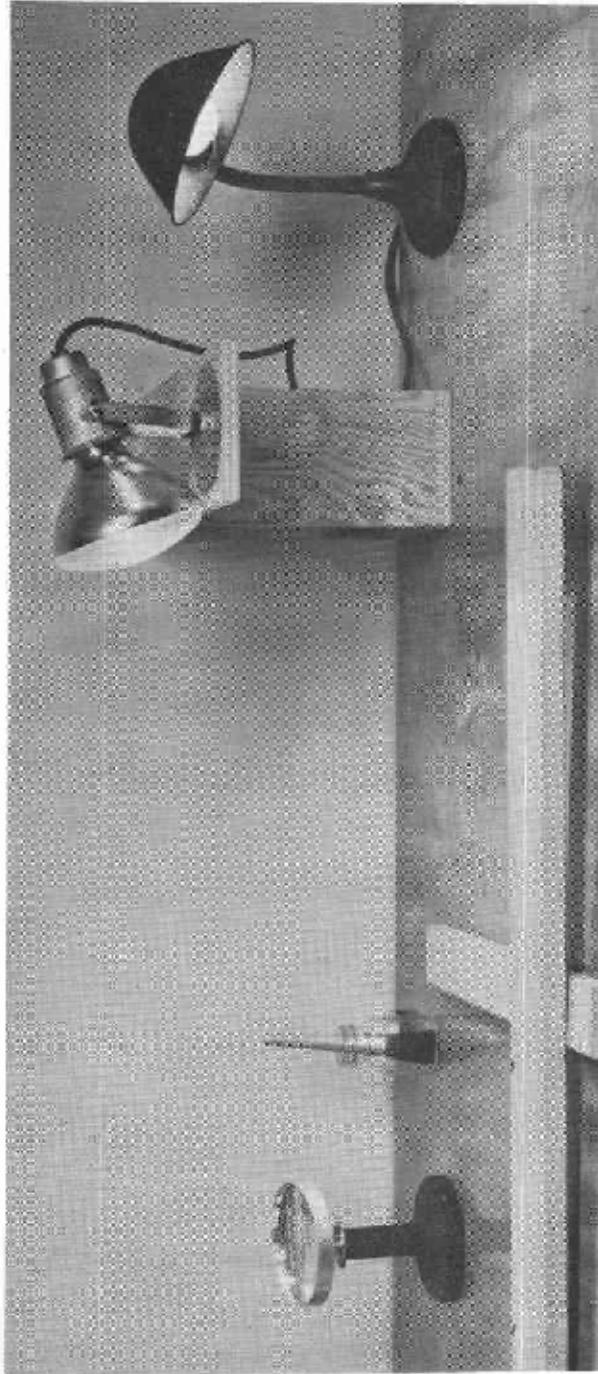


Figure 13.---A convenient arrangement of a reflector spotlight and an incandescent-bulb desk lamp placed on a work table for examination of ladder rails to detect visible compression failures and fiber breakage on the side- and end-grain surfaces.

Z M 80325 F

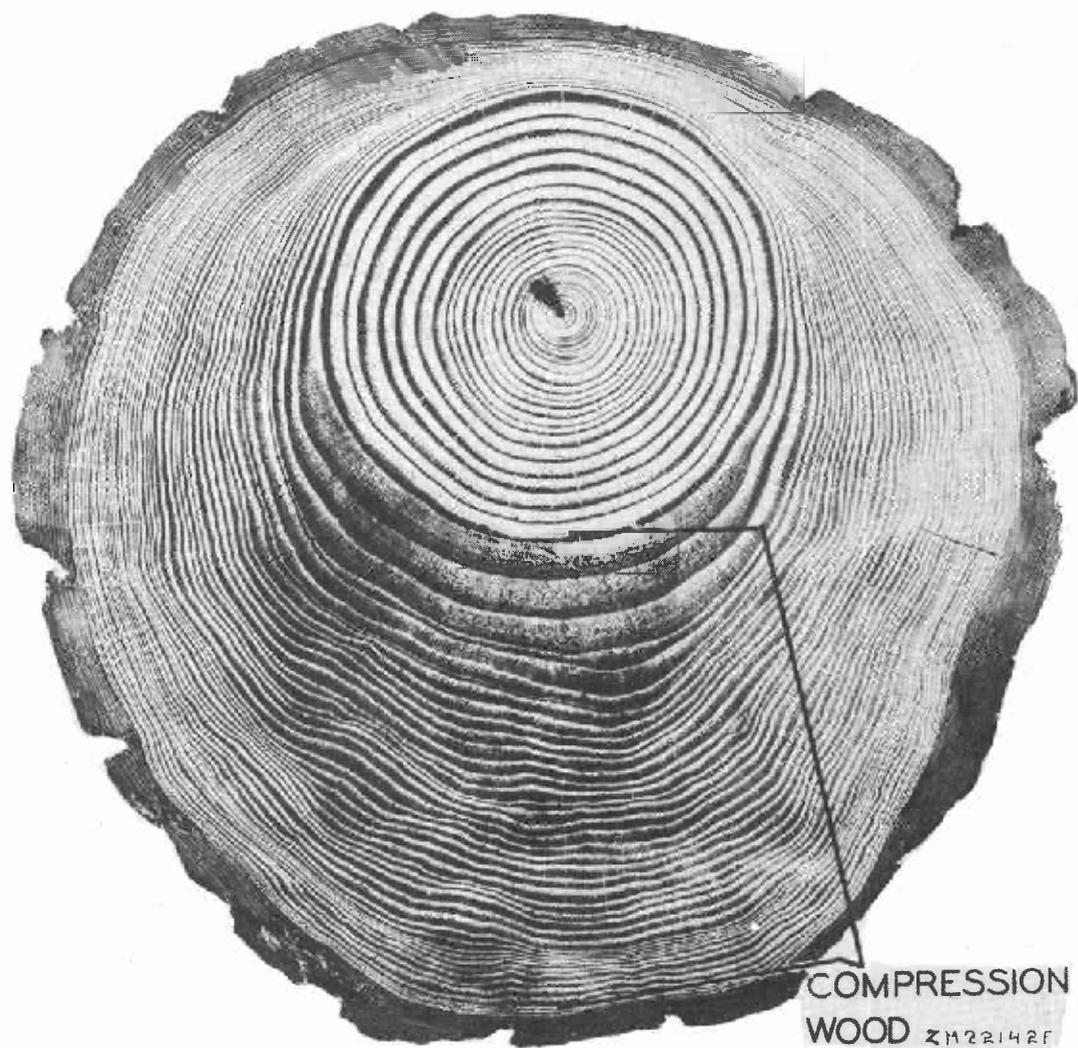


Figure 14.--Cross section of southern pine log showing  
compression wood.

Z M 22142 F



Figure 15.--Cross section of wood photographed by transmitted light. Above, normal wood showing translucent summerwood and, below, compression wood interspersed with normal wood showing location of compression wood by its opaque summerwood.

Z M 38054 F



Figure 16.--Forest Products Laboratory apparatus for detecting compression wood by transmitted light.

Z M 39819 F

FPL FILING SYSTEM DESIGNATION --WU-14

U.S. Forest Products Laboratory.

The role of inspection in wood ladder safety.  
2d ed. Madison, Wis., The ... Laboratory, 1962.  
18 p., illus. (F.P.L. rpt. no. 1994)

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