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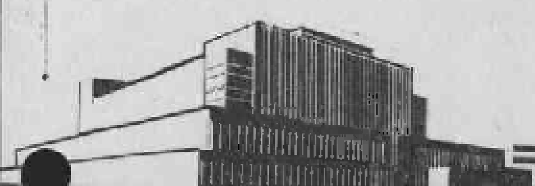

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

QUALITY CONTROL IN MANUFACTURE OF LUMBER FROM SECOND GROWTH[1]

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U. S. Department of Agriculture

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No pretense is made of having practical answers to all the problems which are given so much concern these days relative to the quality of lumber produced from second-growth timber, particularly small-diameter logs. It is well-known that many of the trade difficulties and complaints center around (1) the grading, (2) the dryness, and (3) the warping behavior of the lumber before and during use. The second of these three items influences the third to a degree if moisture changes take place after timber is put into use. How to cope with the first two factors is relatively well understood technically. How to cope with the warping and twisting is less clear, and it is to this point that this discussion is directed.

From one point of view, the situation in which the industry finds itself is due to changes in the pattern of supply-demand due to economic and industrial growth and the last war. From another point of view, however, these changes merely hastened along a situation that would have been more or less inevitable anyway, since it was associated with a replacement of former virgin timber stocks by second growth, a situation that calls for new harvesting and manufacturing techniques, some of which may take considerable time to put into effect.

As forest products technologists we have no easy nostrum to cure industry's difficulties. We can, however, explain why lumber from some second-growth timber behaves in a way that is giving it a bad reputation, and we can suggest lines of control that seem to offer most promise of correcting this behavior. It is up to the men in the industry, however, to work out how such measures can be put into effect.

It has long been recognized that, in most species, lumber from young and small trees gives more trouble from warping and twisting than that from older and larger timber. This is explained by different people in different ways. The closer we can come to finding the correct explanations, the better our chances are of finding the cure for the difficulties. The feeling is sometimes expressed that wood technologists put too much emphasis on discovering new defects in timber, and that timber has enough well-known defects without looking for new ones. But this is probably no more true than that doctors spend too much time looking for new causes of human ailments. Only quacks profess to cure without knowing causes.

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[1]Report originally written by B. H. Paul and Carroll V. Sweet, former Forest Products Laboratory Technologists, in 1949.
[2]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

We can list five general causes for the twisting behavior of lumber cut from second growth. Although they are not altogether separate and independent, it is easiest to consider them separately. Certain of them are readily recognized by mill men from their own practical experience; some of them are less generally recognized. They are as follows:

1. Crooked logs, resulting in cross-grain lumber.
2. Growth rings of sharp curvature, as in box heart lumber or lumber cut from very small timber.
3. Spiral grain, an oblique orientation of fibers having a similar influence as cross grain.
4. Growth stresses, or internal log stresses, as when timber flares out or pinches in on the headsaw.
5. High longitudinal shrinkage, as in very fast growth at the center of southern yellow pine trees and as in compression wood in softwoods and tension wood in hardwoods.

How does each one of these factors apply to the main problem? After that is considered, what can be done to control them?

Crooked Logs

Crooked logs yield lumber which is not straight grain because the grain follows the direction of the crooks rather than the direction of the sawn timber and, since dimensional changes in wood for radial, tangential, and longitudinal shrinkage are unequal, these elements are likely to result in twisted lumber. Straight logs or logs with a mild degree of sweep, as will be discussed later, may be associated with even greater warping tendencies than markedly crooked logs. How direct the connection is between crooked logs and the crooked lumber encountered in the lumber trade is difficult to say. Systematic study of this point would be worth while.

Growth Rings of Sharp Curvature

Lumber that contains the heart center or that is cut from very small trees contains growth rings which, of course, are sharply curved. Because the greatest shrinkage occurs along the line of the growth ring, pieces with sharply curved rings also tend to become sharply curved. If the piece is boxheart, a crack usually opens, as you know; if not boxheart, it tends to cup sharply. In pieces having growth rings oriented at different angles to the length of the piece from end to end, twisting occurs as one end shrinks more than the other. The effects of the direction of growth rings are generally understood and require no further discussion here.

We come now to some of the less easily recognized but nevertheless highly important causes of twisted lumber. They are not only of great practical significance, but are extremely interesting because they relate particularly to how wood and lumber characteristics are predetermined in the growing tree.

Spiral Grain

Spiral grain is most easily recognized in dead standing trees without bark, in which seasoning checks have opened in a spiral about the trunk. The presence of spiral grain in occasional trees complicates the problems encountered by adding one more factor to the several internal forces influencing the behavior of wood. A great deal of study has been given to spiral grain by many scientists. Few of them claim to have arrived at a satisfactory explanation of its cause. H. G. Champion, working in India, reported that seed from straight-grained trees produced fewer spirally-grained trees than seed from twisted trees. It is doubtful, however, if spiral grain can be said to be truly hereditary, because frequently it is found only in a portion of a tree. The evidence at hand, moreover, is that the younger or inner portions of trees are less apt to be spiral or are spiral to a lesser degree than the outer portions. If this is true, the effect, if any, should be somewhat less in timber from young trees. Actually, however, spiral grain in any degree adds to the other difficulties under consideration.

Growth Stresses

Young, fast-growing trees may have a great deal of internal stress in them--enough, in fact, to pull a piece of timber into a bow almost instantaneously when it is sawed. Sawyers see it not infrequently, and especially clearly in hardwoods when a log pulls out of line on the carriage headblocks after a cut has been made from one side of the log. Not always, but often, the tendency is for the ends of the log to spring away from the side from which the cut has been taken; or, in other words, the uncut side is seen to be in tension. After cuts are made from both sides of a log, a cut from the cant may act in the opposite way and pinch the saw. This springing of a whole log, or pieces of a log, after one or more cuts are removed is vivid evidence that stresses are locked up there which, while in equilibrium in the round log, are quickly thrown out of balance when a portion of the log is removed.

We used to hear about fast-growing children having growing pains. Probably doctors do not accept the term any more. It is reported to be the condition that is now diagnosed as rheumatic fever. In the case of young, fast-growing trees we are tempted to make use of the analogy and say they are subject to growing pains. It might not be too bad a term if trees had feelings. The stressed condition in these trees is not, however, associated with the straightening of a tree that has been bent or made to lean for any reason. The term "growth stresses," rather than "growing pains," is what wood technologists prefer to call this condition. They may exist in logs from perfectly normal, straight trees, but in trees that are not straight they occur in exaggerated form and are supplemented by other stresses, as will be discussed later.

An Australian technologist, Mr. R. Jacobs, has brought together some very interesting facts from his own research and that of others on growth stresses in trees. Among other methods of study he has cut planks through the center of logs and then ripped the planks into strips. Some strips shortened on cutting and other lengthened, showing that some were in tension and others in compression. There were differences between hardwoods and softwoods and at different ages, but in general he concluded that in erect hardwoods and softwoods of small-timber size the strips corresponding to the outer layer of the logs were in tension and those corresponding to the inner layer were in compression. Jacobs favors the theory that the growth stresses are associated with the forces which cause the sap stream to rise from the roots to the leaves. When one stops to consider that these forces are sufficient to lift columns of water 100 feet and are concentrated in the outer, living portion of the tree, he realizes that removal of one side of a log creates an appreciable unbalance in these forces, much like breaking a harness trace.

In larger, more mature trees, the action of these stresses is much less pronounced, possibly because of a greater proportion of heartwood; or the action may be reversed from that in young timbers. This could be put forth as a good reason for allowing trees to mature well before cutting them.

High Longitudinal Shrinkage

Everyone familiar with wood knows that normally it does not shrink much lengthwise of the grain. But there are some conditions under which it shrinks more than under others--sometimes very appreciably. Investigations have shown that, when the inner and outer portions of a growth ring are dried separately, the springwood or soft inner part shrinks considerably more lengthwise than the summerwood or dense outer part. Incidentally, this contributes frequently to the shelling of the grain after planing of flat-sawed lumber, but that is a subject beyond the scope of this paper.

Another condition under which wood shrinks substantially with the grain results from the special growth tissue which is put on to make a leaning tree straighten up. In softwood species the special growth in a leaning tree is added to the under side of the stem to push it back to upright position. In hardwood species, strangely enough, the action is different. The special growth in hardwood is added to the upper side of the stem to pull it back to straightness. In softwoods, the special growth tissue is called compression wood, and in hardwoods it is called tension wood. To exert this push and pull on the leaning stems as rapidly and forcibly as possible, a different kind of cell is formed. It is a kind of cell that apparently can exert the maximum pressure along its length, in that the elements making up the walls of this type of cell structure are arranged more obliquely with the axis of the cell than in normal wood. When wood of this type dries out, it shrinks substantially along the grain.

Leaning tree trunks of considerable size do not change their lean appreciably even though a thick layer of compression wood may be produced; but the upper more flexible parts of the stems will become perpendicular through the action of compression wood. When this occurs, a crook results and the disadvantages of crooked logs already mentioned are further increased by the presence of compression wood.

Typical compression wood in conifers can be identified in logs because the pith of the log is off center, which results in markedly eccentric annual growth rings. In addition there are usually large amounts of summerwood in the wider portions of the rings as compared with the narrower portions. In lumber, compression wood usually can be distinguished from normal wood by its relatively lifeless appearance, which results from lack of contrast between springwood and summerwood. The summerwood of compression wood appears less dense and less hornlike than that of normal wood. In general, the annual rings are relatively wide, although in many instances this alone does not distinguish compression wood from normal wood.

Tension wood is not readily identified in hardwood logs or green lumber. In dry lumber, warping and sometimes fuzzy surfaces frequently can be definitely attributed to tension wood by examination under a microscope. A form of wood fibers described by the term "gelatinous" characterizes tension wood. The subject of tension wood, however, has not yet been adequately studied to allow intelligent discussion of its cause and effects.

Under certain conditions, even trees that do not lean produce wood that presents difficulties because of unequal lengthwise shrinkage. It was mentioned earlier that springwood shrinks more along the grain than summerwood. In the center of very rapid-growing southern yellow pine--that is, where the ring width is a quarter-inch or more--there is always a predominance of springwood. In these wide rings there is gradual change from springwood to summerwood, and at least in some cases the summerwood is of unusually low density. This wide-ringed wood may shrink as much as 10 to 20 times more along the grain than narrow-ringed wood near the bark in the same trees. It is wood with less than four rings per inch that is apt to be the main cause of crooking, especially when in combination with wood having growth rings less than 1/4 inch in width. This circumstance is believed to be the cause of a large proportion of the crooking and twisting in second-growth southern yellow pine timber.

It has been the aim throughout this discussion to show that it is the result of differentials in stresses in different parts of a piece of lumber that causes the warping and twisting that have given so much trouble. If a piece of timber consists entirely of one kind of growth tissue, it is not particularly inclined to warp. But in small, uneven-growing second growth, uniformity of structure is not likely to be found very often. In bacon, a streak of lean and a streak of fat satisfy the taste. In a piece of lumber, however, adjacent streaks of wide and narrow rings or combinations of compression wood with normal wood in conifers, or of tension wood and normal wood in hardwoods, can be the cause of a lot of rejected lumber.

These causes of unsatisfactory behavior of lumber suggest lines of control which the practical men in the industry may be able to work out advantageously. None are dead easy to apply, but some are within closer reach for immediate application than others.

1. One line of control within reach of the individual mill man is to cut up his logs in such a way that there is the minimum mixture of fast growth and slow growth. This has already been recognized in the grade rule for No. 2 southern yellow pine 2 by 4 lumber, which does not admit fewer than four rings per inch. The same diligence should be followed by not permitting compression wood and normal wood in the same piece. To accomplish the first result, mill men should attempt to work out methods of turning and sawing that will separate wide- and narrow-ringed portions of a log. Taper sawing is one approach. Taper sawing ordinarily is not used on small second-growth timber. It ought to be tried out, and if found to be at all feasible, it would help to avoid mixtures of different types of wood in the same piece of lumber.

2. The central part of the log containing wood of less than 4 rings per inch, or any part of a log containing compression wood, should be sawed into boards rather than into dimension, because boards can be used in such a way that warping or twisting is less damaging to their utility than to that of framing lumber. Past and present practices in sawing lumber have usually been just the opposite. How far it is practical to go in putting this wide-ringed wood into boards rather than dimension can be determined only by trial.

3. To the extent that crooked logs enter the picture, the standard recommendation of putting them on the carriage so that the sawing can be done across the plane of the crooking instead of parallel to it will help to minimize the form of warping which causes the greatest difficulty in use, that is, edgewise springing.

4. There is another line of control within close reach of the individual mill operator that goes a long way toward meeting the complaints of consumers and maintaining the reputation of good lumber. He can throw out at the mill the pieces that twist instead of shipping them. There is no better way of doing this and killing two birds with one stone than by thorough seasoning before shipment. Careful stacking methods during drying, so that boards and dimension timbers are held straight, will restrict warping during drying by making pieces which are inclined to twist dry in a reasonably straight condition, which will be maintained unless the lumber subsequently undergoes a considerable change of moisture content.

5. While not applicable to stands now being harvested, the most effective quality control for future timber crops is tied to growth control of the forest. The rate of growth can be controlled by density of stocking, thinning, pruning, and other forest management practices. Leaning trees that produce compression wood can be removed in thinnings. With the great impetus now under way in the establishment of "tree farms," growing timber for quality is a step that should not be left out of consideration.

To summarize briefly:

The things that can be done to improve the quality and behavior of timber from young second-growth stands, particularly southern yellow pine are:

1. Avoid combining wood of less than four rings per inch and wood of slower growth in the same piece, especially in 2 by 4's and other dimension lumber.

2. Apply taper sawing to logs showing wide variations in growth rate to keep the grain of the wood parallel to the edges of the lumber.

3. Learn to recognize compression wood at the ends of logs and do not put lumber containing compression wood into high-grade products.

4. Dry lumber thoroughly before shipment, thus making possible the finding of pieces that warp so badly that they are unfit for use.

5. Keep lumber as straight as possible during drying by careful stacking and avoid subsequent moisture content changes.

6. Improve the quality of timber as it grows--set up a growth-rate objective for a high-quality product (possibly as many as eight rings per inch), and maintain a uniform growth by thinning and pruning. Remove leaning trees that will produce compression wood.

While such controls may mean a radical departure from present practice, they appear to be within the realm of possibility. If they are given a trial by forward-looking men of industry, practical means for general adoption should be forthcoming.

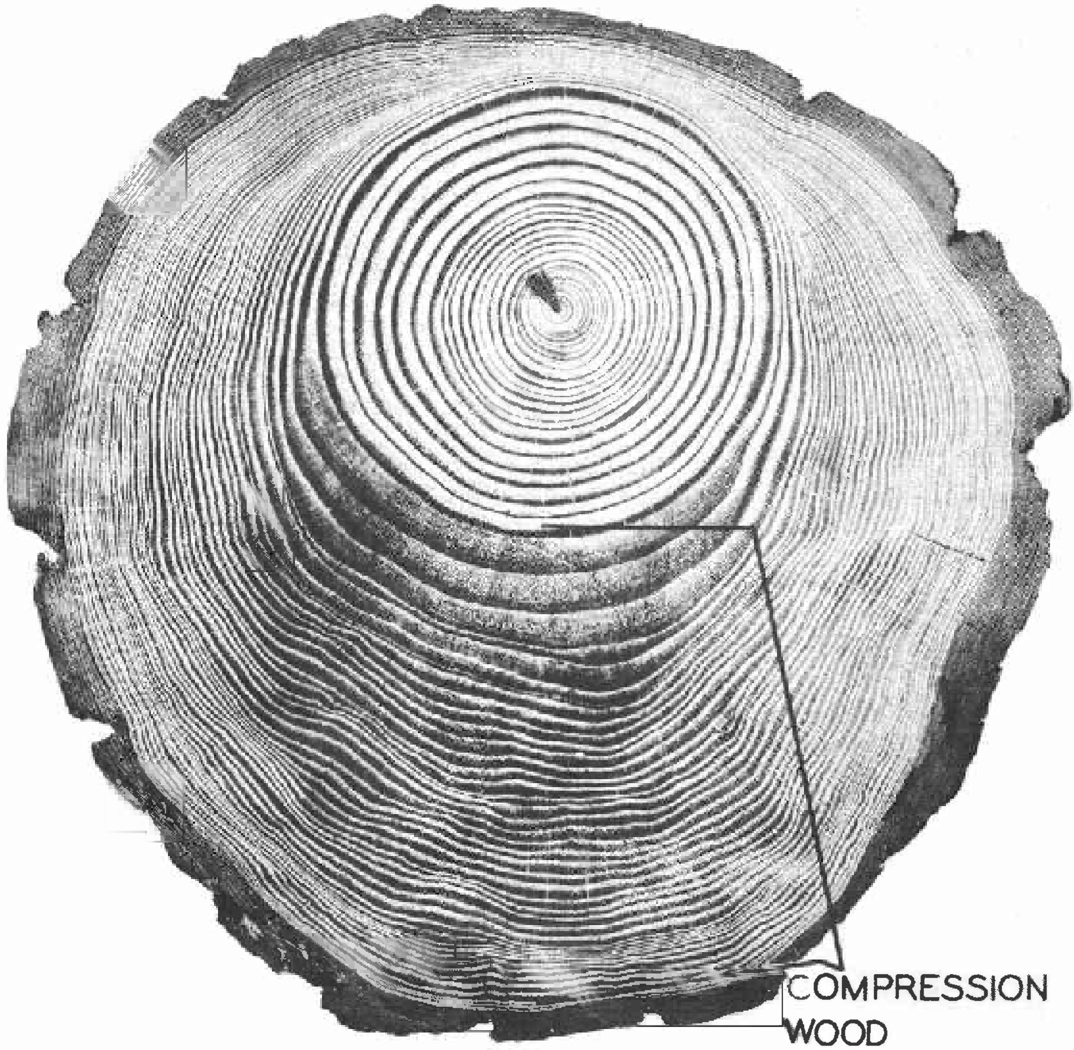

Figure 1.--Compression wood formed in the lower half of this log after the tree was caused to lean. Note the eccentricity of the growth rings and the difference in appearance of normal wood and compression wood.

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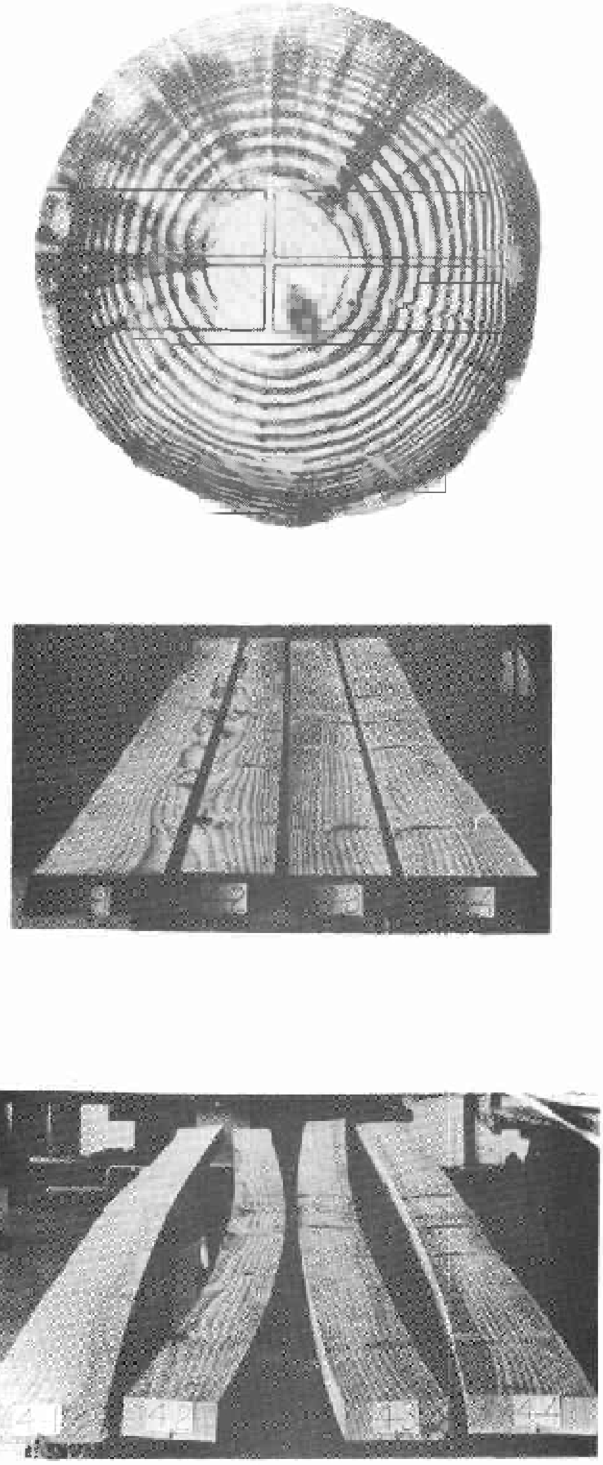

Figure 2.--Top, cross section of loblolly pine log with diagram showing location of planks with reference to pith of tree. Middle, four 12-foot planks while green, immediately after sawing from the log shown above. Bottom, the same planks showing crooking curing air-drying due to abnormally high shrinkage of wide-ringed wood on edge toward the pith.

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- List of publications on Box and Crate Construction and Packaging Data
- List of publications on Chemistry of Wood and Derived Products
- List of publications on Fungus Defects in Forest Products and Decay in Trees
- List of publications on Glue, Glued Products and Veneer
- List of publications on Growth, Structure, and Identification of Wood
- List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products
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- List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components
- List of publications on Wood Finishing
- List of publications on Wood Preservation
- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.