Some relations between growth conditions, wood structure, and pulping quality

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Although wood is the basic raw material of a large section of the pulping industry and its cost constitutes probably one-third of the total cost of pulp production, the casual consideration which it receives is almost amazing. Everyone concedes there is a difference in species, and the industry has followed spruce into some exceedingly remote areas, but to the "right wing" of our pulp industry "wood is wood" and that is all there is to it.

Even technical men seem blind to the significance of wood. Many thousands of dollars have been spent in research on pulping in which careful attention was paid to small differences in liquor composition, chemical concentrations, pressure and temperature control, and little or no heed given to the raw material on which this painstaking work was done. I confess to several such misapplications of effort myself.

It must be admitted that some cognizance is taken of wood under certain circumstances -- especially when things go badly in the pulping process. The pulp mill superintendent's best alibi is a "poor wood." Our Swedish friends have reported that wood grown on a north slope differs in pulping quality from that growing on the south slope. A mill I know of localized their spruce supply for many years to a certain area where experience showed they obtained superior wood. It is, in fact, a matter of common knowledge that conditions of growth influence wood properties which, in turn, are reflected directly in the pulp produced, both as to yield and quality. Research on such factors has been reported in the European literature. In a recent report of the Norwegian Forest Experimental Department, Gustav G. Klem gives an account of contemporary work on tree growth-pulp quality relations, and refers to the work done by Hagglund, Kinnman, Johnson, and Ulfsparré along similar lines. But so far as American operation is concerned little definite information is available on the nature or effect of these differences.

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During the past few years the U. S. Forest Products Laboratory has engaged in a comprehensive study of the pulping of southern pines, especial emphasis being placed on the relation of growth conditions to pulp quality. The significance of these southern species in the pulping field is tremendous. The past 20 years has seen the development of kraft pulping in the South to a point where it dominates the American production of this grade. We are witnessing a continuing expansion of that industry at this moment and also the development of white papers from the southern pine sulphate pulps on an enormous scale. Dr. Herty's work on newsprint production from southern pine has directed earnest attention toward the South as a factor in that large tonnage field. Any day may see the commencement of a newsprint industry based on southern pines. If the reports of saw fly ravages in Canadian spruce are true, that day may come even earlier than is anticipated. At any rate the industry has always followed cheap wood and the South possesses this resource.

Virgin Stands in South Gone

Our job at Madison is to provide factual information which will be of value in the industrial and the land-use problems which arise as the pulping industry progresses along with forestry practice. This paper presents a bird's-eye view of the types of wood which the new stands of the South will provide and how these types react in pulping operations.

I use the term "new stands" advisedly. The virgin timber of the South is practically gone. In its place are tremendous areas of second growth, differing in character markedly from the virgin trees with which the early pulp mills had to deal. It stands to reason that these new trees may differ from the old trees. They have in many (or most) instances developed under an entirely different environment than their ancestors. They have responded to this changed environment in internal and external characteristics -- both physical and chemical in nature -- and their behavior under pulping procedures is likewise different.

Let me give credit to Dr. C. H. Herty for focusing on a very important growth characteristic of young slash pine. He noted that the new young growth of this species is light in color, is free from heartwood and contains less pitchy element than the old trees. His development of this idea is a matter of record.

There are also other growth factors which are significant in the pulping of southern pines. Anyone who investigates the species cannot fail to be impressed by the varying quantities of springwood and summerwood, the difference in growth rate, etc., which are found in different sticks, even of the same species. A factor of importance is the amount of heartwood as related to the amount of the sapwood. Recently, particular attention has been focused on the importance of such abnormal growth characteristics as compression wood and related abnormal fiber.
Growth Conditions vs. Species Differences

A systematic investigation of these growth conditions has shown them to have large significance in pulping — so large that, in our opinion, growth conditions may transcend species difference in importance, and the successful development of southern pine pulping is largely tied in with their intelligent application. Forestry practice will undoubtedly be governed by them. And what is true of the southern pines is, in more or less degree, true in all pulpwoods.

To illustrate some of the more striking of the conditions which will be encountered in the pines, Figure 1 is presented showing cross sections of loblolly pine all coming from the same area.

In this particular sample one important characteristic — heartwood — is lacking. Heartwood is present in the older trees and affects pulp quality because of its dark color and the fact that sulphite liquors will not reduce it. The illustration does, however, provide a striking range for densities, and of springwood and summerwood volumes and ratios. The bearing of density on pulp yield is well known. Lower densities mean lower volume yields. A digester charge of a low specific gravity wood means less pounds of pulp in the blow pit and lower yields per cord, regardless of the weight yields on a given species.

A more significant fact with the pine pulpwoods, however, is the divergent properties of the springwood and summerwood fibers. It is common knowledge that springwood fibers are thinner-walled and more flexible than summerwood fibers (Figure 2). This difference exists in all species but is especially characteristic of the pines. In pulping it is reflected markedly in the nature of the pulps — especially in the surface and sheet characteristics. Figure 3 illustrates two sulphite pulp sheets where these differences are especially noticeable. In processing, the thin-walled springwood fibers collapse to ribbon-like fibers forming dense well-knit sheets, whereas the stiff thick-walled summerwood fibers remain in tubular form, resist processing and form coarse textured sheets, entirely different in properties. In Figure 4 a striking illustration is given for these two types of fibers, showing the collapsed thin-walled springwood and the resistant summerwood tracheids when in the form of pulp. A comparison is made in this figure between a commercial Swedish kraft pulp and a kraft pulp produced from southern pine.

Such a diversified behavior is obviously significant in pulping and papermaking. In slower growth woods, or in woods where the ratios of the two fiber types are maintained consistently, pulping conditions may be selected which will give uniform results. However, as is the case with these pines, when widely variant ratios are encountered some cognizance must needs be taken or nonuniformity of pulp is bound to result.
FIG. 1.
Growth variations in loblolly pine pulpwood from the same stand.

FIG. 4.
Comparison of kraft pulp fibers from southern pine springwood and summerwood, with a Swedish kraft. A. Southern pine kraft fibers. B. Swedish kraft fibers.
There seems, too, a difference in the nature of pines depending on their rate of growth. At present no difference in fiber structure can be specified to account for this but the fact remains that in mechanical pulping, particularly, such differences are observed and this factor needs to be taken into account.

Effect of Abnormal Wood

In recent work, reported at the winter meeting (1) the effect of abnormal wood, such as compression wood, has been noted. European investigators have recognized the significance of such wood in pulping for some time. Compression wood occurs frequently in rapidly growing trees and differs markedly from normal wood in chemical composition, in physical properties, and in pulping properties. It invariably yields weaker pulps in lower yields than are obtained from normal wood. Compression fibers are formed when prevailing winds put the trees under a constant tension. Compression occurs in leaning trees, on the underside of limbs, or under any condition of stress which may occur in growth. In southern pines we find frequent evidence of compression in the butt logs. Such logs frequently differ markedly in pulping properties from sticks taken higher up in the tree.

The wood associated with compression wood is also frequently abnormal. Chemically, this associated wood is not much different from normal wood but microscopical examination shows its fibrils to lie at a greater angle than those of normal fibers and this circumstance may be a clue to its properties. Trees of so-called eccentric growth are frequently found to contain compression and associated abnormal fibers, as are also trees where the growth in early life has been extremely rapid. These evidences may be the beginning of a means of classifying good and bad pulpwood although they are by no means infallible.

Growth differences are generally speaking not evidenced in chemical differences. An exception to this is compression wood but most other types are not readily distinguishable (at least as far as southern pines are concerned) through such analytical constants as we can adduce at the present time. Table 1 presents some data in this connection.

Of course specific chemical components, such as the phlobatannins or phlobaphene dyes found in certain species, have a bearing here, although their influence is more largely governed by difference in species than by difference in growth in the same species.
Table 1.--Chemical analysis of loblolly pine, entire wood, springwood, summerwood, and compression wood

<table>
<thead>
<tr>
<th></th>
<th>Springwood</th>
<th>Summerwood</th>
<th>Compression Wood</th>
<th>Entire Wood</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cellulose, percent</td>
<td>58.3</td>
<td>59.1</td>
<td>46.2</td>
<td>58.2</td>
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<tr>
<td>Alpha cellulose, percent</td>
<td>43.9</td>
<td>46.4</td>
<td>34.6</td>
<td>43.1</td>
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<td>Lignin, percent</td>
<td>28.8</td>
<td>27.4</td>
<td>35.2</td>
<td>27.2</td>
</tr>
<tr>
<td>Pentosans in cellulose, percent</td>
<td>11.6</td>
<td>10.4</td>
<td>11.0</td>
<td>10.0</td>
</tr>
<tr>
<td>Total pentosans, percent</td>
<td>17.9</td>
<td>12.6</td>
<td>12.2</td>
<td>13.0</td>
</tr>
<tr>
<td>Solubility in:</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Hot 1 percent sodium hydrox-ide solution, percent</td>
<td>14.0</td>
<td>12.9</td>
<td>12.6</td>
<td>12.7</td>
</tr>
<tr>
<td>Hot water, percent</td>
<td>4.2</td>
<td>2.5</td>
<td>2.7</td>
<td>4.1</td>
</tr>
<tr>
<td>Alcohol-benzene, percent</td>
<td>3.6</td>
<td>1.5</td>
<td>1.3</td>
<td>3.0</td>
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The samples were sawed from discs on a band saw. They are estimated to contain at least 90 percent of the desired kind of wood.

Influence of Growth Conditions

The influence of growth condition in pulping tests may be illustrated by the experimental results which have been obtained at the U. S. Forest Products Laboratory recently. Table 2 shows data compiled with reference to mechanical pulping. In this process fast-growth wood appears preferable. Lower power consumption, better strength, good color and absence of pitch characterize mechanical pulp from such wood, whereas these qualities are not so satisfactory in slow-growth wood, regardless of the fact that the amounts of summerwood and springwood may be practically equivalent.

Application of the sulphate process to the southern pines also shows that growth rate, springwood-summerwood ratio, and abnormal types, such as compression wood and other wood of high fibril angle, have considerable bearing on the physical properties of the pulps obtained.

These differences are especially noticeable in the color, surface appearance of the pulps, in their bursting and tearing strengths, and in the time required to reduce freeness in treating the pulps in a pebble mill where the pulps are produced under identical conditions. See Figure 5.
Fig. 5.
Effect of growth conditions in pulping of southern pine by the sulphate process.

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Table 2.—General properties of groundwood pulp from various types of loblolly pine compared to the average of commercial newsprint groundwood pulp

<table>
<thead>
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<tbody>
<tr>
<td>Slightly: High: above: Good: No tests</td>
<td>Slightly: High: above: Good: No tests</td>
<td></td>
</tr>
<tr>
<td>High: above: Good: evidence: No tests</td>
<td>High: above: Good: evidence: No tests</td>
<td></td>
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<tr>
<td>Medium: Average: Good: Average: No evidence</td>
<td>Medium: Average: Good: Average: No evidence</td>
<td></td>
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<tr>
<td>Low: Average: Good: Average: No evidence</td>
<td>Low: Average: Good: Average: No evidence</td>
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In comparing rapid and slow growth loblolly pine sulphate pulps of high and low springwood content, the pulps from high springwood material have a lighter color, finer texture, and smoother surface and thus lend themselves to the production of better formed sheets, while the high summerwood pulps are coarse, bulky, darker, more porous, and have a somewhat higher bleach requirement. The differences noted in bursting strength of pulps from the varying wood type are not very consistent but in tearing strength sulphate pulps made from trees high in summerwood show much higher values than those obtained from the ribbon-like fibers of springwood. This latter advantage for summerwood pulps has thus far been evidenced regardless of growth rate, but in trees of rapid growth where a high percentage of springwood is present there is in addition a preponderance of thin-walled cells accounting for lower density and a tendency to lower strength pulps.

Again the appearance of compression wood and other abnormal types associated with it is a signal of a wood type to be avoided where uniformity of digestion and pulp quality, high strength, and easy-bleaching pulps are desired. These abnormal types of wood produce pulps as widely different in yield, strength properties, and bleach requirements as would be obtained from two unrelated species. Yields and strength properties, especially tearing
strength, are markedly lower and the pulps are extremely shivy and have a much higher bleach requirement, so much so that they appear to be practically unbleachable. Therefore, in selecting wood for the manufacture of bleached kraft products, high-grade wrappings, bags, and board stocks care should be taken to select wood of proper characteristics as indicated in the foregoing discussion.

Comparison of Sulphite Pulps from Four Types of Wood

When the four different types of wood, i. e., rapid and slow growth loblolly pine of high and low springwood content, are cooked under the same conditions by the sulphite process, difference in yield, bleach requirements, and strength properties result, the physical properties of the pulps covering nearly the entire range of the present commercial sulphite pulps. By increasing the cooking time in increments of 15 minutes and plotting the results against bleach requirement, it is possible by interpolation to compare the results at any given bleach requirement. Figure 6 shows the results thus obtained for a bleach requirement of 15 percent. It also shows the values for strength, milling time, and solid fraction corresponding to freeness values of 800 and 550. The following trends are evident:

At a maximum temperature of 145° C. about 15 minutes longer were required to produce pulp of the same bleach requirement from the wood having a low percentage of springwood than from the wood containing a high percentage. Lower maximum temperatures would, of course, increase this difference.

The highest yield was obtained from the fast growth wood containing a high percentage of springwood, and the lowest yield was obtained from the fast growth wood having a low percentage of springwood, accounted for by the presence of compression wood and other abnormal wood.

The highest unbleached color as measured by the blue reading was also obtained from the fast-growth wood containing a high percentage of springwood, and the lowest color from the fast-growth wood having a low percentage of springwood.

Greater absorbency and porosity are indicated by the low values obtained from the slow-growth wood and also from the wood having a low percentage of springwood.

The highest bursting strengths were obtained from the fast-growth wood having a high percentage of springwood and from the other extreme, slow-growth wood having a low springwood content.

The tearing strength, more than any other property, was dependent upon the springwood content, decreasing as the amount of springwood increased.
Effect of growth conditions in pulping of southern pine by the sulphite process.
The milling time was greatest for the fast-growth wood containing a high percentage of springwood and was least for the fast-growth wood having a low percentage. However, the milling time is probably the most variable factor in the pebble mill testing.

The solid fraction of the test sheets decreased with decreasing springwood content and also decreased with decreasing growth rate.

A comparison of the pulp from compression wood with that obtained from normal wood in the same log gave a 10 percent reduction in yield, a much darker unbleached color, and a much higher bleach requirement. Although the pulps from the normal wood required only 15 percent of bleach, the pulp from compression wood was practically unbleachable. Also, the compression wood pulp showed a reduction of approximately 50 percent in strength properties.

It was noted in many instances, particularly in the butt logs of the fast-growth wood, that decreases in yield, strength, and other properties were more than would likely be accounted for by the amount of compression wood present. An examination of this wood revealed, among other abnormalities, a high slope of the fibrils in the secondary layer of the fibers relative to the fiber axis. This effect is illustrated in the above data obtained from the sample of fast-growth wood of low springwood content which gave a low yield, color, and strength.

Evidence that the above differences in pulp properties resulting from different growth characteristics in the wood are carried through to the finished paper was obtained in experimental runs of pine newsprint, even though the sulphite pulp constituted only 20 percent of the furnish. The high tearing strength and high porosity exhibited by the pulp from the slow-growth wood of high summerwood content produced corresponding results in an appreciable degree in a newsprint paper made from them.

The data which have been presented in illustrating the effect of growth conditions are by no means complete. Later publications on this subject will elaborate and present in more detail the interesting facts which are being developed in this study.

It is merely intended to emphasize what is so increasingly evident: Conditions of growth do markedly affect pulp yield and pulp quality. As new situations in wood supply are faced, new means must be adopted to cope with the problem of maintaining quality. Approximately one-third of the entire pulp cost is in the wood. More care in selecting this material is essential if pulp uniformity is to be attained. Southern pine pulpwood shows the effects of growth condition to an accentuated degree and illustrates the point to a good advantage but the same problem confronts all pulp producers. Wood is not just wood but is a widely varying raw material. Cognizance must be taken of wood properties and competent methods devised to meet this situation with our basic raw material.

Literature Cited