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THE SUITABILITY OF AMERICAN WOODS
FOR PAPER PULP

By

SIDNEY D. WELLS, Engineer in Forest Products

and

JOHN D. RUE, In Charge of Section of Pulp and Paper
Forests Products Laboratory, Forest Service

CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Standard Pulping Methods</td>
<td>5</td>
</tr>
<tr>
<td>Experimental Procedure</td>
<td>11</td>
</tr>
<tr>
<td>Pulping Characteristics of Groups of Woods</td>
<td>17</td>
</tr>
<tr>
<td>Suitability of Individual Species for Pulping</td>
<td>21</td>
</tr>
<tr>
<td>Tables of Cooking and Strength Data</td>
<td>65</td>
</tr>
</tbody>
</table>
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CONTENTS

<table>
<thead>
<tr>
<th>Page</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Scope and objects of the investigation</td>
<td>1</td>
</tr>
<tr>
<td>The pulp wood situation</td>
<td>2</td>
</tr>
<tr>
<td>Standard pulping methods</td>
<td>5</td>
</tr>
<tr>
<td>Mechanical processes</td>
<td>5</td>
</tr>
<tr>
<td>Chemical processes</td>
<td>7</td>
</tr>
<tr>
<td>Experimental procedure</td>
<td>11</td>
</tr>
<tr>
<td>Equipment</td>
<td>11</td>
</tr>
<tr>
<td>Conduct of tests</td>
<td>11</td>
</tr>
<tr>
<td>Pulping characteristics of groups of woods</td>
<td>17</td>
</tr>
<tr>
<td>Softwoods</td>
<td>17</td>
</tr>
<tr>
<td>Hardwoods</td>
<td>20</td>
</tr>
<tr>
<td>Bark disposal</td>
<td>21</td>
</tr>
<tr>
<td>Suitability of individual species for pulping</td>
<td>21</td>
</tr>
<tr>
<td>Estimation of pulping value</td>
<td>21</td>
</tr>
<tr>
<td>Application of data to operating conditions</td>
<td>23</td>
</tr>
<tr>
<td>Summaries by species</td>
<td>25</td>
</tr>
<tr>
<td>1. Spruces</td>
<td>25</td>
</tr>
<tr>
<td>2. Pines</td>
<td>29</td>
</tr>
<tr>
<td>3. Firs</td>
<td>38</td>
</tr>
<tr>
<td>4. Hemlocks and other conifers</td>
<td>42</td>
</tr>
<tr>
<td>5. Hardwoods—diffuse porous</td>
<td>47</td>
</tr>
<tr>
<td>6. Hardwoods—ring porous</td>
<td>57</td>
</tr>
<tr>
<td>7. Miscellaneous species</td>
<td>62</td>
</tr>
<tr>
<td>8. Chilean woods</td>
<td>64</td>
</tr>
<tr>
<td>Tables of cooking and strength data</td>
<td>65</td>
</tr>
</tbody>
</table>

INTRODUCTION

SCOPE AND OBJECTS OF THE INVESTIGATION

In 1906 the Forest Service commenced, at its pulp and paper laboratory, then located in South Boston, Mass., a study of the pulping characteristics of American woods for the manufacture of paper pulp. Since that time the work has been continued as one of the major research projects of the service. This bulletin is a report of what may be termed the general or "extensive" phase of the investigation, covering all available species which seemed to offer possibilities.

Most of the 94 species studied have been tested by the soda, sulphate, and sulphite processes. Twenty-two have also been tested by the mechanical process in the commercial sized experimental unit operated at Wausau, Wis., from 1911 to 1914, and

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1 The investigation herein reported was started by the Forest Service in 1906-07 under the supervision of H. S. Bristol, at South Boston, Mass. In 1907 the work was transferred to Washington, D. C., where Edwin Sutrenmeister was in charge, and since 1910 has been carried on at the Forest Products Laboratory, Madison, Wis. The following have been successively in charge of the section of pulp and paper at the laboratory: H. E. Surface, O. L. E. Weber, Otto Kress, and John D. Rue. Pulping experiments have been supervised by: Mechanical process, J. H. Thickens and G. C. McNaughton; soda and sulphate processes, R. E. Cooper and Sidney D. Wells; sulphite process, R. E. Cooper, C. S. Gwynne, S. E. Lunak, V. F. Edwards, and R. N. Miller. Throughout the investigation the beater and paper-machine runs have been superintended by J. J. Laing.
reported upon in Department of Agriculture Bulletin No. 343, "Ground-Wood Pulp," by J. H. Thickens and G. C. McNaughton. A small compilation of the chemical pulping experiments up to 1912, by H. E. Surface, was published as an unnumbered Forest Service bulletin entitled "Paper pulps from Various Woods." Since 1912 articles on the subject have appeared from time to time in trade and technical journals, but this bulletin is the first attempt to present a report of the survey as a whole.

The work had two objects: (1) To determine the suitability for paper manufacture of species growing on the national forests, so that the Forest Service might be able to guide timber sales efforts intelligently; and (2) to ascertain the relative merits of species not in common use but available to established pulp mills, so that suitable species might be found to supplement the waning supplies of spruce. The results of the investigation of western species have already been used in consummating national forest timber sales have influenced the establishment not only of pulp mills dependent on national forest timber but also of mills dependent on private holdings. The severe shortage of materials experienced by the paper industry in 1919 emphasized the importance of supplementing the supplies of spruce, and it may be profitable to survey briefly conditions as they are now in order to bring out more clearly the possible application of this part of the experimental work.

THE PULP WOOD SITUATION

According to the latest available statistics, one group of conifers, the spruces, supply 55 per cent, and three groups, the spruces, firs, and hemlocks, supply 77 per cent of the wood consumed by the pulp industry of the United States. Table 1 shows the proportion of the material that principal pulp woods supply for each pulping process.

Table 1.—Pulp wood consumption, by species and processes of manufacture, for the United States, 1922

<table>
<thead>
<tr>
<th>Species pulped</th>
<th>Mechanical process</th>
<th>Sulphite process</th>
<th>Soda process</th>
<th>Sulphate process</th>
<th>Totals by species</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cords</td>
<td>Per cent</td>
<td>Cords</td>
<td>Per cent</td>
<td>Cords</td>
</tr>
<tr>
<td>Spruces</td>
<td>1,303,169</td>
<td>87.3</td>
<td>1,150,600</td>
<td>59.7</td>
<td>1,121</td>
</tr>
<tr>
<td>Firs</td>
<td>89,557</td>
<td>6.0</td>
<td>234,415</td>
<td>1.1</td>
<td>38,378</td>
</tr>
<tr>
<td>Hemlocks</td>
<td>65,776</td>
<td>4.4</td>
<td>763,980</td>
<td>28.8</td>
<td>3,671</td>
</tr>
<tr>
<td>Poplars</td>
<td>8,118</td>
<td>0.5</td>
<td>2,135</td>
<td>1.1</td>
<td>311,488</td>
</tr>
<tr>
<td>Yellow poplar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>102,200</td>
</tr>
<tr>
<td>Guns</td>
<td>52,058</td>
<td>6.6</td>
<td></td>
<td></td>
<td>52,058</td>
</tr>
<tr>
<td>Pines</td>
<td>25,240</td>
<td>1.7</td>
<td>9,665</td>
<td>0.3</td>
<td>117,094</td>
</tr>
<tr>
<td>Larches</td>
<td>2,100</td>
<td>1.1</td>
<td>10,599</td>
<td>0.4</td>
<td>55,565</td>
</tr>
<tr>
<td>All other species</td>
<td>90</td>
<td>0.6</td>
<td>71,625</td>
<td>2.6</td>
<td>199,356</td>
</tr>
<tr>
<td>Total by processes</td>
<td>1,494,027</td>
<td>26.9</td>
<td>2,765,279</td>
<td>49.9</td>
<td>786,968</td>
</tr>
</tbody>
</table>

1 Based on Table 4, "Pulp wood consumption and wood-pulp production, 1922," Bureau of the Census.
2 Includes slabs and other mill waste. Species are basswood, beech, birch, maple, chestnut, cottonwood, Douglas fir, white pine, and willow.
Over 80 per cent of all pulp wood in the United States is consumed in mills situated in the New England, Lake, and Middle Atlantic States. The stand of spruce, fir, and hemlock in this territory is estimated at 3 per cent of the total timber stand of the United States and at about 27 per cent of the total stand of the species mentioned.

As a result of these conditions, pulp wood is now being transported by land and water to many mills over distances of from 500 to 1,000 miles. Imports from the Dominion of Canada are very large. In 1922 Maine depended on Canada for 13 per cent of her spruce, New Hampshire for 35, New York for 64, Pennsylvania for 99, and Michigan for 33 per cent. In addition, 53 per cent of the poplar used by United States mills was imported from Canada. On account of the limited supply and the increased influence of the transportation factor, the average cost of spruce pulp wood f. o. b. mill in the Northeastern States in 1922 was between $15 and $28 a cord, depending on whether it was rough, peeled, or rossed.

With steadily rising pulp wood costs the less efficient mills, without their own timber supply, will eventually be forced out of business. It is only by improvement in operation, in processes, in the handling of timber lands, and by the use of other species, that even the better-equipped and managed of the present mills can continue to operate. The use of hemlock by the Wisconsin mills is an example of what can be done with wood once considered unsuitable for pulp.

The necessity for the older mills to turn to other species and to grow their own pulp wood is indicated by United States Department of Agriculture Bulletin 1241, "How the United States Can Meet Its Present and Future Pulp-wood Requirements." It is there stated that because pulp wood use is confined so largely to a small group of species, over one-half of the 9,148,000 cords required to manufacture the United States paper requirements in 1922 were imported as pulp wood, pulp, or paper. Many States are forced to rely upon wood from without their boundaries. In New England and the Lake States, where much of the industry is concentrated, imports of pulp wood and wood pulp are being relied upon to a greater and greater extent to maintain production levels. Throughout the pulp and paper manufacturing regions there are insufficient forest resources to maintain production for an extended period without an intensive program of timber growing, the elimination of waste, a general tightening up in the manufacturing processes, and the extensive use of other than commonly used species for pulp wood.

A study of the distribution of the stand of timber in the United States by species will indicate the supply of pulp wood available for existing mills and what could be added by the use of additional species. Table 2 shows such distribution as accurately as it can be ascertained with the information at present available.
Table 2.—Total stands of timber of principal kinds suitable for pulp, in millions of cords, by regions

<table>
<thead>
<tr>
<th>Species of timber</th>
<th>New England</th>
<th>Middle Atlantic</th>
<th>Lake</th>
<th>Central</th>
<th>South Atlantic</th>
<th>Lower Mississippi</th>
<th>Rocky Mountain</th>
<th>Pacific coast</th>
<th>Total United States</th>
<th>South east Alaska</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sulphite, mechanical, and sulphate pulp:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spruce and fir</td>
<td>1 85.5</td>
<td>14.0</td>
<td>17.1</td>
<td>3.4</td>
<td>3.4</td>
<td>85.5</td>
<td>205.1</td>
<td>414.0</td>
<td>45.3</td>
<td></td>
</tr>
<tr>
<td>Hemlock</td>
<td>6.4</td>
<td>23.9</td>
<td>51.3</td>
<td>19.7</td>
<td>6.4</td>
<td>2.5</td>
<td>200.9</td>
<td>311.1</td>
<td>121.4</td>
<td></td>
</tr>
<tr>
<td>Jack pine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>91.9</td>
<td>37.9</td>
<td>106.8</td>
<td>23.1</td>
<td>9.8</td>
<td>88.0</td>
<td>406.0</td>
<td>763.5</td>
<td>166.7</td>
<td></td>
</tr>
<tr>
<td>Soda pulp:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspen and cottonwood</td>
<td>6.4</td>
<td>2.2</td>
<td>27.3</td>
<td>10.7</td>
<td>5.1</td>
<td>21.4</td>
<td>12.8</td>
<td>85.9</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Birch, beech, maple</td>
<td>29.0</td>
<td>80.3</td>
<td>136.8</td>
<td>102.6</td>
<td>16.2</td>
<td>16.3</td>
<td>381.2</td>
<td>.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yellow poplar</td>
<td>.7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basswood</td>
<td>2.6</td>
<td>2.2</td>
<td>17.1</td>
<td>10.7</td>
<td>1.7</td>
<td>34.3</td>
<td>168.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red gum</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black and tupelo gums</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>38.0</td>
<td>87.4</td>
<td>181.2</td>
<td>194.0</td>
<td>144.4</td>
<td>190.8</td>
<td>12.8</td>
<td>848.6</td>
<td>.3</td>
<td></td>
</tr>
<tr>
<td>Sulphate pulp:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Southern yellow pine</td>
<td>1.1</td>
<td>15.1</td>
<td>21.4</td>
<td>433.0</td>
<td>487.2</td>
<td>977.8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tamarack and larch</td>
<td>.9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>White and sugar pines</td>
<td>35.0</td>
<td>22.2</td>
<td>21.4</td>
<td>2.5</td>
<td>4.3</td>
<td>128.2</td>
<td>141.0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Western yellow pine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>37.0</td>
<td>37.3</td>
<td>42.8</td>
<td>23.9</td>
<td>457.3</td>
<td>487.2</td>
<td>341.9</td>
<td>491.4</td>
<td>918.8</td>
<td></td>
</tr>
<tr>
<td>Regional total</td>
<td>166.9</td>
<td>162.6</td>
<td>330.8</td>
<td>241.0</td>
<td>611.5</td>
<td>678.0</td>
<td>442.7</td>
<td>897.4</td>
<td>530.9</td>
<td>167.0</td>
</tr>
<tr>
<td>Regional total per cent.</td>
<td>7.9</td>
<td>8.4</td>
<td>8.9</td>
<td>18.3</td>
<td>21.6</td>
<td>15.5</td>
<td>4.6</td>
<td>11.8</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>


1 Contains no allowance for deduction in stand by spruce bud worm, which amounts to 40 per cent or about 27½ million cords in Maine.

In order to make clearer the advantages to be gained by extending the pulp-wood supply to other species, Tables 3 and 4 are presented. These show the amounts of pulp wood consumed in each process in the United States in 1922 and the production of paper by types, together with observations as to the species pulped and the pulps or other raw materials used in the various types of paper.

Table 3.—Pulp wood consumed in the United States, 1922, by processes

<table>
<thead>
<tr>
<th>Pulping process</th>
<th>Cords consumed 1922 1</th>
<th>Species required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical</td>
<td>1,494,027</td>
<td>Easily ground, white, long-fibered species such as spruces and firs.</td>
</tr>
<tr>
<td>Sulphite</td>
<td>2,765,279</td>
<td>Nonresinous long-fibered species such as spruces, firs, and hemlocks. Process may be applied to many of the pines and hardwoods.</td>
</tr>
<tr>
<td>Soda</td>
<td>786,968</td>
<td>Easily pulped, easily bleached hardwoods, such as poplars, birches, maples, beech, and gums. Process may be applied to the conifers. Any species of conifer. Process may be applied with advantage to hardwoods also.</td>
</tr>
<tr>
<td>Sulphate</td>
<td>502,508</td>
<td></td>
</tr>
</tbody>
</table>

1 From Table 1.
On examination of the tables it can be seen how, by the more extended employment of bleached sulphate in book and of semi-bleached or unbleached sulphate in wrapping and bag paper—in many cases with improved results—the use of the more plentiful and less commonly used species may be greatly increased.

Experimental work at the Forest Products Laboratory has demonstrated that the sulphate process applied to the southern pines, in combination with the gums and similar hardwoods of the South, will yield pulps which may be bleached by proper methods and used in the manufacture of book, magazine, and similar high-grade printing papers at reasonable manufacturing cost. The value of this experimental work is emphasized by the fact that the South is advantageously situated in respect to nearness to the publishing centers and availability of fuel, chemicals, and other raw materials. Not only has it enormous quantities of suitable woods available, but owing to climatic conditions the amount of wood which can be grown in the South is from 35 to 40 per cent of the potential productivity of the entire area of forest land in the United States. The growing capacity of unit areas is also very high.

On the other hand, for pulps which require spruce, hemlock, and fir, woods of established value in making paper, there are stands in Oregon, Washington, and Alaska sufficient, under proper timber-growing methods, to supply approximately 5,000,000 cords a year. It has been due largely to economic conditions that the extensive development of these pulp resources has so long been retarded. Up to recent years the only outlet for mills on the Pacific coast has been the local consumption of paper and export to foreign countries. With the rapidly increasing cost of wood in the East greater margins will be created to allow for the cost of transporting pulp and paper from the Pacific coast to other parts of the United States; and such shipments will continue to be an increasing factor in the general situation.

**STANDARD PULPING METHODS**

At the present time there are two main classes of pulp made from wood, mechanical and chemical.

**MECHANICAL PROCESS**

Mechanical pulp is made by simply grinding the wood to pulp on a stone, enough water being used to control the temperature. The
wood for grinding is first cut into bolts of the desired length and the bark completely removed. The clean bolts are then ground either hot or cold, according to the character of pulp desired. The difference in the results obtained is largely in the "freeness," or the rate at which water will drain from the pulp on the paper machine. Water will drain away much faster from hot-ground pulp than from cold-ground pulp. Hot grinding, the American practice, is done by adding only sufficient water at the grindstone to keep the temperature of the pulp in the neighborhood of 150° F. In cold grinding, which is more commonly employed in Europe, much larger quantities of water are used, with a resulting temperature very little above the temperature of the water. Some ground-wood pulp is manufactured from wood that has been steamed or boiled before grinding, but the quantity is so small that it is not considered in this publication. The reader is referred to Department Bulletin No. 343, "Ground-Wood Pulp," for more specific information and reports of tests on various species in the manufacture of mechanical pulp.

In the mechanical process, since very little, if any, chemical action takes place, the physical properties of the wood are of first consideration. One of the most important qualities is the color of the wood, which is directly reflected in the color of the pulp obtained. Only the lightest colored woods can be considered for use in the manufacture of newsprint, for which almost all mechanical pulp is utilized. Although the mechanical process is very destructive to the fibers of the wood and their average length is seriously reduced in the operation, nevertheless long-fibered woods, such as spruce, are desired, since the longer the fibers present in the wood the greater the average fiber length of the pulp obtained.

The hardness and structure of the wood are reflected in the power consumed in grinding pulp of standard strength and in the amount of disintegration caused by the action of the stone in tearing the fibers from the mass. Hardwoods with a dense medullary structure consume from two to three times as much power as softer, lighter woods, and their fibers are to a great extent torn to pieces. As a rule, therefore, their use is barred. Woods which give soft, spongy pulps are also undesirable, as are woods which yield pulps composed of mixtures of fine slivers and débris. A measure of control, however, can be exerted over pulp properties by the manner of dressing the stone.

The size and shape of the pieces of wood used in grinding are of considerable importance in the mechanical process with the customary equipment. The greater the number of pieces of wood fed to the grinders per ton of pulp the greater the number of splinters, since from each piece there is usually a thin slab which passes from the pocket without further reduction after a certain minimum thickness is reached.

Specific gravity is an important consideration, because the higher the specific gravity the greater the weight of pulp obtained from a cord.

The pitch content is also important, since, under given conditions, more than a certain amount will cause trouble in the subsequent paper-making operations.

Discolorations in the wood caused by fungi, molds, or bacteria are usually reflected in the pulp obtained. The durability of the wood used in the mechanical process, i.e., its resistance to the organisms of
decay, is, therefore, of great importance. Not only the color but also the physical properties of the pulps, as well as their paper-making qualities, are seriously influenced by decay, which often causes considerable loss of material. Decay has more serious effects in this process than in any of the chemical processes.

**CHEMICAL PROCESSES**

Of the chemical processes the sulphite, soda, and sulphate processes are standard, and all the wood pulp made by chemical means on a commercial scale is the product of one of the three.

**SULPHITE PROCESS**

The sulphite process is by far the most important from the standpoint of annual tonnage. It consists of the removal of the incrusting matter in the wood by means of a solution of sulphur dioxide in an aqueous solution of calcium or magnesium bisulphite or a mixture of the two. The pulp is usually light colored and in many products may be used without bleaching. The wood is first barked and then chipped to suitable dimensions to permit proper contact and circulation of the cooking liquor during digestion. As the liquor will not dissolve bark, great care must be exercised in the barking operation; for this reason the size and shape of the wood as received at the mill must be taken into consideration. Round wood down to 3 inches in diameter is used in some instances, but the cost of removing the bark and the relatively large proportion of wood lost in the operation have greatly retarded the use of small material. The same reason has discouraged the use of mill waste from lumbering or woodworking operations, and the quantity of such material reported as having been used in the manufacture of paper pulp in 1920 was actually less than that reported in 1914.

Decay often gives considerable trouble in the manufacture of sulphite pulp, since certain fungi prevent the wood from being completely acted on by the liquor. Discolorations in the wood appear in the pulp, the wood affected is incompletely pulped, and trouble from uncooked portions is encountered.

On account of the acid character of the process, resinous matter, tannins, and other extractive substances are not dissolved, and their presence, by resisting the penetration of the cooking liquor, often prevents complete pulping. In the mill they cause trouble on account of shives or excessive screenings. The pitch particles themselves, either alone or combined or agglomerated with the cooking base, create difficulties on the paper machine in numerous ways familiar to the paper maker.

The spruces, firs, and hemlocks are all capable of reduction by the sulphite process without undue trouble from pitch. Most of the pines, cedars, larches, cypresses, and sequoias, and Douglas fir are too resinous or contain other extractive matter which retards the penetration of the cooking liquor. A few of the pines are used to a limited extent, and it seems probable that with more definite information in regard to the fundamental scientific principles governing the sulphite process the rapidly growing and more easily pulped species such as jack pine, loblolly pine, and Virginia pine will come into more general use, especially when the wide range of some of
them is considered. Although some of these species may give as high as 6 per cent screenings on account of knots or small local portions more resinous than the rest of the wood, the uncooked portions can usually be successfully removed with standard equipment, leaving relatively clean pulps of satisfactory color. The pines of the white pine series that were tested (northern white pine, sugar pine, limber pine, and piñon) can not be satisfactorily pulped, even though on inspection they show less resin than the other pines mentioned above. Although the amounts of screenings are small, the pulps contain particles of partially cooked wood which pass through the screen plate slots with the fiber and cause the pulps to be speckly and of poor color. Not only do the extractive substances affect penetrability, but often the structure of the wood itself has considerable influence, and many species show differences in cooking which can be attributed only to this cause.

Although the fibers are separated by the sulphite process without reduction in ultimate length, fiber length is of such importance that, as a rule, only long-fibered woods are pulped in this way. The color is usually of minor significance, except in the case of deeply colored woods, whose coloring substances are often not dissolved in the cooking operation, so that the color of the pulps is affected.

Specific gravity of the wood has the same importance in affecting the yield per cord as in the case of ground-wood pulp, and it also directly affects the quantity of wood per digester charge and thereby the output of the mill.

The bleachability of the pulp and the ease or difficulty of hydration are important considerations. They both depend to a considerable extent on the cooking conditions.

Although the soda process is generally used on hardwoods on account of the greater opacity of the pulp, the sulphite process produces from many species (such as the birches, maples, and gums) greater yields of pulp that can be bleached with much lower consumption of bleach.

SODA PROCESS

The soda process is almost entirely devoted to the pulping of hardwoods. When the Forest Service pulping experiments were started the species in commercial use were the true poplars, yellow poplar, the soft maples, basswood, and possibly a few other of the most easily pulped species. At present, by the use of improved methods, birches, hard maples, gums, beech, chestnut, sycamore, and numerous others are also being pulped. The pulp is usually bleached. It holds loading materials and takes coatings well. It also possesses soft, bulky, and absorbent qualities which, when it is properly mixed with bleached or unbleached sulphite, give an opaque, well felted, and well formed sheet of paper highly esteemed by the printer. Soda pulp is consequently used largely in the manufacture of book, magazine, lithograph, and other papers for printing purposes, and considerable quantities are employed in the manufacture of blotting paper.

The soda process can be applied without difficulty to coniferous woods and to a limited extent is so applied. Usually, however, the greater strength and toughness of pulp produced by the sulphate process from the same wood has limited the use of the soda process for producing strong pulps. Soda pulp from conifers is hard to bleach, and the process is, therefore, little used for bleached pulp
from such species. It is not, however, handicapped by the disagreeable odor characteristic of sulphate mills, which is probably the reason it has not been supplanted entirely by the more recent process.

The soda process consists of the disintegration and solution of the incrusting matter in the wood by means of an aqueous solution of sodium hydroxide, the wood being prepared in a manner similar to that used in the sulphite process. It is not so important, however, to remove entirely the bark, knots, or decayed portions, because under proper conditions the soda liquor disintegrates them. Nevertheless, the wood is usually peeled so as to avoid the consumption of alkali in the solution of the bark or of decayed portions which yield no pulp.

Pitch is not objectionable in the soda process, as it is readily dissolved in the cooking liquor. Tannins, however, consume caustic soda and make necessary the use of larger quantities. Also tannins not removed (by means of water extraction) before the cooking operation usually darken the pulp and render it much more difficult to bleach.

Although fiber length is important, it is not so much so as in the sulphite process, because soda pulp is used almost entirely in the manufacture of printing papers where printing qualities outweigh strength. The color of the wood is also a minor factor, since the coloring matter is in many cases dissolved by the liquor and removed from the pulp. With some woods, however, the coloring matter persists throughout the cooking action, and is apparent in the pulp.

The specific gravity of the wood has the same importance as in the sulphite and mechanical processes.

**Sulphate Process**

The sulphate process, only recently introduced into America, was first used in continuous commercial operation in Quebec in 1907. Since that time the production of sulphate pulp has increased very rapidly. In 1914 about 52,000 tons were produced in the United States. By 1922 production had risen to over 243,000 tons. The reasons for this increase are the larger yields of pulp and the greater strength of the paper.

It is a modification of the soda process in which the active ingredients of the cooking liquor consist of caustic soda and sodium sulphide, usually in the proportion of 2 to 1. Its use is confined almost entirely to conifers. There is no reason why it should not be applied to hardwoods; with the majority of these species easier bleaching pulps are obtained with equal yields. The unbleached pulp from conifers is commonly used in the manufacture of kraft wrapping paper or, in combination with waste papers, for high-test container board.

Although the practice of bleaching sulphate pulp is not very prevalent, work at the Forest Products Laboratory has demonstrated that by using modified methods of bleaching with the standard solutions, and with quantities of bleaching powder not in excess of common commercial practice, very satisfactory results may be obtained. Although the pulp obtained by ordinary methods of bleaching is yellow and does not approach the brilliant white characteristic of bleached sulphite pulp, pulp comparable in brightness is obtained by the modified methods. The opacity of the bleached pulp is
usually greater than that of bleached sulphite pulp. It thus becomes possible to obtain from sulphite pulp papers having printing properties superior to those of papers from bleached sulphite pulp, unless the latter is combined with bleached soda pulp from hardwoods.

The main drawback of the sulphite process lies in the disagreeable odors which characterize it; on this account the mills are usually located on the fringes of population.

The wood is usually barked, although in some mills this step is omitted and any fragments of bark which pass the screening operation are dissolved in the digester. The consequent high consumption of cooking liquor without any return, however, makes it more economical to bark the wood before chipping. Decayed wood does not affect the quality of the pulp as it does in the sulphite process,

![Diagram](image)

**Fig. 1.—Digester used for alkaline cooks prior to 1916, and for sulphite cooks prior to 1911**

but it very seriously affects the yields and consumption of alkali to a ton of pulp. The durability of the wood used is therefore an important consideration from the economic standpoint.

Charred wood is objectionable in this process (as well as in the others), since the particles of carbon survive the cooking operation and appear in the pulp. Pitch, fats, or waxes occasion no trouble, these being readily soluble in the sulphate liquors and furnishing to the cooking liquor combustible matter which helps later in the recovery of the soda.

The penetrability of the wood is a considerable factor in the quality and uniformity of the pulp. The length of the fibers is of major importance, as sulphate pulps are ordinarily used for purposes where strength is required. The color of the wood is a secondary consideration except in a few instances where the coloring matter survives the cooking operations. The specific gravity of the wood is directly reflected in the yield of pulp obtained per cord.
EXPERIMENTAL PROCEDURE  

In the course of the Forest Service experiments several digesters were used for making the cooks. In Figure 1 is shown the lead-lined digester which was used until 1911. From 1911 to 1916 the same equipment, with the lead lining removed, was used for the alkaline cooks only, the equipment shown in Figure 2 being used for the sulphite cooks. Since 1916 the equipment shown in Figures 3 and 4 has been used for the sulphite cooks and that in Figures 5 and 6 for the alkaline cooks. All these digesters held between 60 and 70 gallons, and all gave similar results. All were stationary with the exception of the one shown in Figures 3, and 4, which could be revolved on trunnions to obtain positive circulation. In all the digesters except the earliest, indirect heat as well as direct steam was supplied in order to overcome the excessive radiation characteristic of small-sized apparatus. By that means condensation was obtained comparable in amount to that in commercial equipment. The chipper used was of the usual disk type but of laboratory size. Figure 7 shows the semicommercial beater used, and Figure 8 the combination 12-inch cylinder and Fourdrinier paper machine on which the paper samples were made. Operating in conjunction with the paper machine was a Jordan refining engine of laboratory size, so that the results obtained were comparable to mill practice.

CONDUCT OF TESTS

The chips, cut five-eighths along the grain, were carefully screened to remove sawdust, bark, large pieces, and large knots. Before charging, the moisture content of the wood was determined and the quantities of cooking chemicals and the volume of liquor were calculated from the oven-dry weight of the wood. During cooking,

pressure and temperature were carefully regulated and observations recorded at 15-minute intervals. At the end of the cooking period samples of liquor were taken and, in the case of sulphite cooking, analysis was made and color observed. The digester contents were then discharged into the blow pit. There the pulp was washed free of cooking liquor and drained. In the case of impregnation cooks the digester was completely filled with chips and cooking liquor and the cover bolted on. The pressure tank, I in Figure 3, was next filled, and, by forcing steam into the top of I and opening the connections therefrom to the digester, hydrostatic pressure was set up around the chips, forcing the liquor into them until at the end of from 15 to 30 minutes at a pressure of from 100 to 110 pounds to the square inch they were well penetrated. The digester was then inverted, the valves in the relief pipe L and pipe O (fig. 4) were opened, and the proper quantity of liquor was blown back
into tank X from which it was originally obtained, steam being admitted to the digester above it to supply the force necessary. By weighing and analyzing the liquor before impregnation and during its return the quantity of chemical remaining in the digester could be determined and controlled. After sufficient liquor had been returned to the tank to leave the desired quantity in the digester, the connections referred to were closed, water was added if necessary to give the desired volume in the digester, and the cook was carried on in the usual manner. The usual procedure applied also to screening and other treatments.  

After the pulp was completely washed and drained it was hydraulically pressed, opened up in a swing-hammer shredder, and weighed and sampled for moisture. From the moisture determination the

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bone-dry weight of the pulp was ascertained, and thereby the yield. The pulp was then passed through a diaphragm screen and the screenings were dried and weighed. Samples of the pulp were saved for bleach tests; the rest was treated in the beater to produce the desired quality of waterleaf paper and was run over the machine. Standard strength tests were made on the papers obtained.
Bleaching tests were made by treating various samples of equal weight with quantities of bleach ranging from 5 to 40 per cent of
the weight of the pulp, according to requirements estimated from preliminary observations. Forty grams of pulp in 1,600 cubic centimeters of total liquid were used in each test. The mixture

was kept in constant agitation at a temperature of between 100° and 110° F. until the bleach was exhausted. Hand sheets were made of the pulp, and the measure of bleaching was taken as the quantity of bleach beyond which no improvement in color was observable.

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**Fig. 6.—Digester used for alkaline cooks since 1916 (end elevation)**
The species tested are listed in Table 5, together with their botanical names and the locality where the material obtained was grown.

### Table 5.—Species tested, and locality of growth

<table>
<thead>
<tr>
<th>Common name</th>
<th>Botanical name</th>
<th>Where grown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Softwoods:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black spruce</td>
<td><em>Picea mariana</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Blue spruce</td>
<td><em>Picea pungens</em></td>
<td>Colorado.</td>
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<td>Engelmann spruce</td>
<td><em>Picea engelmannii</em></td>
<td>Idaho.</td>
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<td>Norway spruce</td>
<td><em>Picea abies</em></td>
<td>Tennessee.</td>
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<tr>
<td>Red spruce</td>
<td><em>Picea rubra</em></td>
<td>Oregon.</td>
</tr>
<tr>
<td>Sitka spruce</td>
<td><em>Picea sitchensis</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>White spruce</td>
<td><em>Picea glauca</em></td>
<td>Colo.-Okla.-Tex.</td>
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<tr>
<td>Limber pine</td>
<td><em>Pinus flexilis</em></td>
<td>California.</td>
</tr>
<tr>
<td>Sugar pine</td>
<td><em>Pinus edulis</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Northern white pine</td>
<td><em>Pinus banksiana</em></td>
<td>Do.</td>
</tr>
<tr>
<td>Jack pine</td>
<td><em>Pinus taeda</em></td>
<td>Virginia and South Carolina.</td>
</tr>
<tr>
<td>Loblolly pine</td>
<td><em>Pinus contorta</em></td>
<td>Louisiana.</td>
</tr>
<tr>
<td>Lodgepole pine</td>
<td><em>Pinus palustris</em></td>
<td>California.</td>
</tr>
<tr>
<td>Monterey pine</td>
<td><em>Pinus rigida</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Norway pine</td>
<td><em>Pinus radiata</em></td>
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</tr>
<tr>
<td>Pitch pine</td>
<td><em>Pinus resinosa</em></td>
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</tr>
<tr>
<td>Pond pine</td>
<td><em>Pinus sylvestris</em></td>
<td>Florida.</td>
</tr>
<tr>
<td>Sand pine</td>
<td><em>Pinus virginiana</em></td>
<td>Iowa.</td>
</tr>
<tr>
<td>Scotch pine</td>
<td><em>Pinus echinata</em></td>
<td>Maryland and Tennessee.</td>
</tr>
<tr>
<td>Virginia pine</td>
<td><em>Pinus caribaea</em></td>
<td>Louisiana.</td>
</tr>
<tr>
<td>Short-leaf pine</td>
<td><em>Pinus ponderosa</em></td>
<td>Oregon.</td>
</tr>
<tr>
<td>Slash pine</td>
<td><em>Pseudotsuga menziesii</em></td>
<td>Montana.</td>
</tr>
<tr>
<td>Western yellow pine</td>
<td><em>Abies fraseri</em></td>
<td>Washington.</td>
</tr>
<tr>
<td>Alpine fir</td>
<td><em>Abies grandis</em></td>
<td>Oregon.</td>
</tr>
<tr>
<td>Balsam fir</td>
<td><em>Abies magnifica</em></td>
<td>California.</td>
</tr>
<tr>
<td>Lowland white fir</td>
<td><em>Abies amabilis</em></td>
<td>Washington.</td>
</tr>
<tr>
<td>Noble fir</td>
<td><em>Abies concolor</em></td>
<td>California and Oregon.</td>
</tr>
<tr>
<td>Red fir</td>
<td><em>Pseudotsuga taxifolia</em></td>
<td>California.</td>
</tr>
<tr>
<td>Silver fir</td>
<td><em>Tsuga canadensis</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>White fir</td>
<td><em>Tsuga heterophylla</em></td>
<td>Washington.</td>
</tr>
<tr>
<td>Douglas fir</td>
<td><em>Larix laricina</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Carolina hemlock</td>
<td><em>Larix occidentalis</em></td>
<td>Montana.</td>
</tr>
<tr>
<td>Eastern hemlock</td>
<td><em>Libocedrus de数码tens</em></td>
<td>California.</td>
</tr>
<tr>
<td>Western hemlock</td>
<td><em>Chamaecyparis lawsoniana</em></td>
<td>Oregon.</td>
</tr>
<tr>
<td>Tamarack</td>
<td><em>Chamaecyparis thyoides</em></td>
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<tr>
<td>Western larch</td>
<td><em>Juniperus virginiana</em></td>
<td>Arkansas.</td>
</tr>
<tr>
<td>Incense cedar</td>
<td><em>Thuja plicata</em></td>
<td>Washington.</td>
</tr>
<tr>
<td>Port Orford cedar</td>
<td><em>Taxodium distichum</em></td>
<td>California.</td>
</tr>
<tr>
<td>Southern white cedar</td>
<td><em>Sequoia sempervirens</em></td>
<td>Washington.</td>
</tr>
<tr>
<td>Eastern red cedar</td>
<td><em>Populus tremuloides</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Western red cedar</td>
<td><em>Populus balsamifera</em></td>
<td>Montana.</td>
</tr>
<tr>
<td>Southwestern Redwood</td>
<td><em>Populus deltoides</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Redwood</td>
<td><em>Populus canadensis</em></td>
<td>Minnesota.</td>
</tr>
<tr>
<td>Hardwoods (diffuse-porous):</td>
<td><em>Populus grandidentata</em></td>
<td>West Virginia.</td>
</tr>
<tr>
<td>Aspen</td>
<td><em>Lirioidendron tulipifera</em></td>
<td>Wisconsin.</td>
</tr>
<tr>
<td>Balsam poplar</td>
<td><em>Acer negundo</em></td>
<td>Missouri.</td>
</tr>
<tr>
<td>Eastern cottonwood</td>
<td><em>Acer rubrum</em></td>
<td>Ohio.</td>
</tr>
<tr>
<td>Norway poplar</td>
<td><em>Acer saccharum</em></td>
<td>Washington.</td>
</tr>
<tr>
<td>Large-tooth aspen</td>
<td><em>Betula papyrifera</em></td>
<td>Canal Zone.</td>
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<tr>
<td>Yellow poplar</td>
<td><em>Betula lutea</em></td>
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<tr>
<td>Balsam poplar</td>
<td><em>Fagus grandifolia</em></td>
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<tr>
<td>Black willow</td>
<td><em>Nyssa sylvatica</em></td>
<td>Michigan.</td>
</tr>
<tr>
<td>Sandbar willow</td>
<td><em>Nyssa aquatica</em></td>
<td>New Hampshire.</td>
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<tr>
<td>Red alder</td>
<td><em>Liriodendron tulipifera</em></td>
<td>Pennsylvania.</td>
</tr>
<tr>
<td>Balsam poplar</td>
<td><em>Magnolia acuminata</em></td>
<td>South Carolina and Tennessee.</td>
</tr>
<tr>
<td>Box elder</td>
<td><em>Magnolia virginiana australis</em></td>
<td>Louisiana and Florida.</td>
</tr>
<tr>
<td>Red maple</td>
<td><em>Platanus occidentalis</em></td>
<td>Tennessee and South Carolina.</td>
</tr>
<tr>
<td>Sugar maple</td>
<td><em>Aesculus glabra</em></td>
<td>West Virginia.</td>
</tr>
<tr>
<td>Paper birch</td>
<td><em>Rhizopora mangle</em></td>
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<td>Yellow birch</td>
<td><em>Butia capitata</em></td>
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<td>Beech</td>
<td><em>Pseudotsuga menziesii</em></td>
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<tr>
<td>Black gum</td>
<td><em>Eucalyptus gunnii</em></td>
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<tr>
<td>Tupelo gum</td>
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</tr>
<tr>
<td>Red gum</td>
<td><em>Ostrya virginiana</em></td>
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<tr>
<td>Cucumber magnolia</td>
<td><em>Carpinus caroliniana</em></td>
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<td>Sweet bay</td>
<td><em>Nyssa macrophylla</em></td>
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<tr>
<td>Sycamore</td>
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<td>Butternut</td>
<td><em>Aesculus glabra</em></td>
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<tr>
<td>Ohio buckeye</td>
<td><em>Gleditsia triacanthos</em></td>
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</tr>
<tr>
<td>Mangrove</td>
<td><em>Robinia pseudoacacia</em></td>
<td>Florida.</td>
</tr>
</tbody>
</table>
The material was selected from localities, within the commercial range of the species, where average conditions existed. Representative specimens were taken and efforts were made to maintain the amounts of heartwood and sapwood in the chips at as nearly as possible the same proportions as would occur in the usual run of pulp wood at the mill.

The Chilean woods listed were tested in response to a request from the Department of State in 1913. The species studied were submitted by Alejandro Rosselot, of Santiago, Chile, and represented what he considered the most important Chilean species from the standpoint of paper manufacture. At a later date tests were made on pehuén (Araucaria arauocana) submitted by a Chicago lumber concern, the material having been obtained from a stand about 500 miles south of Mendoza, Argentina, on the eastern slope of the Andes. The species is native to both Argentina and Chile. The data here presented on South American species are not at all complete. Much more detailed information as to the extent of the stands of various species, paper consumption, transportation facilities, labor, fuel, water supply, etc., will be necessary before any application of the pulping data is warranted.

**PULPING CHARACTERISTICS OF GROUPS OF WOODS**

**SOFTWOODS**

All of the spruces tested are suitable for pulping by any of the processes and are capable of yielding pulp of the best quality. The main considerations with the spruces are the size, straightness, and density of the wood. Although they vary somewhat in fiber length, even the species with the shortest fiber are capable of producing pulp of the best quality.

The hemlocks are used in all chemical processes. Sulphite pulp from hemlock hydrates more readily than that from spruce and will

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**Table 5.—Species tested, and locality of growth—Continued**

<table>
<thead>
<tr>
<th>Common name</th>
<th>Botanical name</th>
<th>Where grown</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hardwoods (ring-porous):</strong></td>
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<td></td>
</tr>
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<td>Common catalpa</td>
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<td>Chestnut</td>
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<td>Hackberry</td>
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<td>Sassafras varifolium</td>
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<td>Rock elm</td>
<td>Ulmus racemosa</td>
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<td>Slippery elm</td>
<td>Ulmus fulva</td>
<td>Indiana</td>
</tr>
<tr>
<td>American elm</td>
<td>Fraxinus americana</td>
<td>Wisconsin</td>
</tr>
<tr>
<td>White ash</td>
<td>Quercus borealis maxima</td>
<td>Arkansas</td>
</tr>
<tr>
<td>Red oak</td>
<td>Quercus alba</td>
<td>Tennessee</td>
</tr>
<tr>
<td>White oak</td>
<td>Hicoria alba</td>
<td>Do.</td>
</tr>
<tr>
<td>Mockernut hickory</td>
<td>Robinia pseudoacacia</td>
<td>Virginia</td>
</tr>
<tr>
<td>Black locust</td>
<td>Allanthus altissima</td>
<td>Georgia</td>
</tr>
<tr>
<td><strong>Miscellaneous:</strong>*</td>
<td>Yucca ela</td>
<td>Pennsylvania</td>
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<tr>
<td>Soapweed</td>
<td>Sabal palmetto</td>
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<tr>
<td>Cabbage palmetto</td>
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<td>Louisiana</td>
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<tr>
<td><strong>Chilean woods:</strong></td>
<td>(?)</td>
<td>Chile</td>
</tr>
<tr>
<td>Olivillo</td>
<td>Laurelia aromatica</td>
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</tr>
<tr>
<td>Laurel</td>
<td>Nothofagus dombeyl</td>
<td>Do.</td>
</tr>
<tr>
<td>Coigue</td>
<td>Persea lingue</td>
<td>Do.</td>
</tr>
<tr>
<td>Lingie</td>
<td>Nothofagus obliqua</td>
<td>Do.</td>
</tr>
<tr>
<td>Roble pellin</td>
<td>Quillaja supinaria</td>
<td>Do.</td>
</tr>
</tbody>
</table>

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not make paper of quite as great strength. The unbleached pulp is
darker and requires more bleach. Western hemlock is much more
easily pulped than eastern hemlock, and the pulp more nearly
resembles that from spruce. Western hemlock is used to a certain
extent in the manufacture of mechanical pulp, but the power require-
ments to produce pulp of the same strength as spruce are somewhat
greater; or, if pulp is produced with the same power consumption,
a weaker pulp requiring more sulphite in the manufacture of standard
newsprint is obtained.

The firs can be used in all the processes. They produce pulp very
similar to that from spruce in practically every characteristic. With

red fir, however, both the sulphite and mechanical pulps are darker
colored, and the sulphite is more difficult to bleach.

As to the pines, general statements can not be made with the same
assurance. Lodgepole pine and western yellow pine have been used
successfully in extensive experiments in the manufacture of mecha-
nical pulp, the color of which was satisfactory and the strength, power
consumption considered, closely comparable to that of spruce.
Under the sulphite process, jack pine, loblolly pine, lodgepole pine,
Norway pine, pond pine, sand pine, and Virginia pine yielded pulp
of very fair quality, capable of bleaching with reasonable quantities
of chemical. In the case of loblolly pine, lodgepole pine, Norway
pine, sand pine, and Virginia pine the uniformity of the digestion

Fig. 7.—Beater of semicommercial type used in the pulping experiments
was very satisfactory. With jack pine and pond pine the screenings ran from 3 to 6 per cent—which, however, is not prohibitive.

Northern white pine, sugar pine, limber pine, and piñon are all capable of manufacture into mechanical pulp of excellent quality. In the sulphite process, however, penetration by the cooking liquors is very slow and the results are unsatisfactory. All the pines reduce readily under the alkaline processes and produce pulp that may be bleached, although the product is less satisfactory than the standard bleached sulphite pulps.

Larches, Douglas fir, southern cypress, and cedars with light-colored wood can be pulped by the sulphite process, although with

Fig. 8.—Combination cylinder and Fourdrinier paper machine upon which the paper samples were made

more difficulty than hemlock. The quantities of bleach required are high but are within the range of commercial feasibility. None of these woods has been satisfactorily reduced by the alkaline processes to pulp bleachable with a reasonable quantity of bleach. Southern cypress is the most difficult. Redwood and cedars with dark-colored wood are very difficult to pulp or to bleach by the sulphite process. Consideration of the mechanical processes for these woods is not warranted, owing to their dark color. Their light weight and consequently the low yields obtained discourage consideration of them for the alkaline processes, although very satisfactory pulps for unbleached wrapping paper can be obtained.
In the case of species more or less resinous, it frequently happens that by the mechanical or sulphite-processes pulps of satisfactory strength and color can be obtained, but that the presence of "pitch" gives rise to operating difficulties in the paper mill. The laboratory experimental runs in which the pulps were studied were so short that the degree to which "pitch" troubles would be encountered was not ascertained accurately. It is possible that the difficulties would be decreased or eliminated by a judicious use, on the grinders or in the beaters, of some highly colloidal material such as bentonite. At the suggestion of the laboratory staff bentonite has been used commercially in both sulphite and mechanical pulping operations, with satisfactory results. It may become an important factor in extending the use of resinous pulp woods.

**HARDWOODS**

The fibers of hardwoods are short and hence not suited to the manufacture of strong, tough papers. They do, however, contribute to the formation of a well-closed, smooth-surfaced sheet of the type that is essential for a satisfactory print paper. In news and similar cheap print papers this characteristic is obtained more economically by the addition of ground wood than by the addition of a short-fibered chemical pulp; hence bleached hardwood chemical pulps find their most extensive use in print papers of the higher grades. The alkaline-cooked pulps, by virtue of their softness, bulk, and opacity, are most favored. The sulphite pulps are harder and less opaque but yield better, bleach whiter, and require less bleach. Their lack of opacity may be overcome by the addition of mineral fillers. A more extensive use of hardwood sulphite pulps in the manufacture of book, envelope, and similar paper may be expected, especially in paper mills that are already equipped for the production of sulphite.

The following hardwoods, with diffuse-porous structure, can be reduced readily by the sulphite process and bleached with small quantities of chemical: Poplars, willows, maples, birches, gums, magnolias, sycamore, and butternut. Of these with ring-porous structure, hackberry, elm, ash, and hickory can be readily or fairly readily pulped and bleached. The pulp usually contains small dark-colored specks, which, however, disappear on bleaching. Of diffuse-porous woods difficult to pulp and bleach to a satisfactory product there were tested basswood, red gum, and Ohio buckeye; of ring-porous woods difficult to pulp and bleach, common catalpa, chestnut, sassafras, slippery elm, red and white oak, and black locust. In both cases the difficulty of pulping is probably due to extractive matter or to structure which prevents penetration of the wood by the cooking liquor.

The hardwoods, in general, are unsuited to the manufacture of mechanical pulp, on account of the high power consumption required and the weakness of the pulp. By the adoption of new principles in grinding, however, it may become practicable to use the lighter colored of the hardwoods, such as the poplars, birches, and gums, for the manufacture of mechanical pulp.

All the hardwoods are capable of reduction by the soda or sulphate processes. The poplars and basswood among the diffuse-porous species are very easily pulped and bleached, and yellow poplar, willows, soft maples, beech, red alder, and balsa fairly easily.
birches, hard maples, gums magnolias, Ohio buckeye, butternut, and mangrove are rather difficult but are within the realm of profitable utilization. Of the ring-porous woods chestnut, after extraction, and the elms are fairly easily pulped and bleached. Unextracted chestnut, however, yields a pulp which is very inferior and very difficult to bleach. Common catalpa, hackberry, and white ash are rather difficult; sassafras, red and white oak, mockernut hickory, and black locust are very difficult.

**BARK DISPOSAL**

In considering the availability of various species for paper pulp the question of the utilization of the bark removed in the preparation of the wood naturally occurs. The feasibility of such utilization depends to a very large extent on local conditions, and each species and locality should be studied independently. Attempts to make use of this waste have met with considerable success in a number of cases. The most obvious means of utilization is as fuel, and at many mills it is found that the burning of the bark supplements the fuel supply to an appreciable extent. This is especially true if the bark is obtained from knife barkers or, in case the wood is barked wet in drum barkers, if as much water as possible is removed by means of a press before feeding to the furnaces. The barks from some species, such as hemlock, contain sufficient tannin to justify recovery of the latter by means of water extraction before burning. Extracted hemlock tanbark has also been found a suitable material for use with rags for the manufacture of roofing felt, and considerable quantities have been used for that purpose. Redwood bark is so utilized on a commercial scale.

Experiments with bark from the southern pines indicate that satisfactory roofing felt may be made with it by adding enough sulphate pulp from the same wood to give the required strength for passing through the impregnating bath. Spruce bark has been used as a portion of the furnish in the manufacture of board and cheap wrapping papers, such as car liner. Balsam fir and spruce barks have been used in finely shredded form in the manufacture of heat-insulation material.

**SUITABILITY OF INDIVIDUAL SPECIES FOR PULPING**

Descriptive summaries dealing with the pulping characteristics of various species under one or more of the various processes are given on pages 25 to 65. These summaries include brief statements about names of species, their range, specific gravity, and fiber length.

The information on names and range is based on the revised "Check List of the Forest Trees of the United States," by George B. Sudworth (United States Department of Agriculture (Miscellaneous Circular 92.)

**ESTIMATION OF PULPING VALUE**

All statements appearing in the summaries as to yields and quality of pulp and consumption of bleach are to be regarded as estimates of results to be expected under commercial operating conditions. In arriving at such estimates the writers have considered, (1) under the chemical pulp, the results of a limited number of laboratory tests on each species—usually not more than two or three for each pulping process—the data for which are recorded in Tables 6 to 12, and, under
the mechanical pulps, the results published in Department Bulletin No. 343, "Ground-Wood Pulp"; (2) the relation of yield and quality of pulp to particular conditions of pulping and to the characteristics of individual woods; and, (3) limitations affecting the reproduction of laboratory results at the mill. These considerations are briefly discussed in the next three paragraphs.

LABORATORY PULPING TESTS

Although the operation of the tests recorded in Tables 6 to 12 was standardized as far as possible, it was necessary to vary cooking conditions according to the character of the wood pulped. It is fully recognized that, with very little information available beforehand to guide the selection of the conditions, the cooks frequently failed to produce the best results. In such cases conclusions as to practical pulping values must be arrived at largely by a process of deduction based upon later and more exact knowledge of the factors involved. The figures shown in the tables represent, however, results obtained under specific selected conditions of operation. They make up the most comprehensive body of data that has been compiled with regard to the pulping of American species by the various chemical processes. They are presented in this bulletin as a matter of scientific record and for the possible guidance of future research.

CONDITIONS OF PULPING AND CHARACTER OF WOOD

For a number of years the laboratory has conducted special studies of spruce, loblolly pine, jack pine, and aspen in an effort to relate yield and quality of pulp to the conditions of pulping and to the characteristics of the wood itself. The results of these special studies have been published at intervals in Government bulletins or in the trade and technical journals. Many of the most important results have been obtained comparatively recently. Had the information been available at an earlier stage of the general study of American species, the conditions of pulping could have been selected so as to yield pulps in the laboratory more nearly equal, in both quantity and quality, to those now considered possible of realization on a commercial scale. In preparing the descriptive summaries of species, however, the aim has been to interpret the results of the pulping tests in the light of the more recently acquired knowledge and so arrive at reasonably accurate estimates of the practical pulping characteristics of the species studied.

COMMERCIAL ADAPTATION OF EXPERIMENTAL RESULTS

Laboratory equipment is designed to provide accurate control over a relatively wide variety of operating conditions. If it were possible to duplicate laboratory control on a commercial scale, laboratory results could, of course, be duplicated with mathematical accuracy. Such, however, is rarely the case. In mill practice unavoidable variations or irregularities are encountered, among which may be mentioned those in acid concentration, moisture content and quality of wood, temperature rise, pressure and wetness of steam, circulation of digester liquor, and end point of cook. It must be borne in mind also that the data recorded in the tables were obtained on a much smaller scale than obtains at the mill. It is true that wherever
opportunity has offered to carry on cooks in the mill under similar conditions, similar results have been obtained. Nevertheless there is always the possibility of divergence on account of the larger volumes of commercial cooks and the greater ratio of volume of digester to surface.

In estimating the pulping characteristics of the various woods, it has necessarily been assumed that the mill operator will take advantage of the best information available as to methods of operation. Due consideration has been given, however, to variations and irregularities of mill conditions, which militate against the highest yields and quality of pulp.

**APPLICATION OF DATA TO OPERATING CONDITIONS**

The oven-dry weight of the wood per cubic foot, green volume, given in the summaries, may be used as a factor in converting pulp yield by weight to yield per cord or any other unit of volume. Yields per cord may be determined by multiplying the yield of pulp based on weight by the oven-dry weight of the wood per cubic foot, and the product by the number of cubic feet solid wood obtained from a cord—due attention being given the character of the wood available from the particular species. The yields of pulp to be expected per cord or per thousand board feet are not directly stated as such because it was thought advisable that the reader exercise his own judgment in interpreting the data in this respect. The volume of solid wood per cord is an uncertain figure, which may vary from as little as 50 up to 100 cubic feet, according to the kind, shape, dimensions, soundness, and mechanical condition of the material. Rosed 2-foot spruce bolts of mixed diameters ranging from 6 to 14 inches contain slightly over 100 cubic feet per cord, and 100 cubic feet is assumed in figuring yields. Four-foot rossed bolts run 2 to 3 per cent less, 4-foot peeled bolts about 7 per cent less, and 4-foot rough bolts from 20 to 25 per cent less. The solid cubical content of mill waste varies enormously. Frequently 2 cords of mill waste will be found to yield only as much solid wood as 1 cord of 4-foot round bolts with the bark on.

The yield of oven-dry pulp is given in percentage of the oven-dry weight of the chips. Yields of less than 40 per cent are, in general, too low for profitable production, especially from woods lighter than 22 or 23 pounds to the cubic foot. Bleachability, discussed later, is a factor entering into calculations in this connection.

The physical characteristics of the species under consideration are not dwelt upon, such information being readily available in various works on forestry and on properties and uses of wood. They are, however, of especial importance in so far as they affect the ease with which the wood may be chipped and the bark removed; many species which may be easily pulped are rejected on account of the difficulty in handling them in the wood room.

In considering the suitability of a species in a given locality for pulp-making purposes, account should be taken of its growth habits, since the same species often varies greatly in properties with the latitude, altitude, character of soil, and other conditions of its environment.

Neither the durability of a species (i.e., resistance to decay) nor its susceptibility to insect attack is covered in this report, although
both are of immense importance from a practical standpoint, since it is customary to keep on hand at the mills at least one year’s supply of pulp wood, and since much of the wood is in storage for considerably longer periods. Balsam fir, for example, shows admirable pulping qualities by any of the processes and yet is not well regarded by the industry, for the reason that it is very susceptible to both insect attack and decay. Although red alder is a wood excellently adapted to the manufacture of soda pulp, unless methods of handling can be devised whereby loss from its excessive susceptibility to decay may be avoided its use as a pulp wood will remain out of the question. Reference works on the pathological and entomological characteristics of various species are available and should be consulted in any particular case.

The fiber lengths stated are the averages of such measurements, often very limited in number, as have been made by the Forest Service or, where Forest Service measurements are not available, by other investigators. They offer only an indication of what may be expected from the species given. Since many of these measurements were made the significance of a further element, namely, the position of the fibers in the tree with reference to height, has been investigated in considerable detail. It has been found that the fiber length in one tree may vary from 0.8 to 7.65 milimeters \(^4\) or even from 0.3 to 8.6 milimeters.\(^5\) The length of the fibers undoubtedly affects the character of the pulp obtainable. The fineness of the fiber is also a very important characteristic.

Physical properties, however, considered alone, may lead to contradictory conclusions. Thus rather poor and tender pulps were obtained from redwood with a fiber length of 5\(^\frac{1}{2}\) milimeters, whereas an extremely tough and durable sheet was obtained from yellow birch sulphate pulp with a fiber length of only 1\(^\frac{1}{2}\) milimeters. The substance forming the fiber is of great importance in this respect and varies with different species as well as with different treatments.

The information on color and quality given in the summaries under the heading “Unbleached pulp” has particular reference to uses in which bleaching is not ordinarily practiced. Sulphite pulp, for instance, is often used without bleaching, as in conjunction with mechanical pulp in the manufacture of newsprint, and for that reason it must be light in color and free from shives. Sulphate pulp for wrapping paper is seldom bleached.

In other large uses, however, bleaching qualities are important. Exceptionally well-operated mills bleach spruce sulphite with as little as 10 per cent of bleaching powder of standard strength, but the average is well over 15 per cent. Some mills are using as much as 25 per cent on pulp obtained from the species available and yet are showing a profit.

Under the characteristics of sulphate pulps from the pines the bleach consumption in two stages is often shown. Tests indicated that in this case the consumption was only half that required in one stage and the color obtained was a purer white. Not all species were so tested, however, and the fact that the bleach requirement for two steps is not mentioned does not mean that better results

\(^4\) GERRY, E. MICROSCOPY OF PULPWOODS. Paper, Apr. 21, 1920.
might not occasionally be obtained by that procedure. It was found, however, that the advantages did not hold for sulphite.

In the soda process, the color of the unbleached pulp is not mentioned, since the pulp is almost invariably bleached before using.

In sulphate pulps from conifers strength is the outstanding requirement, although bleaching qualities are coming into account as the use of the bleached product increases.

With mechanical pulps color is the major consideration and sheet-forming qualities are important. Strength is also a desideratum, since the stronger the pulp the less sulphite is required to manufacture paper of specified strength. Many species otherwise suitable are not economically feasible for mechanical pulp on account of the power required in grinding. Power consumption may therefore be the controlling factor.

The power requirements given in the summaries for the various species apply to the production of ground wood of standard strength. On account of local conditions it may prove advisable to grind coarser or weaker pulps in order to use less power and gain in production and make up for the lower strength of the paper by using more sulphite.

When the establishment of a plant in an area new to the industry is in contemplation it is advisable to obtain pulping and papermaking tests on representative local samples of the species the use of which is intended. It is, of course, obvious that a complete survey of the locality should be made to ascertain the amounts of suitable species available, their rapidity of growth, the distribution and character of stands, etc. There should also be an economic survey of the supply of labor, living conditions, freight rates to centers of consumption, character and quantity of water available, and cost of fuel and power.

SUMMARIES BY SPECIES

Yields in all cases refer to the oven-dry weight of the pulp and are based on the oven-dry weight of the wood. Bleach requirements are expressed as percentages of the oven-dry weight of the pulp.

In the discussion of the coniferous species no mention is made of soda pulp, for the reason that strength and susceptibility to bleach, the most important qualities of the conifers, are better brought out by the sulphate than by the soda process.

1. THE SPRUCES

Black Spruce (Picea mariana)

Other names in use.—Double spruce and spruce pine. In the trade the wood is often mixed with red and white spruce and called eastern spruce.

Range.—Labrador to the MacKenzie River, and northwestward into Alaska; southward through Newfoundland, eastern Canada, Michigan, Wisconsin, Minnesota to central Pennsylvania, and in the northeastern mountains to northern Virginia.

Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—2.6 mm.

By Sulphite Process

Reduces readily.

Unbleached pulp: Strong, of fine texture and excellent color, although occasionally somewhat pitchy; bleached easily to excellent white.

Yields: 45 to 50 per cent.

Bleach required: 10 to 20 per cent.

Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond paper.
By Sulphate Process

Reduces readily.
Unbleached pulp: Strong, of fine texture.
Yields: 45 to 50 per cent of strong pulp.
Bleaching properties probably similar to those of white spruce.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength.
Power required: Comparable to that for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.

Blue Spruce (Picea pungens, formerly P. parryna)

Other names in use.—Parry’s spruce, white spruce, silver spruce, and Colorado blue spruce.
Range.—Central Rocky Mountain region—Colorado, eastern Utah, southern and northwestern Wyoming, and northern New Mexico and Arizona.
Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—2.8 mm.

By Sulphate Process

Reduces readily.
Unbleached pulp: Strong, of fine texture and excellent color; bleaches easily to excellent white.
Yields: 45 to 50 per cent.
Bleach required: 10 to 20 per cent.
Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond papers.

By Sulphite Process

Reduces readily.
Unbleached pulp: Strong, of fine texture.
Yields: 45 to 50 per cent of strong pulp; 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 15 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength.
Power required: Comparable to that for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.

Engelmann Spruce (Picea engelmannii)

Other names in use.—White spruce, balsam, mountain spruce, and silver spruce.
Range.—From southeastern and northern Arizona and southern New Mexico northward through the Rocky Mountain region to British Columbia, and westward to the eastern slopes of the Cascade Mountains in Oregon and Washington.
Oven-dry weight per cubic foot, green volume.—21 pounds.
Fiber length.—3 mm.

By Sulphate Process

Reduces readily.
Unbleached pulp: Strong, of fine texture and excellent color; bleaches easily to excellent white.
Yields: 45 to 50 per cent.
Bleach required: 10 to 20 per cent.
Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond papers.

By Sulphite Process

Reduces readily.
Unbleached pulp: Strong, of fine texture.
Yields: 45 to 50 per cent of strong pulp.
Bleaching properties probably similar to those of white spruce.
By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength.
Power required: Comparable to that for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.

Norway Spruce (Picea abies, formerly P. excelsa)

Other names in use.—Spruce, fir, common spruce, and white fir.
Range.—From the Urals and Lapland to the Pyrenees and Alps. Planted in the eastern United States.
Oven-dry weight per cubic foot, green volume.—30 pounds.
Fiber length.—

By Sulphite Process

Reduces readily.
Unbleached pulp: Strong, of fine texture and excellent color; bleaches easily to excellent white.
Yields: 45 to 50 per cent.
Bleach required: 10 to 20 per cent.
Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Strong, of fine texture.
Yields: 45 to 50 per cent of strong pulp; 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 15 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength.
Power required: Comparable to that for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.

Red Spruce (Picea rubra, formerly P. rubens)

Other names in use.—Yellow spruce. Trade names of the lumber are eastern spruce, West Virginia spruce, Canadian spruce, and Adirondack spruce.
Oven-dry weight per cubic foot, green volume.—24 pounds.
Fiber length.—3.7 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Strong, of fine texture and excellent color, although occasionally somewhat pitchy; bleaches easily to excellent white.
Yields: 45 to 50 per cent.
Bleach required: 10 to 20 per cent.
Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Strong, of fine texture.
Yields: 45 to 50 per cent of strong pulp.
Bleaching properties probably similar to those of white spruce.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength.
Power required: Comparable to that for white spruce.
Uses to which pulp is suited: Practically all uses requiring round wood.
Sitka Spruce (Picea sitchensis)

Other names in use.—Tideland spruce and western spruce. Trade names of the lumber are Sitka spruce, yellow spruce, silver spruce, and west coast spruce.

Range.—Pacific coast region (extending inland about 50 miles) from the east end of Kadiak Island and Alaska to northern California.

Oven-dry weight per cubic foot, green volume.—24 pounds.

Fiber length.—3.5 mm.

By Sulphite Process

Reduces readily.

Unbleached pulp: Strong and of excellent color, texture not quite so fine as that of white spruce; bleaches easily to excellent white.

Yields: 45 to 50 per cent.

Bleach required: 10 to 20 per cent.

Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Strong, of fairly fine texture.

Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.

Bleach required: 20 to 30 per cent in one stage, or 15 to 20 per cent in two stages.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.

Pulp: Slightly grayish in color and of standard strength.

Power required: Comparable to that for white spruce.

Uses to which pulp is suited: Practically all uses requiring ground wood.

White Spruce (Picea glauca, formerly, P. canadensis)

Other names in use.—Single spruce, cat spruce, skunk spruce, and blue spruce. The lumber, mixed with that of red spruce, is sold as eastern spruce.

Range.—Labrador to Hudson Bay and northwestward through Alaska to Bering Strait; southward in the Atlantic region to Maine, New Hampshire, Vermont, northern New York, Michigan, Wisconsin, and Minnesota.

Oven-dry weight per cubic foot, green volume.—24 pounds.

Fiber length.—2.8 mm.

By Sulphite Process

Reduces readily.

Unbleached pulp: Strong, of fine texture and excellent color, although occasionally somewhat pitchy; bleaches easily to excellent white.

Yields: 45 to 50 per cent.

Bleach required: 10 to 20 per cent.

Uses to which pulp is suited: News, wrapping, book, high-grade printing, and bond papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Very strong, of fine texture.

Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.

Bleach required: 20 to 30 per cent in one stage, or 15 to 20 per cent in two stages.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduced readily.

Pulp: Of excellent color and standard strength.

Power required: 60 to 80 horsepower-days per ton (in actual commercial practice).

Uses to which pulp is suited: Practically all uses requiring ground wood.
2. THE PINES

Limber Pine (Pinus flexilis)

*Other names in use.*—White pine and Rocky Mountain pine.

*Range.*—Chiefly in Rocky Mountain region from Alberta and Montana to western Texas and New Mexico; westward in mountains of northern Arizona, Utah, Nevada, and California.

*Oven-dry weight per cubic foot, green volume.*—23 pounds.

*Fiber length.*—

**By Sulphite Process**

Does not reduce satisfactorily.

**By Sulphate Process**

Reduces readily.

Unbleached pulp: strong.

Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.

Bleach required: More than 20 per cent in one stage, or 15 to 20 per cent in two stages.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber boards.

**By Mechanical Process**

Reduces readily.

Pulp: Of good color and standard strength; somewhat pitchy.

Power required: 30 to 40 per cent more than for white spruce.

Uses to which pulp is suited: Limited chiefly by content of pitch.

Pinon (Pinus edulis)

*Other names in use.*—Nut pine, piñon pine, and scrub pine.

*Range.*—From central Colorado southward to western Texas and western Oklahoma; westward to eastern Utah, and through New Mexico to northern, central, and southeastern Arizona; mountains of northern Mexico; Lower California.

*Oven-dry weight per cubic foot, green volume.*—31 pounds.

*Fiber length.*—2 mm.

**By Sulphite Process**

Reduces with difficulty. Too much resin for uniform cooking.

Unbleached pulp: Of fair strength and color. Somewhat shivy, often pitchy.

Yields: 40 to 45 per cent.

Bleach required: 20 to 30 per cent.

Uses to which pulp is suited: Possibly wrapping papers.

**By Sulphate Process**

Reduces readily.

Unbleached pulp: Fairly strong but somewhat shivy.

Yields: 40 to 45 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

**By Mechanical Process**

Probably too pitchy and knotty for grinding.

Sugar Pine (Pinus lambertiana)

*Other names in use.*—California sugar pine and big pine.

*Range.*—Northwestern Oregon to southern and Lower California. The heaviest stands are found from Tulare to Eldorado counties in California.

*Oven-dry weight per cubic foot, green volume.*—23 pounds.

*Fiber length.*—4.1 mm.
By Sulphite Process

Reduces readily but unevenly.
Unbleached pulp: Of dull greenish-brown color and fair strength. Shivy and harsh.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Wrapping papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: More than 20 per cent in one stage, or 15 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Probably similar to that of northern white pine.

Northern White Pine (Pinus strobus)

Other names in use.—White pine, eastern white pine, Wisconsin white pine, Minnesota white pine, Canadian white pine, and cork pine. The term "white pine" is also often applied in the trade to other species of pine the wood of which more or less resembles northern white pine in appearance and quality.

Range.—From Newfoundland to Lake Winnipeg and southward through the Lake States, the New England States, and the Appalachians as far south as northern Georgia.

Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—4.1 mm.

By Sulphite Process

Reduces fairly readily but unevenly.
Unbleached pulp: Dull greenish brown in color; shivy and harsh.
Yields: 50 to 55 per cent.
Bleach required: More than 25 per cent.
Uses to which pulp is suited: Limited chiefly by dark color, shiviness, and harshness.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 15 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: of good color and standard strength, but pitchy.
Power required: 30 to 40 per cent more than for white spruce.
Uses to which pulp is suited: Limited chiefly by content of pitch.

Jack Pine (Pinus banksiana, formerly, P. divaricata)

Other names in use.—Scrub pine, gray pine, banksiana pine, and Hudson Bay pine.


Oven-dry weight per cubic foot, green volume.—24 pounds.
Fiber length.—2.5 mm.
By Sulphite Process

Reduces readily but unevenly.
Unbleached pulp: Of good color and strength and fine texture, but shivy and pitchy.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Wrapping and printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong and of fine texture.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: More than 20 per cent in one stage, or 15 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces fairly readily.
Pulp: Grayish in color but of standard strength; somewhat pitchy.
Power required: 40 to 50 per cent more than for white spruce.
Uses to which pulp is suited: Limited chiefly by poor color and presence of pitch.

LOBLOLLY PINE (Pinus taeda)

Other names in use.—Old-field pine, rosemary pine, sap pine, Virginia pine, and bastard pine. The lumber is usually mixed with that of short-leaf pine and is sold as short leaf or North Carolina pine.

Range.—South Atlantic and Gulf States from New Jersey, southern Delaware, eastern Maryland, and eastern West Virginia to central Florida; west to eastern Texas; northward into southwestern Oklahoma, Arkansas, and southern border of middle and west Tennessee.

Oven-dry weight per cubic foot, green volume.—30 pounds.
Fiber length.—3.0 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Slightly darker than white spruce sulphite and with a decided reddish-gray tone; of fair strength, with rather coarse fibers; probably pitchy.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Wrapping and printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Of good strength. Fibers long and rather coarse.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade wrapping papers, fiber board, and book stock.
From 1 to 10 gallons (in case of selected materials) of turpentine per cord of wood cooked may be recovered from the digester relief.

By Mechanical Process

Reduces readily.
Pulp: Coarser and weaker than pulp from the spruces and inclined to be pitchy; color good from wood cut in the fall, poorer from wood cut in the spring.
Power required: 50 to 60 per cent more than for white spruce, to attain same strength of pulp.
Uses to which pulp is suited: Limited chiefly by poor color and presence of pitch.
Lodgepole Pine (Pinus contorta)  6


Range.—From Alaska (Yukon River) southward in the Pacific coast region to California (Mendocino County) and through interior British Columbia, the mountains of Washington and Oregon to California (Sierra Nevada to San Jacinto Mountains); plateau east of the Rocky Mountains (latitude 50°) and south through the Rocky Mountain Region to New Mexico and northern Arizona.

Oven-dry weight per cubic foot, green volume.—24 pounds.

Fiber length.—2.3 mm.

By Sulphite Process

Reduces readily.

Unbleached pulp: Of excellent color, fine fibered and very strong; probably somewhat pitchy; easily bleached.

Yields: 45 to 50 per cent.

Bleach required: 10 to 20 per cent.

Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Very strong.

Yields: 45 to 50 per cent of strong pulp.

Bleaching characteristics probably similar to those of jack pine.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.

Pulp: Of excellent color and standard strength.

Power required: 15 to 25 per cent more than for white spruce.

Uses: Practically all uses requiring ground wood.

Note.—The properties stated above apply to the lodgepole pine grown in the Rocky Mountain regions, which contains much less pitch than that grown in the lowlands and coastal regions. The pulping properties of the latter are similar to those of jack pine.

Long-leaf Pine (Pinus palustris)


Range.—Atlantic coast region from southeastern Virginia to southern Florida and westward to eastern Texas; northward in Alabama to the northern part of the State, to northwestern Georgia, central and western Mississippi and western Louisiana almost to the northern border of the State.

Oven-dry weight per cubic foot, green volume.—34 pounds.

Fiber length.—3.7 mm.

By Sulphite Process

Long leaf pine varies enormously in pitch content, and although selected trees might be used, it would be advisable to consider the use of this species on a commercial scale.

By Sulphate Process

Reduces readily.

Unbleached pulp: Strong, rather coarse, and very long fibered; requires special beater treatment to develop maximum strength. Strength is usually sacrificed to secure standard formation of sheet.

Yields: 45 to 50 per cent of strong pulp, 40 to 45 per cent of pulp for bleaching.

6 The Rocky Mountain form of this tree, upon which the following tests were made, was formerly and is still designated variously as Pinus murrayana, P. contorta var. murrayana, and P. contorta var. latifolia, the Pacific coast form being restricted to P. contorta. The Rocky Mountain form contains much less pitch than that from the lowlands and coastal regions. The properties of the lowland and coast form are approximately as given for jack pine.
Bleach required: 20 to 30 per cent in one stage, or 15 to 25 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.
From 2 to 36 gallons (in the case of selected material) of turpentine and pine oil per cord of wood may be recovered from the digester relief.

By Mechanical Process

Not suitable for mechanical pulp on account of the high pitch content usually encountered.

Monterey Pine (*Pinus radiata*, formerly, *P. insignis*)

*Other names in use.*—Monterey pine is the name universally used for this species.

*Range.*—Occurs only in a few small areas near the coast of southern California.

*Oven-dry weight per cubic foot, green volume.*—29 pounds.

*Fiber length.*—

*By Sulphite Process*

Reduces fairly readily.

Unbleached pulp: Strong and of fair color; somewhat coarser than spruce sulphite pulp; fairly easily bleached.

Yields: 45 to 50 per cent.

Bleach required: 20 to 30 per cent.

Uses to which pulp is suited: Wrapping and printing papers.

*By Sulphate Process*

Reduces readily.

Unbleached pulp: Very strong, difficult to bleach.

Yields: 45 to 55 per cent of strong pulp.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

*By Mechanical Process*

Behavior probably similar to that of jack pine.

Norway Pine (*Pinus resinosa*)

*Other names in use.*—Red pine, hard pine, and northern pine.

*Range.*—From Nova Scotia to northern Ontario to southern Manitoba; southward through the Northern States to Massachusetts, southeastern Pennsylvania, northeastern Ohio, central Michigan, and northern Wisconsin; southern Wisconsin and northeastern Minnesota.

*Oven-dry weight per cubic foot, green volume.*—27 pounds.

*Fiber length.*—3.7 mm.

*By Sulphite Process*

Reduces fairly readily.

Unbleached pulp: Of good color, fairly fine-fibered and fairly strong; probably somewhat pitchy; fairly easily bleached.

Yields: 45 to 50 per cent.

Bleach required: 15 to 25 per cent.

Uses to which pulp is suited: Few. Limited chiefly by content of pitch.

*By Sulphate Process*

Reduces readily.

Unbleached pulp: Very strong.

Yields: 45 to 55 per cent of strong pulps, 40 to 45 per cent of pulp for bleaching.

Bleach required: 30 to 40 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

*By Mechanical Process*

Behavior probably similar to that of jack pine.

31897°—27—3
Pitch Pine (Pinus rigida)

Other names in use.—Hard pine, yellow pine, and sap pine.

Range.—From the coast of Maine to eastern Ontario, and southward in the Atlantic coast region to southern Virginia and along the mountains to northern Georgia; west to western New York, northeastern and northwestern Pennsylvania, eastern Ohio and Kentucky, and eastern Tennessee.

*Oven-dry weight per cubic foot, green volume.*—20 pounds.

*Fiber length.*—

**By Sulphite Process**

Reduces with difficulty.
Unbleached pulp: Too pitchy for commercial production; bleaches with some difficulty to a fairly satisfactory quality.
Yields: 45 to 50 per cent.
Bleach required: 30 to 40 per cent.
Uses to which pulp is suited: Limited chiefly by content of pitch.

**By Sulphate Process**

Reduces readily.
Unbleached pulp: Very strong; fibers longer and coarser than spruce.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach: 20 to 30 per cent in one stage, or 15 to 25 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers, fiber board, and book stock.

Turpentine may be recovered from the digester relief in quantities warranting consideration.

**By Mechanical Process**

Probably too resinous for successful grinding.

Pond Pine (Pinus rigida serotina, formerly, P. serotina)

Other names in use.—Spruce pine, bastard pine, pocoson pine, bay pine, black pine, marsh pine, and meadow pine.

Range.—Atlantic coast region from southern New Jersey and southeastern Virginia to east-central Florida and probably farther south; on the west coast of Florida from Pensacola to Citrus County and probably much farther south. Range imperfectly known.

*Oven-dry weight per cubic foot, green volume.*—31 pounds.

*Fiber length.*—

**By Sulphite Process**

Reduces readily.
Unbleached pulp: Of a reddish-gray tone, about the same color as hemlock sulphite, but fibers somewhat coarser. Probably somewhat pitchy. Bleaches easily.
Yields: 45 to 50 per cent.
Bleach required: 10 to 20 per cent.
Uses to which pulp is suited: Wrapping and printing papers.

**By Sulphate Process**

Reduces readily.
Unbleached pulp: Of good strength. Fibers are longer but coarser than those of spruce.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers, fiber board, and book stock.
From 1 to 10 gallons (in the case of selected material) of turpentine per cord of wood cooked may be recovered from the digester relief.

**By Mechanical Process**

Behavior probably similar to that of loblolly pine.
SAND PINE (Pinus clausa)

Other names in use.—Old-field pine, Florida spruce pine, scrub pine, and upland spruce pine.

Range.—Coast of Alabama and western Florida; east coast of Florida from St. Augustine to New River.

Oven-dry weight per cubic foot, green volume.—29 pounds.

Fiber length.—

By Sulphite Process

Reduces readily.
Unbleached pulp: Of good color; rather weak, with fibers of average fineness; probably somewhat pitchy; easily bleached.
Yields: 25 to 35 per cent (figures subject to modification by further investigation).
Bleach required: 10 to 20 per cent.
Uses to which the pulp is suited: Wrapping and printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Of fair strength.
Yields: 40 to 45 per cent.
Bleach required: Probably more than 20 per cent.
Uses to which the pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Behavior probably similar to that of jack pine.

SCOTCH PINE (Pinus sylvestris)

Other names in use.—Northern pine, Scots pine (Scotland), and Scotch fir (England).

Range.—Europe, northern Asia up to 700 feet above sea-level in the far north, 6,500 feet in southern Europe. Planted in eastern United States.

Oven-dry weight per cubic foot, green volume.—37 pounds (data from English sources).

Fiber length.—

By Sulphite Process

Reduces with difficulty and very unevenly.
Unbleached pulp: Of fair color but shivy; probably somewhat pitchy.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Few. Limited chiefly by content of pitch and shives.

By Sulphate Process

Reduces readily.
Unbleached pulp: Of good strength.
Yields: 40 to 45 per cent of strong pulp, 35 to 40 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

Turpentine may probably be recovered from the digester relief in quantities sufficient to warrant consideration.

By Mechanical Process

Behavior probably similar to that of jack pine.

VIRGINIA PINE (Pinus virginiana)

Other names in use.—Scrub pine, Jersey pine, and spruce pine. The lumber is often sold as North Carolina pine.

Range.—Mainly from central and southern New Jersey and central, southern, and western Pennsylvania to Georgia and northern Alabama; west into Ohio, southern Indiana, northeastern Mississippi, and middle Tennessee.

Oven-dry weight per cubic foot, green volume.—26 pounds.

Fiber length.—2.8 mm.
Reduces readily.
Unbleached pulp: Of about the same color as hemlock sulphite, but with somewhat coarser fibers: probably pitchy.
Yields: Probably 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Wrapping and printing papers.

**By Sulphate Process**

Reduces readily.
Unbleached pulp: Of good strength; fibers longer and coarser than those of spruce.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers, fiber board, and book stock.
From 1 to 10 gallons (in the case of selected material) of turpentine per cord of wood may be recovered from the digester relief.

**By Mechanical Process**

Reduces readily.
Pulp: Coarser than spruce pulp, and pitchy.
Power required: 50 to 60 per cent more than for white spruce, to obtain the same strength of product.
Uses to which pulp is suited: Limited chiefly by content of pitch.

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**Short-leaf Pine (Pinus echinata)**

*Other names in use.*—Yellow pine, short-leafed pine, spruce pine, and bull pine. The lumber frequently goes under the name of North Carolina pine.

*Range.*—From southeastern New York to western Florida, and westward into West Virginia, southern Illinois, southern Missouri, eastern Oklahoma, and eastern Texas.

*Oven-dry weight per cubic foot, green volume.*—31 pounds.

*Fiber length.*—3.7 mm.

**By Sulphite Process**

Reduces fairly readily.
Unbleached pulp: Fairly strong; of the same color as hemlock sulphite, but with somewhat coarser fibers; probably pitchy.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Wrapping papers.

**By Sulphate Process**

Reduces readily.
Unbleached pulp: Fairly strong; fibers longer and coarser than those of spruce.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers, fiber board, and book stock.
From 1 to 10 gallons (in the case of selected materials) of turpentine per cord of wood may be recovered from the digester relief.

**By Mechanical Process**

Behavior similar to that of scrub pine.
Pulps obtained from wood cut in the fall have good color, those from wood cut in the spring considerably poorer color.
Uses to which pulp is suited: Limited chiefly by content of pitch.
SLASH PINE (Pinus caribaea, formerly, P. cubensis and P. heterophylla).

Other names in use.—Swamp pine, bastard pine, meadow pine, pitch pine, spruce pine, and saltwater pine.

Range.—Atlantic coast region (60 to 100 miles inland) from South Carolina to southern Florida; westward in the coast region of the Gulf States to eastern Louisiana.

Oven-dry weight per cubic foot, green volume.—37 pounds.
Fiber length.——

By Sulphite Process

Probably too resinous for consideration.

By Sulphate Process

Reduces readily.
Unbleached pulp: Strong; fibers rather long and coarse.
Yields: 45 to 50 per cent of strong pulp.
Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

From 2 to 30 gallons of turpentine and pine oil per cord of wood may be recovered from the digester relief.

On account of its rapid growth, the high quality of lumber obtained from it, its large yields of rosin, turpentine, and pine oil, and the ease with which it reduces to an easy-bleaching pulp, slash pine is worthy of consideration for replanting areas with a view to establishing a group of industries related to each other and dependent on a self-perpetuating supply of wood.

By Mechanical Process

Probably too resinous for consideration.

WESTERN YELLOW PINE (Pinus ponderosa)


Range.—From British Columbia and the Black Hills of South Dakota southward in the Pacific and Rocky Mountain region to western Texas, northwestern Nebraska, and Mexico.

Oven-dry weight per cubic foot, green volume.—24 pounds.
Fiber length.—3.6 mm.

By Sulphite Process

Reduces fairly readily but unevenly.
Unbleached pulp: Dark in color, and shivy.
Yields: 45 to 50 per cent.
Bleach required: Probably more than 20 per cent.
Uses to which pulp is suited: Limited chiefly by dark color and content of pitch and shives.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong, the long, fine fibers having exceptionally good felting properties.
Yields: 45 to 50 per cent.
Bleach: Probably more than 25 per cent.
Probably enough turpentine may be recovered from the digester relief to warrant consideration.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces fairly readily.
Pulp: Of satisfactory color and soft texture, but coarser than spruce pulp; probably pitchy.
Power required: 40 to 50 per cent more than for spruce, to obtain pulp of the same strength.
Uses to which pulp is suited: Limited by coarseness and pitchiness.
Pehuen (*Araucaria aurocana*, formerly, *A. imbricata*)

Other names in use.—Native names for this species are pehuen and piño piñon. In English-speaking countries it is commonly referred to as Araucaria pine and monkey-puzzle.

Range.—Southern Brazil, Argentina, Chile.

Oven-dry weight per cubic foot, green volume.—33 pounds.

Fiber length.—

By Sulphite Process

Reduces readily.

Unbleached pulp: Light brown in color and of fair strength.

Yields: 45 to 55 per cent.

Bleach required: Probably more than 20 per cent.

Uses to which pulp is suited: Wrapping papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Of good strength, but somewhat softer than spruce sulphate.

Yields: 45 to 50 per cent.

Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.

Uses to which pulp is suited: Kraft wrapping papers and fiber board.

By Mechanical Process

Probably yields a fair grade of pulp of about the color of jack pine ground wood, with reasonable consumption of power.

3. THE FIRS

Alpine fir (*Abies lasiocarpa*)

Other names in use.—Sub-alpine fir, balsam, white fir, white balsam, Oregon balsam-tree, pumpkin tree, mountain balsam, black balsam, and balsam fir.

Range.—Rocky Mountain region from northern Arizona; southwestern New Mexico to Montana and Idaho, and westward through the mountains of Oregon and Washington and northward to Alaska: high ranges of British Columbia and Alberta.

Oven-dry weight per cubic foot, green volume.—21 pounds.

Fiber length.—

By Sulphite Process

Reduces readily.

Unbleached pulp: Of excellent color and strength, easily bleached.

Yields: 45 to 50 per cent.

Bleach required: 10 to 15 per cent.

Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Very strong.

Yields: 45 to 50 per cent of strong pulp, 40 to 45 per cent of pulp for bleaching.

Bleach required: 20 to 30 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.

Pulp: Of excellent color and standard strength.

Power required: 15 to 25 per cent more than for spruce.

Uses to which pulp is suited: Practically all uses requiring ground wood.
BALSAM FIR (Abies balsamea)

Other names in use.—Balsam, Canada balsam, Balm of Gilead fir, blister pine, fir pine, fir-tree, single spruce, silver pine, and she-balsam. The lumber is frequently called eastern fir in the market.

Range.—From Newfoundland and Labrador to Hudson Bay and northwestern to the Great Slave Lake region, and south to Pennsylvania (and along high mountains to Virginia), Michigan, Minnesota, and northeastern Iowa.

Oven-dry weight per cubic foot, green volume.—21 pounds.

Fiber length.—2.7 mm.

By Sulphite Process

Reduces readily under slightly milder conditions than are required for spruce. Unbleached pulp: Of good color and excellent strength, but slightly softer, as a rule, than spruce sulphite; fairly easily bleached.

Yields: 45 to 50 per cent.
Bleached required: 15 to 25 per cent.
Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 45 to 50 per cent of strong pulp, 40 to 45 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength. On account of the susceptibility of this species to insect attack and decay, inferior pulps are often obtained which are not characteristic of the sound wood.
Power required: 15 to 25 per cent more than for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.

LOWLAND WHITE FIR (Abies grandis)

Other names in use.—White fir, silver fir, yellow fir, Oregon white fir, western white fir, great silver fir, and balsam fir.

Range.—Pacific coast region from Vancouver Island to western California and from Washington and Oregon to northern Idaho and Montana.

Oven-dry weight per cubic foot, green volume.—23 pounds.

Fiber length.—3.2 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of excellent color and strength; fibers somewhat coarser than spruce fibers; fairly easily bleached.
Yields: 45 to 55 per cent.
Bleach required: 15 to 25 per cent.
Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 45 to 50 per cent of strong pulp, 35 to 45 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color.
Power required: 15 to 25 per cent more than for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.
**BULLETIN**

**Practically Papers**

**Noble Fir (Abies nobilis)**

*Other names in use.*—Red fir, larch, noble fir, and bigtree.

*Range.*—Western Washington and Oregon and northern California.

*Oven-dry weight per cubic foot, green volume.*—22 pounds.

*Fiber length.*—

**By Sulphite Process**

Reduces readily.
Unbleached pulp: Of excellent color and strength; fibers fine and tough; easily bleached.

Yields: 45 to 50 per cent.

Bleach required: 10 to 15 per cent.

Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

**By Sulphate Process**

Reduces readily.
Yields: 45 to 50 per cent of strong pulp, 40 to 45 per cent of pulp for bleaching.

Bleach required: 20 to 30 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

**By Mechanical Process**

Reduces readily.
Pulp: Of excellent color and standard strength.

Power required: 20 per cent less than for spruce.

Uses to which pulp is suited: Practically all uses requiring ground wood.

**Red Fir (Abies magnifica)**

*Other names in use.*—California red-bark fir and California red fir.

*Range.*—California (Sierra Nevada Mountains) and northward in the Cascade Mountains of southern Oregon.

*Oven-dry weight per cubic foot, green volume.*—23 pounds.

*Fiber length.*—

**By Sulphite Process**

Reduces fairly readily.
Unbleached pulp: Very strong, darker then spruce sulphite but lighter than hemlock sulphite; fibers fairly fine; fairly easily bleached.

Yields: 45 to 50 per cent.

Bleach required: 15 to 25 per cent.

Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

**By Sulphate Process**

Reduces readily.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.

Bleach required: More than 30 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

**By Mechanical Process**

Reduces readily.
Pulp: Color slightly reddish; of standard strength.

Power required: 15 to 25 per cent more than for spruce.

Uses to which pulp is suited: Practically all uses requiring ground wood, except as limited by dark color.

**Silver Fir (Abies amabilis)**

*Other names in use.*—Red fir, red silver fir, fir, and larch.

*Range.*—From southeastern Alaska to Vancouver Island and British Columbia and southward in the Cascade Mountains to northern Oregon; also in the coast mountains of Washington and Oregon.

*Oven-dry weight per cubic foot, green volume.*—22 pounds.

*Fiber length.*—
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP 41

By Sulphite Process

Reduces readily.
Unbleached pulp: Of excellent color and strength; fairly easily bleached.
Yields: 45 to 50 per cent.
Bleached required: 20 to 30 per cent.
Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong, long fibered.
Yields: 48 to 53 per cent of strong pulp.
Bleaching properties probably similar to those of noble fir.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Behavior similar to that of white spruce.

White Fir (Abies concolor)

Other names in use.—Balsam fir, silver fir, white balsam, bastard pine, and blue fir.
Range.—Southwestern Oregon to southern California; northern Arizona and New Mexico to Colorado and northern Utah.
Oven-dry weight per cubic foot, green volume.—22 pounds.
Fiber length.—3.5 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of excellent color and strength; fibers larger and somewhat coarser than spruce fibers; easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 10 to 15 per cent.
Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 48 to 53 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.
Pulp: Of excellent color and standard strength. Pulps from young trees are usually of better quality than from old trees on account of the susceptibility of this species to heart rot.
Power required: 15 to 20 per cent more than for white spruce.
Uses to which pulp is suited: Practically all uses requiring ground wood.

Douglas Fir (Pseudotsuga taxifolia)

Other names in use.—Red fir, yellow fir, Oregon pine, Douglas spruce, red pine, Puget Sound pine, Santiam quality fir, and red spruce.
Range.—From the Rocky Mountain region (in the United States) and northward to central British Columbia; westward to the Pacific coast and southward into northern Mexico and the mountains of western Texas. Over one-half of the present stand is in western Washington and Oregon.
Oven-dry weight per cubic foot, green volume.—28 pounds.
Fiber length.—4.4 mm.

By Sulphite Process

Reduces with difficulty on account of the pitchy character of the wood.
Unbleached pulp: Of fair strength and poor color; probably somewhat pitchy.
Yields: 45 to 50 per cent.
Bleach required: 20 to 25 per cent.
Uses to which the pulp is suited: Limited chiefly by poor color and content of pitch.
4. HEMLOCKS AND OTHER CONIFERS

CAROLINA HEMLOCK (Tsuga caroliniana)

Other names in use.—Spruce pine, hemlock, and hemlock spruce.
Range.—Mountains of southwestern Virginia and western North Carolina to northern Georgia; very local.
Oven-dry weight per cubic foot, green volume.—30 pounds.
Fiber length.—3 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Slightly lighter in color than eastern hemlock sulphite, but otherwise similar; fairly easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Same as for eastern hemlock.

By Sulphate Process

Reduces readily.
Unbleached pulp: Strong.
Yields: 45 to 50 per cent of strong pulp, 35 to 40 per cent of pulp for bleaching.
Bleach: More than 30 per cent.
Uses to which pulp is suited: Same as for eastern hemlock.

By Mechanical Process

Behavior probably similar to that of eastern hemlock.

EASTERN HEMLOCK (Tsuga canadensis)

Other names in use.—Hemlock, hemlock spruce, and spruce pine.
Range.—Nova Scotia to eastern Minnesota, to southwestern Wisconsin, southern Michigan, and Indiana; southward in the Atlantic coast region to Delaware and Maryland, and southward along the mountains to northern Alabama and Georgia.
Oven-dry weight per cubic foot, green volume.—24 pounds.
Fiber length.—3 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Very strong, as compared with spruce sulphite; darker in color and with a decided reddish-gray tone; fibers somewhat coarser and more readily hydrated in the beater; fairly easily bleached.
Yields: 40 to 45 per cent.
Bleach required: 15 to 25 per cent.
Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 45 to 50 per cent of strong pulp, 40 to 45 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent in one stage, or 10 to 20 per cent in two stages.
Uses to which pulp is suited: High-grade kraf t wrapping papers and fiber board.
By Mechanical Process

Reduces fairly readily.

Pulp: Slightly reddish in color, somewhat brittle.

Power required: 50 to 60 per cent more than for white spruce, to obtain standard strength.

Uses to which pulp is suited: As partial substitute for white spruce ground wood.

Western Hemlock (Tsuga heterophylla)

Other names in use.—Hemlock, western hemlock, hemlock spruce, and Alaska pine. In the lumber trade the wood is often called West coast and Pacific hemlock. In England it is largely known as western hemlock fir and Prince Albert’s fir.

Range.—From southeastern Alaska to northern Idaho and northwestern Montana, and southward in Washington and western Oregon to northwestern California. The best stands are found in the coast region and through the Cascade Mountains at an elevation of 1,500 to 3,500 feet.

Oven-dry weight per cubic foot, green volume.—23 pounds.

Fiber length.—2.7 mm.

By Sulphite Process

Reduces readily, more like spruce than eastern hemlock.

Unbleached pulp: Tough and strong; much lighter in color and finer in texture than eastern hemlock.

Yield: 45 to 50 per cent.

Bleach required: 15 to 25 per cent.

Uses to which pulp is suited: News, wrapping, book, and high-grade printing papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Very strong and tough.

Yields 45 to 50 per cent of strong pulp.

Bleaching properties probably similar to those of eastern hemlock.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces readily.

Pulp: Of excellent color and standard strength.

Power required: 10 to 15 per cent more than for spruce.

Uses to which pulp is suited: Practically all uses requiring ground wood.

Tamarack (Larix laricina formerly L. americana)

Other names in use.—Larch, hackmatack, and American larch.

Range.—From Newfoundland and Labrador northward, through the Hudson Bay region, to the Mackenzie River and reappearing in Alaska between Cook Inlet and the Yukon River; southward in the East to northern and eastern Pennsylvania, western Maryland, northeastern West Virginia, northern Ohio, Indiana, and Illinois, and northeastern Minnesota; in western Canada extending southward along the eastern base of the Rockies.

Oven-dry weight per cubic foot, green volume.—31 pounds.

Fiber length.—2.6 mm.

By Sulphite Process

Reduces with difficulty.

Unbleached pulp: Brash, shivy, and dark in color; fairly easily bleached to satisfactory product.

Yields: 40 to 45 per cent.

Bleach required: 15 to 25 per cent.

Uses to which pulp is suited: Low-grade wrapping papers.

By Sulphate Process

Reduces readily.

Unbleached pulp: Very strong and tough.

Yields: 45 to 50 per cent of strong pulp, 35 to 40 per cent of pulp for bleaching.

Bleach required: 25 to 30 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.
By Mechanical Process

Reduces readily.
Pulp: Light grayish green in color.
Power required: 40 to 50 per cent more than for white spruce to obtain standard strength.
Uses to which pulp is suited: Practically all uses requiring ground wood.

Western Larch (Larix occidentalis)

Other names in use.—Larch, tamarack, hackmatack, red American larch, and western tamarack. The lumber is variously called western larch, Montana larch, Oregon larch, and British Columbia tamarack.
Range.—Southern British Columbia and south in the Cascade Mountains to the Columbia River, and to western Montana; also in southeastern Washington, northeastern Oregon, and northern Idaho.
Oven-dry weight per cubic foot, green volume.—28 pounds.
Fiber length.—2.6 mm.

By Sulphite Process

Reduces with difficulty and very unevenly.
Unbleached pulp: Brash, shivy, and dark in color; bleaches to fairly satisfactory product.
Yields: 40 to 45 per cent of pulp for bleaching.
Bleach required: 15 to 25 per cent.
Uses to which pulp is suited: Low-grade wrapping papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Very strong.
Yields: 45 to 50 per cent of strong pulp.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Reduces with difficulty.
Pulp: Rather coarse, decidedly brown in color.
Power required: Two and half times more than for white spruce, to obtain standard strength.
Uses to which pulp is suited: Limited by poor color and coarseness.

Incense Cedar (Libocedrus decurrens)

Other names in use.—Cedar, post cedar, bastard cedar, and California post cedar.
Range.—From northwestern Oregon southward through California into Mexico and Lower California. The commercial range is confined largely to the mountains of northern California and southern Oregon.
Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—2 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Very dark in color; bleaches with difficulty.
Yields: 40 to 45 per cent.
Bleach required: More than 35 per cent.
Uses to which pulp is suited: Limited chiefly by poor color.

By Sulphate Process

Reduces readily. Best results obtained at cooking temperatures corresponding to steam pressures below 80 pounds per square inch.
Unbleached pulp: Fine fibered and very strong, but strength easily impaired by too high temperatures during cooking.
Yields: 40 to 45 per cent of strong pulp, 35 to 40 per cent of pulp for bleaching.
Bleach required: More than 30 per cent.
Uses to which pulp is suited: Kraft wrapping papers and fiber board.

By Mechanical Process

Pulp too dark for ordinary ground-wood uses.
Port Orford Cedar (Chamaecyparis lawsoniana)

Other names in use.—Lawson’s cypress, Oregon cedar, ginger pine, and white cedar.

Range.—Pacific coast region from southwestern Oregon to northwestern California, extending inland about 40 miles. The bulk of the timber of commercial importance is confined to a strip 20 to 25 miles wide along the Pacific coast in Coos and Curry Counties, Oreg.

Oven-dry weight per cubic foot, green volume.—26 pounds.

Fiber length.—2.6 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Strong, fine fibered; rather difficult to bleach.
Yields: 45 to 55 per cent.
Bleach required: 25 to 30 per cent.
Uses to which pulp is suited: Wrapping papers and some print papers.

By Sulphate Process

Reduces readily. Best results obtained at cooking temperatures corresponding to steam pressures below 80 pounds per square inch.
Unbleached pulp: Very strong, but strength easily impaired by too high temperatures during cooking.
Yields: Not fully determined; possibly 40 to 45 per cent.
Bleach required: 25 to 30 per cent.
Uses to which pulp is suited: Kraft wrapping papers and fiber board.

By Mechanical Process

Probably unsuited to grinding because of color and nature of the wood.

Southern White Cedar (Chamaecyparis thyoides)

Other names in use.—White cedar, swamp cedar, post cedar, and juniper.

Range.—Atlantic coast region from southern Maine to northern Florida westward to Mississippi (Pearl River).

Oven-dry weight per cubic foot, green volume.—20 pounds.

Fiber length.—2.1 mm.

By Sulphite Process

Pulping characteristics probably similar to those of Port Orford cedar.

By Sulphate Process

Reduces readily. Best results obtained at cooking temperatures corresponding to pressures below 80 pounds per square inch.
Unbleached pulp: Very strong, but strength easily impaired by too high temperatures during cooking.
Yields: 45 to 50 per cent of strong pulp, 38 to 43 per cent of pulp for bleaching.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Probably reduces readily to satisfactory pulps with reasonable power consumption.

Eastern Red Cedar (Juniperus virginiana)

Other names in use.—Cedar, juniper, and savin. Trade names for the wood are eastern red cedar and Tennessee red cedar.

Range.—Nova Scotia and New Brunswick to Georgia (coast), southern Alabama and Mississippi; west in Ontario (Georgian Bay) to eastern North and South Dakota, southern Michigan, eastern Nebraska and Kansas, southeastern Oklahoma, southwestern Arkansas, and eastern Texas.

Oven-dry weight per cubic foot, green volume.—27 pounds.

Fiber length.—2.8 mm.
By Sulphite Process

Wood too oily for reduction to satisfactory pulp.

By Sulphate Process

Reduces readily. Cooking temperatures corresponding to 80 pounds steam pressure should not be exceeded. The knotty character of the wood and the smallness of the average bolt would offer difficulties in the wood room.

Unbleached pulp: Strength easily impaired by too high cooking temperatures; practically impossible to bleach.

Yields: 40 to 45 per cent.

From 5 to 10 gallons of cedar oil per cord of wood may be recovered from the digester relief.

Uses to which pulp is suited: Kraft wrapping papers.

By Mechanical Process

Wood too dark in color, too oily, and too knotty for the production of satisfactory pulp.

Western Red Cedar (Thuja plicata)

Other names in use.—Red cedar, canoe cedar, arborvitae, shinglewood, gigantic, cedar, Pacific red cedar, and western cedar.

Range.—From the coast of southern Alaska to northern California; eastward through British Columbia and northern Washington to northern Idaho and Montana.

Oven-dry weight per cubic foot, green volume.—19 pounds.

Fiber length.—3.8 mm.

By Sulphite Process

Pulp: Dark in color, shivy, and practically impossible to bleach.

Uses to which pulp is suited: Limited chiefly by poor color and shiviness.

By Sulphate Process

Reduces readily. It is probable that the digester pressure during cooking should not exceed 90 pounds per square inch.

Unbleached pulp: Very strong.

Yields: 40 to 45 per cent.

Uses to which pulp is suited: High-grade kraft wrapping papers and fiber board.

By Mechanical Process

Wood too dark for production of satisfactory pulp.

Southern Cypress (Taxodium distichum)

Other names in use.—Cypress, bald cypress, red cypress, black cypress, white cypress, yellow cypress, and Gulf cypress.

Range.—From southern Delaware southward in the Atlantic coast region to southern Florida; westward in the Gulf Coast region to western Texas, and northward through Louisiana to Oklahoma, Arkansas, northern and western Mississippi and Tennessee, southeastern Missouri, western Kentucky, southern Illinois, and southwestern Indiana. The greater part of the supply of this timber is in Louisiana and Florida.

Oven-dry weight per cubic foot, green volume.—27 pounds.

Fiber length.—3.3 mm.

By Sulphite Process

Reduces with difficulty.

Unbleached pulp: Fairly strong but very dark in color; difficult to bleach.

Yields: 45 to 50 per cent.

Bleach required: 25 to 35 per cent.

Uses to which pulp is suited: Limited chiefly by poor color.
By Sulphate Process

Reduces readily.
Unbleached pulp: Soft and long fibered; required careful beating to develop satisfactory strength.
Yields: 50 to 55 per cent of strong pulp, 35 to 40 per cent of pulp for bleaching.
Bleach required: More than 25 per cent.
Uses to which pulp is suited: Kraft wrapping papers and fiber board.

By Mechanical Process

Not suited to ground-wood production because of color.

REDWOOD (Sequoia sempervirens)

Other names in use.—Sequoia, California redwood, and coast redwood.
Range.—From the southern borders of Oregon southward in the Pacific coast region 20 to 30 miles inland to about 100 miles south of San Francisco.
Oven-dry weight of the wood per cubic foot, green volume.—23 pounds.
Fiber length.—5.5 mm.

By Sulphite Process

Reduces readily but unevenly.
Unbleached pulp: Fairly strong but brash, shivy, dark in color, and practically impossible to bleach.
Yields: About 50 per cent.
Uses to which pulp is suited: Low-grade wrapping papers.

By Sulphate Process

Reduces readily.
Unbleached pulp: Fairly strong; fibers very long but soft and tender. Best results are obtained when chips are leached before cooking and 10 to 20 per cent of their weight extracted as a tanninlike dark red coloring substance.
Yields: 35 to 40 per cent.
Bleach required: More than 30 per cent, even when yield is reduced to 30 per cent.
Uses to which pulp is suited: No. 2 kraft wrapping paper; with very careful beating, possibly No. 1 kraft.
Both the specific gravity of the wood and the percentage yield by weight are low and combine to reduce the yield per cord below that of the coniferous woods generally pulped.

By Mechanical Process

Wood too dark for production of satisfactory pulp.

5. HARDWOODS—DIFFUSE-POROUS

Possible uses: Reference is directed to page 20 for a discussion of the uses of hardwood pulps as a group. Individual species differ as to the ease or difficulty with which pulps of satisfactory quality can be produced rather than as to specific uses for which they may be suited. Therefore no discussion of specific uses of pulps from the individual species will be attempted in the summaries.

Sulphate process: Practically all American hardwoods can be pulped by the sulphate process as readily as by the soda process. The sulphate pulps usually bleach with less bleaching powder than soda pulps; otherwise the two classes show practically no difference in quality. The soda process, however, since it was established earlier than the sulphate and operates with greater freedom from offensive odors, has remained almost without challenge for the pulping of hardwoods. Therefore the sulphate process will be referred to only incidentally in this section.

ASPEN (Populus tremuloides)

Other names in use.—Quaking asp, American aspen, aspen leaf, white poplar, trembling poplar, American poplar, poplar, popple, trembling aspen, and quaking aspen.
Range.—Southern Labrador to Hudson Bay (southern shores) and northward to the Mackenzie River (near mouth); southward through Northeastern
United States and in the mountains to southern Kentucky, to northern Ohio, Indiana and Illinois, eastern and central Iowa and northern Missouri.

Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—1 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of excellent color; usually contains small black specks, which, however, disappear on bleaching: easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 10 to 15 per cent.

By Soda Process

Reduces fairly readily.
Unbleached pulp: Bleaches easily.
Yields: 45 to 50 per cent.
Bleach required: 10 to 15 per cent.

By Mechanical Process

Aspen is readily reduced to mechanical pulp, yielding 85 to 86 per cent of standard strength with approximately three times as much power as is required for spruce. Upon the introduction of the ground-wood process aspen came to be used to a considerable extent on account of the light color of the pulp. Spruce has now supplanted it because much less power is required and pulp of greater strength and better felting properties is obtained.

Balsam Poplar (Populus balsamifera)

Other names in use.—Balsam, balm of Gilead, cottonwood, and faca mahac.
Oven-dry weight per cubic foot, green volume.—26 pounds.
Fiber length.—1 mm.

By Sulphite Process

Reduces with exceptional ease.
Unbleached pulp: Of excellent color; not contaminated with black specks characteristic of aspen; very easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 5 to 10 per cent.

By Soda Process

Reduces readily.
Unbleached pulp: Fairly easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process

Behavior probably similar to that of aspen.

Cottonwood

Other names in use.—For the purposes of this bulletin both eastern cottonwood (Populus deltoides) and southern cottonwood (P. deltoides virginiana) are included under the name "cottonwood."

Range.—The range of eastern cottonwood is commonly recognized as northwestern Vermont, through western New York, eastern border of Pennsylvania, and central Maryland; central-eastern Mississippi. The complete range is imperfectly known. Southern cottonwood ranges from Quebec and Lake Champlain southward through western New England to Florida; westward to southern Minnesota, the Dakotas, eastern Nebraska, Kansas, Oklahoma, and Texas.
Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—1.3 mm.

†About 7 to 12 per cent when cooked by sulphate process to yields indicated.
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP 49

By Sulphite Process

Pulping properties probably similar to those of aspen, but pulp less contaminated with black specks.

By Soda Process

Reduces readily.
Unbleached pulp: Fibers longer than those from aspen; fairly easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process

Behavior similar to that of aspen.

Largetooth Aspen (Populus grandidentata)

Other names in use.—Poplar, largetoothed poplar, large poplar, white poplar, popple, and large American aspen.

Range.—Nova Scotia, New Brunswick, southern Quebec, and Ontario to northern Minnesota, and northeastern North Dakota; southward to Pennsylvania, Ohio, and Iowa, and along the Alleghany Mountains to North Carolina, central Kentucky and Tennessee.

Oven-dry weight per cubic foot, green volume. —22 pounds.
Fiber length. —1.1 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of excellent color; bleaches fairly readily.
Yields: 45 to 50 per cent.
Bleach required: 15 to 20 per cent.

By Soda Process

Reduces readily.
Unbleached pulp: Bleaches fairly readily.
Yields: 40 to 45 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process

Behavior probably similar to that of aspen.

Yellow Poplar (Liriodendron tulipifera)

Other names in use.—Tulip poplar, tulip-tree, whitewood, poplar, white poplar, blue poplar, and hickory poplar.

Range.—From Rhode Island to southwestern Vermont and west to Lake Michigan; south to northern Florida, southern Alabama and Mississippi; west of Mississippi River in northeastern Louisiana, southeastern Missouri, and northeastern Arkansas.

Oven-dry weight per cubic foot, green volume. —26 pounds.
Fiber length. —1.8 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of poor color, though less contaminated with black specks than is aspen sulphite; difficult to bleach.
Yields: 45 to 50 per cent.
Bleach required: 20 to 25 per cent.

By Soda Process

Reduces fairly readily.
Unbleached pulp: Stronger than aspen pulp; fairly easily bleached.
Yields: 40 to 45 per cent.
Bleach required: 15 to 20 per cent.

Tests were also made on Norway poplar (Populus canadensis eugenei, a hybrid) which behaves like cottonwood. Norway poplar is believed to be a cross between P. deltoides and P. nigra italica—a European species—and the resultant hybrid has been planted extensively in this country.

About 12 to 18 per cent when cooked by sulphate process to yields indicated.
By Mechanical Process

Behavior probably similar to that of aspen, but slightly less power required for pulp of standard strength.

Basswood (Tilia glabra, formerly Tilia Americana)

Other names in use.—American linden, linn, lime tree, and whitewood.
Range.—New Brunswick to Lake Superior (eastern shores) and to Lake Winnipeg (southern shores) and the Assiniboine River; south to Pennsylvania, Ohio, through Michigan, Indiana, and Illinois and eastern Nebraska to Missouri.
Oven-dry weight per cubic foot, green volume.—21 pounds.
Fiber length.—1.1 mm.

By Sulphite Process

Unbleached pulp: Very shivy, incapable of satisfactory bleaching.

By Soda Process

Reduces readily.
Unbleached pulp: Fairly easy to bleach.
Yields: 45 to 50 per cent.
Bleach required: 20 to 25 per cent. 10

By Mechanical Process

Behavior probably similar to that of aspen.

Black Willow (Salix nigra)

Other names in use.—Swamp willow and willow. The lumber is usually called willow.
Range.—Southern New Brunswick, Quebec and Ontario to Georgia and central Alabama; west to southeastern North Dakota, eastern South Dakota, Nebraska, Kansas, Oklahoma, southwestern Arkansas, western Texas.
Oven-dry weight per cubic foot, green volume.—21 pounds.
Fiber length.—0.8 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of excellent color, somewhat contaminated with black specks; fairly easily bleached.
Yields: 50 to 55 per cent.
Bleach required: 15 to 20 per cent.

By Soda Process

Reduces readily.
Unbleached pulp: Fairly easy to bleach.
Yields: 45 to 50 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process

Behavior probably similar to that of aspen.

Sandbar Willow (Salix longifolia, formerly, in part, S. fluviatilis)

Other names in use.—Long-leafed willow, narrow-leafed willow, and riverbank willow.
Range.—Quebec to Athabasca and southward through western New England to Virginia; westward to Colorado and southern Texas.
Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—0.7 mm.

By Sulphite Process

Reduces easily.
Unbleached pulp: Of poor color; bleaches easily.
Yields: 45 to 50 per cent.
Bleach required: 5 to 10 per cent.

10 About 10 to 13 per cent when cooked by sulphate process to yields indicated.
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP

By Soda Process

Reduces readily.
Unbleached pulp: Bleaches with difficulty.
Yields: 40 to 45 per cent.
Bleach required: 25 to 30 per cent.

By Mechanical Process

Behavior probably similar to that of aspen.

Red Alder (Alnus rubra)

Other names in use.—Alder and western alder.
Range.—From southeastern Alaska to southern California.
Oven-dry weight per cubic foot, green volume.—23 pounds.
Fiber length.—1.2 mm.

By Sulphite Process

Not determined.

By Soda Process

Reduces readily.
Unbleached pulp: Fairly easy to bleach.
Yields: 40 to 45 per cent.
Bleach required: 20 to 25 per cent.11
Red alder is much more susceptible to decay than ordinary pulp woods.

By Mechanical Process

Behavior probably similar to that of aspen.

Balsa (Ochroma lagopus)

Other names in use.—Balsa and balsa wood are the English and the commoner trade names for the wood. Common native names are lanero and lanillo in Cuba, bombast mahoe in Jamaica, and guano in Spanish Honduras.
Range.—Tropical America, Cuba, Jamaica, and Porto Rico.
Oven-dry weight per cubic foot, green volume.—7 pounds.
Fiber length.—1.33 mm.

By Sulphite Process

Not determined.

By Sulphate Process

Reduced readily.
Unbleached pulp: Fairly easily bleached.
Yield: 55 to 60 per cent. The lightness of the wood makes the yield on the volume basis extremely low.
Bleach required: 25 to 30 per cent.
Uses to which pulp is suited: Balsa is probably of no commercial value as a pulp wood because of the extremely low yield per unit of volume.

By Mechanical Process

Not determined.

Box Elder (Acer negundo)

Other names in use.—Ash-leaved maple and three-leaved maple.
Range.—From central New York and western New England, southward to central Florida; westward to Minnesota, Iowa, eastern Kansas, Missouri, southeastern Oklahoma, and southwestern Arkansas, northern Alabama, western Louisiana, and eastern Texas.
Oven-dry weight per cubic foot, green volume.—30 pounds.
Fiber length.—

By Sulphite Process

Behavior probably similar to that of red maple.

11 About 15 to 20 per cent when cooked by sulphate process to yields stated.
By Soda Process
Reduces readily.
Unbleached pulp: Rather difficult to bleach.
Yields: 35 to 40 per cent.
Bleach required: 25 to 30 per cent.\[12\]

By Mechanical Process
Behavior probably similar to that of black gum.

Red Maple (Acer rubrum)
Other names in use.—Swamp maple, soft maple, and water maple. The trade name of the lumber, mixed with that of silver maple, is soft maple.
Range.—From Newfoundland to southern Florida and westward to western Wisconsin, northwestern Minnesota, southeastern Iowa, eastern Oklahoma, southwestern Arkansas, and eastern Texas.
Oven-dry weight per cubic foot, green volume.—30 pounds.
Fiber length.—0.8 mm.

By Sulphite Process
Reduces very easily.
Unbleached pulp: Of rather poor color; usually contains small black specks, which disappear upon bleaching; easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 5 to 15 per cent.

By Soda Process
Reduces vary easily.
Unbleached pulp: Fairly easy to bleach.
Yields: 40 to 45 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process
Behavior probably similar to that of black gum.

Sugar Maple (Acer saccharum)
Other names in use.—Hard maple, sugar-tree, and rock maple. The lumber is called hard maple and white maple by the trade.
Range.—From southern Newfoundland and Nova Scotia (along the St. Lawrence and Saguenay Rivers, Lake St. John, and the northern borders of the Great Lakes) to Lake of the Woods, Ontario, Minnesota, northeastern South Dakota, Iowa, eastern Kansas, central and southeastern Oklahoma, southwestern Arkansas, and eastern Louisiana; south (through the Northern States and on the Allegheny Mountains) to northern Georgia; west to eastern Nebraska, eastern Kansas, and eastern Texas.
Oven-dry weight per cubic foot, green volume.—35 pounds.
Fiber length.—

By Sulphite Process
Reduces very easily.
Unbleached pulp: Of excellent color; bleaches easily.
Yields: 45 to 50 per cent.
Bleach required: 10 to 20 per cent.

By Soda Process
Reduces with some difficulty.
Unbleached pulp: Rather difficult to bleach.
Yields: 40 to 45 per cent.
Bleach required: 25 to 30 per cent.\[13\]

By Mechanical Process
Behavior probably similar to that of black gum.

\[12\] About 15 to 20 per cent when cooked by sulphate process to yields stated.
\[13\] About 20 to 27 per cent when cooked by sulphate process to yields stated.
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP 53

Paper Birch (Betula papyrifera)

Other names in use.—Canoe birch and white birch.
Range.—From Labrador to Hudson Bay (southern shores); southward to New York (Long Island) and northern Pennsylvania, central Michigan, northern Wisconsin, North Dakota, South Dakota (Black Hills), eastern Nebraska, and Wyoming. The best stands occur in the central portion of Maine, in a strip extending from the coast to the White Mountains of New Hampshire.

Oven-dry weight per cubic foot, green volume.—34 pounds.
Fiber length.—1.2 mm.

By Sulphite Process

Reduces easily.
Unbleached pulp: Of poor color; fairly easy to bleach.
Yields: 45 to 50 per cent.
Bleached required: 10 to 20 per cent.

By Soda Process

Reduces with some difficulty.
Unbleached pulp: Fairly easy to bleach.
Yields: 35 to 40 per cent.
Bleached required: 15 to 20 per cent.

By Mechanical Process

Characteristics similar to those of aspen except that the pulp, though light colored, has a pinkish tinge.

Yellow Birch (Betula lutea)

Other names in use.—Gray birch, swamp birch, and silver birch. The lumber is sold as birch.
Range.—From Newfoundland and along the northern shores of St. Lawrence Gulf to Abitibi Lake and Rainy River; southward through northern Minnesota to central Iowa, and through the Northern States to eastern Tennessee, western North Carolina, northern Georgia, and Delaware. Wisconsin, Michigan, and New York have the largest stands.

Oven-dry weight per cubic foot, green volume.—34 pounds.
Fiber length.—1.5 mm.

By Sulphite Process

Reduces readily.
Unbleached pulp: Of good color; fairly easily bleached.
Yields: 45 to 50 per cent.
Bleached required: 15 to 20 per cent.

By Soda Process

Reduces with some difficulty.
Unbleached pulp: Fairly easy to bleach.
Yields: 40 to 45 per cent.
Bleached required: 15 to 20 per cent.

By Mechanical Process

Behavior probably similar to that of paper birch.

Beech (Fagus grandifolia, formerly, F. atropunicea)

Other names in use.—Red beech and white beech.
Range.—New Brunswick to Lake Huron (northern shores) and Minnesota; south to western Florida and west to Missouri and Texas (Trinity River).

Oven-dry weight per cubic foot, green volume.—36 pounds.
Fiber length.—1.1 mm.

By Sulphite Process

Not determined.
Reduces with slightly more difficulty than aspen.  
Unbleached pulp: Easy to bleach.  
Yields: 45 to 50 per cent.  
Bleach required: 10 to 15 per cent.

Not determined.

**By Mechanical Process**

**Black Gum (Nyssa sylvatica)**

*Other names in use.*—Tupelo and pepperidge.  
*Range.*—From Maine (Kennebec River) to northern Florida; west to southern Ontario, southern Michigan, southeastern Missouri, Oklahoma, southwestern Arkansas, and eastern Texas.  
*Oven-dry weight per cubic foot, green volume.*—30 pounds.  
*Fiber length.*—1.7 mm.

Reduces readily.  
Unbleached pulp: Fairly easy to bleach.  
Yields: 45 to 50 per cent.  
Bleach required: 15 to 20 per cent.

Reduces readily.  
Unbleached pulp: Slightly stronger than aspen pulp; rather difficult to bleach.  
Yields: 35 to 40 per cent.  
Bleach required: 20 to 30 per cent.

A pulp of standard strength, very light colored and fine fibered, is produced with a consumption of approximately three times as much power as is required for spruce.

**Tupelo Gum (Nyssa aquatica)**

*Other names in use.*—Sour gum, bay poplar, cotton gum, large tupelo, swamp poplar, and hickory poplar. The lumber usually goes under the names tupelo and sap gum in the market.  
*Range.*—Atlantic coast region from southern Virginia to northern Florida, and through the Gulf States to central Texas; northward through Arkansas, west Tennessee, and Kentucky, southern and southeastern Missouri to southern Illinois.  
*Oven-dry weight per cubic foot, green volume.*—29 pounds.  
*Fiber length.*—1.6 mm.

Reduces readily.  
Unbleached pulp: Of fair color; fairly easily bleached.  
Yields: 45 to 50 per cent.  
Bleach required: 15 to 25 per cent.

Reduces readily.  
Unbleached pulp: Slightly stronger than aspen pulp; rather difficult to bleach.  
Yields: 35 to 40 per cent.  
Bleach required: 25 to 30 per cent.

Behavior probably similar to that of black gum.

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14 About 15 to 25 per cent when cooked by sulphate process to yields stated.  
15 About 20 to 27 per cent when cooked by sulphate process to yields stated.
**RED GUM (Liquidambar styraciflua)**

*Other names in use.*—Gum, sweet gum, liquidambar, and star-leaved gum. In the lumber markets red gum is the name applied to the heartwood and sap gum to the sapwood of the tree. In foreign markets the heartwood is called satin walnut and the sapwood, hazel pine.

*Range.*—From southwestern Connecticut to southeastern Missouri, Arkansas and Oklahoma, south to central Florida and eastern Texas. The commercial range is largely confined to the moist lands of the lower Ohio and Mississippi basins and the lowlands of the southeastern coast.

*Oven-dry weight per cubic foot, green volume.*—27 pounds.

*Fiber length.*—1.6 mm.

*By Sulphite Process*

Reduces readily.

Unbleached pulp: Dark colored and rather difficult to bleach, differing in this respect from pulps from the true gums (Nyssa).

Yields: 45 to 50 per cent.

Bleach required: 35 to 40 per cent.

Uses to which pulp is suited: Limited chiefly by resistance to bleach.

*By Soda Process*

Reduces fairly readily.

Unbleached pulp: Rather difficult to bleach.

Yields: 35 to 40 per cent.

Bleach required: 15 to 20 per cent.

*By Mechanical Process*

Behavior probably similar to that of black gum.

**CUCUMBER MAGNOLIA (Magnolia acuminata)**

*Other names in use.*—Cucumber tree, cucumber, and mountain magnolia. The lumber is usually sold as yellow poplar.

*Range.*—From western New York through southern Ontario and south to southern Illinois and Indiana, and south in the Appalachian Mountains to southern Georgia, southern Alabama, and northeastern Mississippi, central Kentucky and Tennessee, northeastern, southern, and southwestern Arkansas, and eastern Oklahoma, and southwestern Missouri.

*Oven-dry weight per cubic foot, green volume.*—27 pounds.

*Fiber length.*—1.3 mm.

*By Sulphite Process*

Reduces readily.

Unbleached pulp: Dark colored, rather difficult to bleach.

Yields: 45 to 50 per cent.

Bleach required: 25 to 30 per cent.

Uses to which pulp is suited: Limited chiefly by resistance to bleach.

*By Soda Process*

Reduces easily.

Unbleached pulp: Rather difficult to bleach.

Yields: 45 to 50 per cent.

Bleach required: 20 to 30 per cent.

*By Mechanical Process*

Behavior probably similar to that of black gum.

**SWEET BAY (Magnolia virginiana australis, formerly included as a form of M. glauca)**

*Other names in use.*—White bay, swamp laurel, and swamp magnolia.

*Range.*—From southeastern North Carolina (vicinity of Wilmington) and southward in the coast region of South Carolina and Georgia (to Randolph and Carroll Counties), throughout Florida, and westward in the Gulf States to eastern
Texas (Nueces River, San Augustine County); in Alabama, extending to Macon and Dallas Counties, and also to Sand and Lookout Mountains, in Mississippi, to the northeast corner of the State, and in western Louisiana, to Winn and Natchitoches Parishes.

Oven-dry weight per cubic foot, green volume.—29 pounds. Fiber length.—1.3 mm.  

By Sulphite Process

Reduces readily.
Unbleached pulp: Of poor color; easily bleached.
Yields: 40 to 45 per cent.
Bleach required: 10 to 15 per cent.

By Soda Process

Reduces readily.
Unbleached pulp: Rather difficult to bleach.
Yields: 35 to 40 per cent.
Bleach required: 25 to 30 per cent.  

By Mechanical Process

Behavior probably similar to that of black gum.

Sycamore (Platanus occidentalis)

Other names in use.—Button-wood, buttonball-tree, and plane-tree.

Range.—Southwestern Maine to northern Vermont, southern Ontario and Michigan, central and southern Iowa, southeastern Nebraska, eastern Kansas, Oklahoma, and southwestern Arkansas, south to western Florida, central Alabama, and Mississippi, to western Texas.

Oven-dry weight per cubic foot, green volume.—29 pounds.
Fiber length.—1.7 mm.  

By Sulphite Process

Reduces readily.
Unbleached pulp: Easily to bleach.
Yields: 45 to 50 per cent.
Bleach required: 10 to 15 per cent.

By Soda Process

Reduces readily.  
Unbleached pulp: Fairly easy to bleach.
Yields: 45 to 50 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process

Not determined.

Butternut (Juglans cinerea)

Other names in use.—White walnut and oil nut.

Range.—Southern New Brunswick to Delaware and in the Appalachian Mountains to Georgia and Alabama, westward through Ontario to eastern South Dakota, eastern Iowa, southeastern Nebraska, central Kansas, southern Missouri, and northern Arkansas.

Oven-dry weight per cubic foot, green volume.—22 pounds.
Fiber length.—1.2 mm.  

By Sulphite Process

Reduces readily.
Unbleached pulp: Of poor color; fairly easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 15 to 20 per cent.

By Soda Process

Reduces readily.
Unbleached pulp: Very difficult to bleach.
Yields: 45 to 50 per cent.

20 to 25 per cent when cooked by sulphate process to yields stated.
17 The wood is difficult to chip if it is allowed to dry out, presumably on account of the numerous and broad medullary rays.
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP

By Mechanical Process

Ohio Buckeye (Aesculus glabra)

Other names in use.—Buckeye, American horse chestnut, and stinking buckeye.

Range.—From Pennsylvania (western slopes of the Allegheny Mountains) to northern Alabama, and west to southern Iowa, northeastern Kansas, Missouri, and southeastern Nebraska.

Oven-dry weight per cubic foot, green volume.—21 pounds.

Fiber length.—

By Sulphite Process

Reduces readily.
Unbleached pulp: Silver-gray in color; rather difficult to bleach.
Yields: 45 to 50 per cent.
Bleach required: 20 to 25 per cent.

By Soda Process

Reduces fairly readily.
Unbleached pulp: Rather difficult to bleach.
Yields: 40 to 45 per cent.
Bleach required 25 to 30 per cent.

By Mechanical Process

Mangrove (Rhizophora mangle)

Other names in use.—This species is known only as mangrove.

Range.—Southern coast of Florida.

Oven-dry weight per cubic foot, green volume.—56 pounds.

Fiber length.—

By Sulphite Process

Reduces readily.
Unbleached pulp: Short fibered, rather difficult to bleach.
Yields: 40 to 45 per cent.
Bleach required: 25 to 30 per cent.

By Soda Process

Common Catalpa (Catalpa bignonioides, formerly C. catalpa)

Other names in use.—Indian bean, bean-tree, common catalpa, catawba, and cigar-tree.

Range.—Believed to be indigenous only in southwestern Georgia, western Florida, central Alabama, Mississippi, and southwestern Missouri. It is widely
cultivated for ornament, however, and is naturalized elsewhere in the eastern United States as far north as southern New York, and also in Europe.

Oven-dry weight per cubic foot, green volume.—31 pounds.

Fiber length.—

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Decidedly pinkish in color, frequently specky; very difficult to bleach.
Yields: 45 to 50 per cent.
Bleach required: 35 to 40 per cent.

By Soda Process

Reduces readily.
Unbleached pulp: Fairly easy to bleach.
Yields: 40 to 45 per cent.
Bleach required: 15 to 20 per cent.

By Mechanical Process

Not determined.

CHESTNUT (Castanea dentata)

Other names in use.—Chestnut is one of the few trees of commercial importance that has but one name.

Range.—The entire stand of chestnut in the United states is being rapidly depleted by a fungous disease known as the "chestnut blight." Before it was attacked by the blight, chestnut grew in commercial quantities from New Hampshire and Vermont southward and westward in Connecticut, Massachusetts, New York, Pennsylvania, and along the Appalachian Mountains to northern Georgia. The commercial supply has been greatly diminished by the blight in the northern part of this region, and the best remaining stands are located in the southern Appalachians.

Oven-dry weight per cubic foot, green volume.—25 pounds.

Fiber length.—1 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Olive-brown in color; very difficult to bleach.
Yields: 40 to 45 per cent.
Bleach required: 35 to 40 per cent.

By Soda Process

Does not reduce satisfactorily. When extracted, however, for the tannin content, chestnut chips reduce readily. The following statements apply to pulp made from extracted chips:

Unbleached pulp: Bleaches easily.
Yields: 35 to 40 per cent.
Bleach required: 10 to 15 per cent.

By Mechanical Process

Not determined.

HACKBERRY (Celtis occidentalis)

Other names in use.—Sugarberry and nettle-tree.

Range.—From New England to Virginia and westward to eastern North Dakota, Iowa, southwestern Missouri, and western Kansas.

Oven-dry weight per cubic foot, green volume.—30 pounds.

Fiber length.—1.1 mm.

By Sulphite Process

Reduced readily.
Unbleached pulp: Exceptionally light colored; easily bleached.
The color of the bleached pulp is better than that obtained with any other wood pulp, comparing favorably with that of the finest bleached cotton.
Yield: 40 to 45 per cent.
Bleached required: 10 to 15 per cent.
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP

By Soda Process

Reduces readily.
Unbleached pulp: Rather difficult to bleach; differs from soda pulps of most other species on account of being noticeably less opaque.
Yields: 35 to 40 per cent.
Bleached required: 20 to 30 per cent.

By Mechanical Process

Not determined.

Sassafras (Sassafras variifolium, formerly S. sassafras)

Other names in use.—Sassafras is the universal name for this species.
Range.—From southern Maine and eastern Massachusetts through southern Vermont, southern Ontario, and central Michigan, southeastern Iowa to eastern Kansas, Arkansas, and Oklahoma; south to central Florida, and eastern Texas.
Oven-dry weight per cubic foot, green volume.—26 pounds.
Fiber length.—0.9 mm.

Not successfully reduced.

By Sulphite Process

Reduces readily.

By Soda Process

Unbleached pulp: Very difficult to bleach except where yields are too low for commercial consideration.
Yields: 30 to 35 per cent.
Bleached required: 30 to 35 per cent.

By Mechanical Process

Not determined.

Rock Elm (Ulmus racemosa)

Other names in use.—Cork elm and hickory elm. Rock elm is the usual name applied to the lumber.
Range.—From Quebec (eastern townships) through Ontario, and south through northwestern New Hampshire to southern Vermont, and to northern New Jersey; westward through northern New York, southern Michigan, and central Wisconsin; southwestern Minnesota to northeastern Nebraska, western Missouri, eastern Kansas, and middle Tennessee.
Oven-dry weight per cubic foot, green volume.—36 pounds.
Fiber length.—1.3 mm.

Reduces readily.
Unbleached pulp: Of poor color; easily bleached.
Yields: 45 to 50 per cent.
Bleach required: 10 to 15 per cent.

By Sulphite Process

Reduces readily.
Unbleached pulp: Fairly easy to bleach.
Yields: 45 to 50 per cent.
Bleach required: 20 to 25 per cent.

By Soda Process

Not determined.

Slippery Elm (Ulmus fuva, formerly U. pubescens)

Other names in use.—This species is also commonly known as red elm and moose elm. The lumber is often sold as “gray elm.”
Range.—From the lower St. Lawrence River through Ontario to South Dakota and eastern Nebraska, southeastern Kansas, southwestern Arkansas, and Oklahoma; south to western Florida, central Alabama, and Mississippi, western Louisiana, and central Texas.
Oven-dry weight per cubic foot, green volume.—30 pounds.
Fiber length.—1.7 mm.
Reduces very imperfectly.
Unbleached pulp: Specky and dark.
Yields: 45 to 50 per cent.
Uses to which pulp is suited: Limited chiefly by imperfect reduction.

By Sulphite Process

Reduces readily.
Unbleached pulp: Difficult to bleach.
Yields: 35 to 40 per cent.
Bleach required: 30 to 40 per cent.

By Soda Process

Not determined.

AMERICAN ELM (Ulmus americana)

Other names in use.—White elm, water elm, and elm. The lumber is known variously as soft elm, gray elm, and hard gray elm.

Range.—From southern Newfoundland to Lake Superior and to the eastern base of the Rocky Mountains, south to southern Florida, west to North Dakota, South Dakota, western Nebraska, central Kansas, Oklahoma, southwestern Arkansas, and west central Texas.

Oven-dry weight per cubic foot, green volume.—27 pounds.
Fiber length.—1.6 mm.

By Sulphite Process

Behavior probably similar to that of rock elm.

By Soda Process

Not determined.

WHITE ASH (Fraxinus americana)

Other names in use.—Lumber of the several ashes is usually sold as “ash,” and the term “white ash” is generally used to indicate heavy, strong material of high quality from which the lighter wood is excluded. Pumpkin ash is a term frequently employed to designate soft and brittle ash wood.

Range.—White ash is found over nearly all the eastern half of the United States. It occurs from Nova Scotia and New Brunswick to Florida and westward through southern Quebec and Ontario to eastern Minnesota, eastern Nebraska and Kansas, Oklahoma, southwestern Arkansas, and eastern Texas.

Oven-dry weight per cubic foot, green volume.—34 pounds.
Fiber length.—1.2 mm.

By Sulphite Process

Reduces fairly readily.
Unbleached pulp: Of poor color, specky; rather difficult to bleach.
Yields: 45 to 50 per cent.
Bleach required: 20 to 30 per cent.
Uses to which pulp is suited: Few.

By Soda Process

Reduced by soap.
Unbleached pulp: Rather difficult to bleach.
Yields: 40 to 45 per cent.
Bleach required: 25 to 30 per cent.
Uses to which pulp is suited: Few.

By Mechanical Process

Not determined.

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\(^{11}\) From 15 to 20 per cent when cooked by sulphate process to yields stated.
\(^{12}\) About 18 to 24 per cent when cooked by sulphate process to yields stated.
THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP

RED OAK (Quercus borealis maxima, formerly Q. rubra)

Other names in use.—Black oak, spotted oak, mountain oak, and Spanish oak. The term "red oak" is used commercially to indicate the wood of a number of species included in the red-oak group, which is one of the two groups (namely "red" and "white") into which the oaks are divided commercially in the trade.

Range.—The northern range is not fully determined. Red oak occurs from western New York and Pennsylvania westward through Ohio and southern Michigan and southward to Georgia, Tennessee, Alabama, and Mississippi to Arkansas and Oklahoma; westward to eastern Nebraska and central Kansas.

Oven-dry weight per cubic foot, green volume.—35 pounds.
Fiber length.—1.5 mm.

By Sulphite Process
Reduces readily.
Unbleached pulp: Of fair color, but specky; rather difficult to bleach.
Yields: 45 to 50 per cent.
Bleach required: 20 to 25 per cent.
Uses to which pulp is suited: Limited chiefly by speckiness.

By Sulphate Process
Reduces readily.
Unbleached pulp: Rather difficult to bleach.
Yields: 35 to 40 per cent.
Bleach required: 15 to 25 per cent.
Uses to which pulp is suited: When undercooked, high yields are obtained of a pulp suitable for the manufacture of wrapping paper of fair strength; otherwise possible uses are few.

By Mechanical Process
Not determined.

WHITE OAK (Quercus alba)

Other names in use.—"West Virginia soft white oak," stave oak, and "forked-leaf white oak" are trade names. Lumber of several other species of the white oak group is classed as "white oak".

Range.—From southern Maine to southwestern Quebec and through southern Ontario, Lower Peninsula of Michigan, and southern Minnesota, eastern Iowa, southeastern Nebraska, and eastern Kansas, Arkansas, and Oklahoma; south to western Florida and eastern Texas.

Oven-dry weight per cubic foot, green volume.—37 pounds.
Fiber length.—1.5 mm.

By Sulphite Process
Reduces with some difficulty.
Unbleached pulp: Specky; difficult to bleach.
Yields: 45 to 50 per cent.
Bleach required: 30 to 35 per cent.

By Soda Process
Reduces readily.
Unbleached pulp: Very difficult to bleach.
Yields: 35 to 40 per cent.
Bleach required: 35 to 40 per cent.29

By Mechanical Process
Not determined.

MOCKERNUT HICKORY (Hicoria alba)

Other names in use.—Mockernut hickory, mockernut, and white heart hickory. The lumber is generally sold as hickory, a name under which several hickories are included.

Range.—Southwestern Ontario to Florida and west to southeastern Iowa, Missouri, eastern Oklahoma, and southwestern Arkansas, and in the Gulf States to eastern Texas.

Oven-dry weight per cubic foot, green volume.—40 pounds.
Fiber length.—1.4 mm.

29 About 22 to 25 per cent when cooked by sulphate process to yields stated.
By Sulphite Process
Reduces readily.
Unbleached pulp: Specky; rather difficult to bleach.
Yields: 40 to 45 per cent.
Bleach required: 15 to 20 per cent.

By Soda Process
Reduces readily.
Unbleached pulp: Very difficult to bleach.
Yields: 30 to 35 per cent.
Bleach required: More than 35 per cent.\(^2\)

By Mechanical Process
Not determined.

Black Locust (*Robinia pseudoacacia*)

Other names in use.—Locust and yellow locust.
Range.—From Pennsylvania to northern Georgia, also southern Illinois and southwestern Indiana. Widely naturalized through cultivation and other agencies throughout the United States east of the Rocky Mountains.
Oven-dry weight per cubic foot, green volume.—41 pounds.
Fiber length.—

By Sulphite Process
Reduces with difficulty and very unevenly.
Unbleached pulp: Not satisfactory.

By Soda Process
Reduces fairly readily.
Unbleached pulp: Does not bleach satisfactorily.
Yields: 40 to 45 per cent.

Not determined.

Ailanthus (*Ailanthus altissima, formerly A. glandulosa*)

Other names in use.—Tree of Heaven and Chinese sumac.
Range.—Native of China; but has been widely naturalized in the eastern United States.
Oven-dry weight per cubic foot, green volume.—24 pounds.
Fiber length.—1.2 mm.

By Sulphite Process
Not determined.

By Soda Process
Reduces readily.
Unbleached pulp: Very easy to bleach.
Yields: 45 to 50 per cent.
Bleach required: 5 to 10 per cent.

By Mechanical Process
Not determined.

7. MISCELLANEOUS SPECIES

Soapweed (*Yucca elata, formerly Y. radiosa*)

Other names in use.—Spanish bayonet and Spanish dagger.
Range.—Southwestern Texas to southern Arizona; northern Mexico.
Oven-dry weight per cubic foot, green volume.—18 pounds.
Fiber length.—

Not determined.

Sulphite Pulp

Soda Pulp

Soapweed is readily reduced by the soda process, yielding a pulp containing 20 to 30 per cent of rather short fibers. The remainder is pithy material, the

\(^2\) Bleach requirement greatly reduced when cooked by sulphate process.
cells of which are very little longer than their diameter. A few special uses might be developed for this material, but it could hardly be used for standard pulp products on account of the probable cost of collection, nonuniformity of the pulp obtained, low yields, and the difficulty in completely removing soil and other foreign matter from the material before cooking.

**Mechanical Pulp**

Not determined.

**Cabbage Palmetto** (*Sabal palmetto*)

*Other names in use.*—Palmetto and cabbage tree.

*Range.*—Coast region from North Carolina to southern Florida, and on the Gulf coast to western Florida.

*Oven-dry weight per cubic foot, green volume.*—23 pounds.

*Fiber length.*—

**Sulphite Pulp**

Cabbage palmetto under the sulphite process yields 35 to 40 per cent of dark, raw, and brash pulp not suited for any of the common uses.

**Sulphate Pulp**

Cabbage palmetto can be reduced by the sulphate process under low steam pressure to satisfactory pulp fairly easy to bleach. The pulp is stronger than aspen soda pulp, and may be used in the manufacture of book, magazine, and other similar papers, preferably in combination with 20 to 40 per cent of bleached pulp from coniferous woods. The pulp consists of a mixture of fairly long fibers and pithy material. The proportion of pithy material, however, does not seriously affect the character of the sheet except in so far as it makes it weaker than would be the case with the long-fibered portion alone. Yields of 40 to 45 per cent are obtained, requiring 25 to 30 per cent of standard bleaching powder.

**Soda Pulp**

Cabbage palmetto when cooked by the soda process yields 35 per cent of coarse, tender fiber difficult to bleach and not suited for any of the common uses.

**Mechanical Pulp**

Not determined.

**Cane** (*Arundinaria macrosperma*)

*Other names in use.*—Large cane and giant cane.

*Range.*—River bottoms from Virginia to Florida, westward to Louisiana and along the Mississippi and its tributaries as far north as Kentucky, Tennessee, and Missouri.

*Oven-dry weight per cubic foot, green volume (in piles).*—10 pounds.

*Fiber length.*—

**Sulphite Pulp**

Not determined.

**Soda Pulp**

Cane reduces readily by the soda process to an easily bleached pulp having greater average fiber length than aspen soda pulp and capable of use in the manufacture of book, magazine, and similar papers. It could probably be used without admixture of longer-fibered pulps from coniferous woods. The fiber is soft, opaque, and contains much less pith than is usual for this sort of material. Yields of 33 to 42 per cent are obtained, requiring 15 to 18 per cent of standard bleaching powder.

**Mechanical Pulp**

Not determined.

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2 When chopped for the digester, the material occupies 1 cubic foot for each 14 pounds of oven-dry material, in comparison with 10 pounds to the cubic foot of space occupied by spruce chips.)
8. CHILEAN WOODS

Olivillo

Description.—The bark is light ash-gray, about one-half inch thick, compact, comparatively smooth, and is not broken into fissures nor can it be readily separated into scales. The wood does not resemble any commercial native wood. It has a very open structure and contains one-quarter by volume of wood fibers having walls of moderate thickness, the rest being made up of parenchyma or vascular tissue.

Oven-dry weight per cubic foot, green volume.—
Fiber lengths.—Average, 2.15 mm; maximum, 2.62 mm; minimum, 1.34 mm.

Soda Pulp

Olivillo yields a pulp with a longer fiber than has been obtained from any North American hardwoods, which would render it suitable for use unbleached in the manufacture of wrapping paper of considerable strength. Although it is rather difficult to bleach, with bleaching in two stages economical means of operation might possibly be evolved. Yields of 35 to 40 per cent are obtained, requiring 30 to 40 per cent of standard bleaching powder.

Laurel (Laurelia aromatic)

Range.—Laurel grows from 34° south latitude to Llanquihue, Chile.

Description.—The bark is dark reddish brown, about one-half inch thick, is not broken into fissures but can be readily separated into scales. The wood resembles that of silver maple (Acer saccharinum). Fiber walls are moderately thick.

Oven-dry weight per cubic foot, green volume.—
Fiber lengths.—Average, 0.86 mm.; maximum, 1.02 mm.; minimum, 0.7 mm.

Soda Pulp

The action of the caustic soda in cooking is slower than with most species, and the same is true with the solutions in bleaching. The pulp is similar to aspen soda pulp. Yields of 40 per cent are obtained, requiring 30 to 35 per cent of standard bleaching powder.

Coigue (Nothofagus dombeyi)

Range.—Grows abundantly throughout Chile.

Description.—The bark is grayish, one-half inch thick, and separated into low flat ridges. The inner bark is very fibrous. The wood strongly resembles red gum (Liquidambar styraciflua), with about the same proportion of vascular and woody tissue and fairly thick-walled fibers, although the pores are slightly larger.

Oven-dry weight per cubic foot, green volume.—
Fiber lengths.—Average 0.85 mm.; maximum, 1.02 mm.; minimum, 0.7 mm.

Soda Pulp

Coigue is readily reduced by the soda process to fairly easily bleached pulp similar to aspen soda pulp. Yields of 40 to 45 per cent are obtained, requiring 15 to 20 per cent of standard bleaching powder.

Lingue (Persea lingue)

Range.—From Aconcagua to Llanquihue, Chile.

Description.—The bark is deep reddish brown about one-half inch thick and strongly resembles that of hemlock. It is separated by narrow fissures into broad flat plates. The wood strongly resembles butternut (Juglans cinerea), and has large pores. The fibers are moderately thin-walled with comparatively large lumen.

Oven-dry weight per cubic foot, green volume.—
Fiber lengths.—Average, 1.11 mm.; maximum, 1.6 mm.; minimum, 0.61 mm.

Soda Pulp

Yields of 40 to 45 per cent are obtained, requiring 20 to 30 per cent of standard bleaching powder.

These woods were submitted by Senor Alejandro Rosselot, member of Congress, Santiago, Chile.
Roble Pellin (Nothofagus obliqua)

Range.—From 33° south latitude to Llanquihue, Chile.

Description.—The bark is reddish brown with light-gray particles. It is one-half inch thick, not ridged, and readily separated into thin, broad, flat scales. The wood closely resembles coigue.

Oven-dry weight per cubic foot, green volume.—

Fiber lengths.—Average, 1.45 mm.; maximum, 1.76 mm.; minimum, 1.12 mm.

Soda Pulp

Roble pellin is readily reduced by the soda process, but the pulp is very difficult to bleach. Yields of 30 to 35 per cent are obtained, requiring 35 to 40 per cent of standard bleaching powder.

There is little likelihood of this species being considered for pulp, on account of its great durability and consequently higher value for railroad ties and structural timber.

Quillai (Chilean Cane) (Quillaja saponaria)

Description.—Resembles cane, except that it is solid and much stronger.

Oven-dry weight per cubic foot, green volume.—

Fiber lengths.—Average, 2.2 mm.; maximum, 2.66 mm.; minimum, 1.34 mm.

Soda Pulp

Quillai reduces readily by the soda process, yielding 40 to 45 per cent of pulp of very good fiber length and capable of use in the manufacture of papers of moderate strength.

On account of the light color of the pulp it might be considered for use unbleached in the manufacture of newsprint.

**TABLES OF COOKING AND STRENGTH DATA**

Tables 6 to 18 give for most of the woods included the results of a majority of the test cooks made. They cover cooking conditions, yields, and strength of the resulting pulps. For reasons already stated, the data are not in all cases representative of what are, according to the final conclusions, the practical pulping characteristics of the species. They may be considered, however, as illustrative of possible operating conditions, which in some cases are to be avoided rather than imitated.

The column headings in the tables are, in general, self-explanatory. In the tables of sulphite cooks the columns showing the composition of the cooking liquor give the percentage of SO₂ in the liquor as free, combined, and total, with the commonly accepted understanding that the free is the excess over that required to combine with the base and form normal sulphite, even though the latter does not exist as such. "Duration of cook" is the total time of cooking, from turning on steam to blowing. The steam pressures shown refer in all cases to pressures above atmospheric. It is to be noted that these are partial pressures as distinguished from total pressures shown on the gauge. The quantity of bleach required was found by methods already described in "Experimental procedure."

In the strength data the strength factor is obtained by dividing the Mullen test value by the weight per ream of the paper tested. The average stretch and average breaking length are the average of those values in each direction as determined on the Schopper tensile strength tester for paper. The number of double folds was obtained on the standard Schopper folding tester. In the cases of both the folding and the tearing tests due allowance must be made for the weight of the sheet, since the values have not been converted to a standard or unit weight basis for want of any known conversion factor. Strength tests are shown for relatively few of the cooks of hardwoods, since, on account of their short fibers, hardwoods are not often used in papers where strength is of major importance.

Some of the raw cooks listed in the tables were worked into paper by a special beater treatment. This would indicate possibilities of combining chemical with mechanical disintegration of the chips and of producing paper of moderate strength from unbleached pulps at yields between 70 and 80 per cent. Work with caustic soda and caustic soda and sulphur has recently demonstrated this to be possible. Light-colored sulphite pulps with yields of over 70 per cent have been made, but additional work is necessary to perfect the details. The bearing of these developments on the utilization of mill waste or of southern woods for newsprint is apparent. The exceptional strength of pulp so obtained from the hardwoods is also of interest.

31897°—27——5
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<tr>
<th>Species</th>
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<th>Cook</th>
<th>Date</th>
<th>Moist weight</th>
<th>Oven-dry weight</th>
<th>Total</th>
<th>Free</th>
<th>Combined</th>
<th>Per 100 pounds chips</th>
<th>Volume</th>
<th>SO4</th>
<th>Time to maximum temperature</th>
<th>Time to maximum pressure</th>
<th>Duration of cook</th>
<th>Maximum pressure per square inch</th>
<th>Gas pressure at blow per square inch</th>
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<td>Yields based on oven-dry weight of chips charged</td>
<td>Bleach required (35 per cent available chlorine) per 100 pounds oven-dry pulp</td>
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1 Impregnation used. 2,300 c. c. H$_2$SO$_4$ 1.13 sp. gr., added. 3 Pulp of excellent strength and quality. Not run into paper. 4 Ball mill tests gave 1,240 folds.
<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity of wood used</th>
<th>Impregnating liquor</th>
<th>Penetration</th>
<th>Cooking liquor</th>
<th>Black liquor ratio combined to total absorbent</th>
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<td>Moist weight</td>
<td>Over-dry weight</td>
<td>Before penetration</td>
<td>After penetration</td>
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<td>Lbs.</td>
<td>Galons</td>
<td>Grams per liter</td>
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Notes: The data are for the spruces—Soda or sulphate process.
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<td>Cook No.</td>
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1 Pulp extremely raw. Not run into paper. 2 Unbleached pulp of very good color. 3 Unbleached pulp of very good color. Paper exceptionally free from shives. 4 Pulp badly burned. Not run into paper. 5 Ratio line to magnesia, 17:10. 6 Pulp evidently burned. 7 Pulp of excellent strength and quality. Not run into paper.


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**Notes:**
- The table provides data on the cooking and strength of various pine species using soda or sulphate processes.
- The cooking data includes the quantity of wood used, impregnating liquor concentration, and cooking liquor parameters.
- Penetration values are given in °C and pounds per square inch.
- The table also includes concentration, duration, temperature, and black liquor ratio combined to total alkali.
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<th>Apr. 17, 1919</th>
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Footnotes at end of table.
| Species                           | Shipment No. | Cook No. | Date          | Maximum rice per square inch | Pressure increased period | Duration at maximum pressure | Crude pulp | screenings | Oil per ton | Bleached required (63 per cent available chlorine) per 100 pounds oven-dry pulp | Yields based on oven-dry weight of chips charged | Calculated | Weight per ton 24 x 30-
00 | Thickness | Tensile test per square inch | Strength factor per pound per year | Average breaking length | Average double folds | Average Elmendorf tearing test | Conditions during test | Relative humidity | Temperature |
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1. Recook of pulp from soda cook with 45 per cent yield.
2. 23.3 g. p. l. Na₂CO₃ in cooking liquor.
3. 44.1 g. p. l. Na₂CO₃ in cooking liquor.
4. "Lightwood used." 
5. Water-soaked chips.
6. Equal parts water-soaked and air-dried chips mixed.
7. Unbarked wood; 96 per cent wood, 4 per cent bark.
8. Bark only; pulp shivy and unserviceable.
9. Yaryan process extracts chips retained on 12-mesh screen (70 per cent).
10. Unextracted chips retained on screen (64 per cent).
12. 2.2 gallons distilled during pressure increase period.
13. 12 per cent bleach in two steps.
14. Paper of fair strength; no strength tests recorded.
15. 18 per cent bleach in two steps.
17. 16 per cent bleach in two steps.

THE SUITABILITY OF AMERICAN WOODS FOR PAPER PULP

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**Table 10.—Cooking and strength data: The fir—Sulphite process**
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<th>Species</th>
<th>Ship-</th>
<th>Cook</th>
<th>Date</th>
<th>Yields based on oven-dry weight of chips charged</th>
<th>Bleach required (35 per cent available chlorine) per 100 pounds oven-dry pulp</th>
<th>Cooking data—Continued</th>
<th>Strength data</th>
<th>Conditions during test</th>
<th>Relative humidity</th>
<th>Temperature ° F.</th>
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1 Gas pressure held 11.5 hours on account of stopped relief valve.
2 Gas pressure held 2 hours.
3 Pulp very shifty.
4 Pulp apparently of excellent strength; not run into paper.
5 Unbleached pulp of excellent color and quality.
6 Unbleached pulp decidedly yellow.
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<th>Species</th>
<th>Shipment No.</th>
<th>Cook No.</th>
<th>Date</th>
<th>Moist weight</th>
<th>Over-dry weight</th>
<th>Quantity of wood used</th>
<th>Impregnating liquor</th>
<th>Penetration</th>
<th>Cooking liquid</th>
<th>Per 100 pounds bone-dry chips</th>
<th>Black liquor ratio combined to total alkali</th>
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**Table 11:** Cooking and strength data: The fir—Soda or sulphate process

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<th>Shipment No.</th>
<th>Cook No.</th>
<th>Date</th>
<th>Moist weight</th>
<th>Over-dry weight</th>
<th>Quantity of wood used</th>
<th>Impregnating liquor</th>
<th>Penetration</th>
<th>Cooking liquid</th>
<th>Per 100 pounds bone-dry chips</th>
<th>Black liquor ratio combined to total alkali</th>
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**Table 11:** Cooking and strength data: The fir—Soda or sulphate process
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<th>Pressure increased during</th>
<th>Duration at maximum pressure</th>
<th>Crack pulp</th>
<th>Yields based on oven-dry weight of chips charged</th>
<th>Strength data</th>
<th>Conditions during tests</th>
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<td>Douglas fir (Pseudotsuga taxifolia)</td>
<td>533</td>
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<td></td>
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<tr>
<td></td>
<td>100</td>
<td>Nov. 9, 1920</td>
<td>100</td>
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### Table 12.—Cooking and strength data: Hemlocks and other conifers—Sulphite process

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<th>Species</th>
<th>Shipments</th>
<th>Cook No.</th>
<th>Date</th>
<th>Moist weight</th>
<th>Oven-dry weight</th>
<th>Cooking data</th>
<th>Quantity of wood used</th>
<th>Cooking liquor</th>
<th>Cooking period</th>
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<td>Carolina hemlock (Tsuga caroliniana)</td>
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<td>531</td>
<td>Feb. 7, 1921</td>
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<td>60.3</td>
<td></td>
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<td>532</td>
<td>Feb. 8, 1921</td>
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<td>535</td>
<td>Feb. 15, 1921</td>
<td>85.8</td>
<td>51.3</td>
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<td>536</td>
<td>Sept. 21, 1921</td>
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<td>600</td>
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<td>50.0</td>
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<td>601</td>
<td>Aug. 20, 1922</td>
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<td>435</td>
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<td>544</td>
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<td>62.2</td>
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<td>441</td>
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<td>Species</td>
<td>Ship No.</td>
<td>Cook No.</td>
<td>Date</td>
<td>Crude pulp</td>
<td>Screenings</td>
<td>Yields based on oven-dry weight of chips charged</td>
<td>Bleach required (35 per cent available chlorine) per 100 pounds oven-dry pulp</td>
<td>Calculated Weight per ream 24 x36-500</td>
<td>Thickness</td>
</tr>
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<td>-----------------------------------------------------------------------------</td>
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<td>852</td>
<td>331</td>
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<td>0.57</td>
<td>21.93</td>
<td>43.3</td>
<td>3.4</td>
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<td>563</td>
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<td>20.93</td>
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<td>3.4</td>
<td>60.6</td>
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<td>404</td>
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<td>0.57</td>
<td>21.93</td>
<td>43.3</td>
<td>3.4</td>
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<td>406</td>
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<td>0.57</td>
<td>21.93</td>
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<td>813</td>
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<td>N.B.</td>
<td>N.B.</td>
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1 Hand sheet from pulp ground in ball mill for 60 minutes.  
2 Paper very brash and dirty.  
3 Pulp raw, brash, and very dark colored.
Table 13.—Cooking and strength data: Hemlocks and other conifers—Soda or sulphate process

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<th>Species</th>
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<th>Impregnating liquor</th>
<th>Penetration</th>
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<td>After penetration</td>
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<td>Pressure per square inch</td>
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<td>Do</td>
<td>Oct. 19, 1917</td>
<td>72.2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do</td>
<td>June 21, 1921</td>
<td>65.6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Do</td>
<td>June 20, 1921</td>
<td>68.3</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Do</td>
<td>Sept. 6, 1921</td>
<td>128.0</td>
<td></td>
<td></td>
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<td></td>
</tr>
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</table>

1 Color of bleached pulp below standard.
2 Chips bleached 72 hours in warm water.
<table>
<thead>
<tr>
<th>Species</th>
<th>Cooking data—Continued</th>
<th>Strength data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cooking data</td>
<td>Strength data</td>
</tr>
<tr>
<td></td>
<td>Steam</td>
<td>Yields based on oven-dry weight of chips charged</td>
</tr>
<tr>
<td></td>
<td>Lbs.</td>
<td>Minutes</td>
</tr>
<tr>
<td>Eastern hemlock (Tsuga canadensis)</td>
<td>5</td>
<td>215</td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Feb. 16, 1966</td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>Jun. 30, 1966</td>
</tr>
<tr>
<td></td>
<td>152</td>
<td>July 3, 1966</td>
</tr>
<tr>
<td>Carolina hemlock (Tsuga caroliniana)</td>
<td>222</td>
<td>Jan. 10, 1966</td>
</tr>
<tr>
<td></td>
<td>222</td>
<td>May 4, 1966</td>
</tr>
<tr>
<td></td>
<td>222</td>
<td>May 5, 1966</td>
</tr>
<tr>
<td>Western hemlock (Tsuga heterophylla)</td>
<td>225</td>
<td>Jun. 26, 1966</td>
</tr>
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<td></td>
<td>225</td>
<td>Jun. 27, 1966</td>
</tr>
<tr>
<td>Tamarack (Larix laricina) 26-E</td>
<td>84</td>
<td>Sept. 1, 1966</td>
</tr>
<tr>
<td>Western larch (Larix occidentalis)</td>
<td>19</td>
<td>Mar. 24, 1966</td>
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<tr>
<td>Incense cedar (Libocedrus decurrens)</td>
<td>277</td>
<td>Sept. 20, 1966</td>
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Table 13.—Cooking and strength data: Hemlocks and other conifers—Soda or sulphate process—Continued
<table>
<thead>
<tr>
<th>Species</th>
<th>Date</th>
<th>Age</th>
<th>Chip</th>
<th>Core</th>
<th>N.B.</th>
<th>24</th>
<th>36</th>
<th>57</th>
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</thead>
<tbody>
<tr>
<td>Port Orford cedar (Chamaecyparis lawsoniana)</td>
<td>Jan. 18, 1921</td>
<td>100</td>
<td>75</td>
<td>360</td>
<td>37.2</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Southern white cedar (Chamaecyparis thyoides)</td>
<td>May 18, 1923</td>
<td>90</td>
<td>90</td>
<td>450</td>
<td>46.0</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Eastern red cedar (Juniperus virginiana)</td>
<td>Nov. 12, 1920</td>
<td>90</td>
<td>45</td>
<td>300</td>
<td>36.5</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Western red cedar (Thuja plicata)</td>
<td>Nov. 10, 1920</td>
<td>100</td>
<td>55</td>
<td>390</td>
<td>33.7</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Southern cypress (Taxodium distichum)</td>
<td>May 29, 1917</td>
<td>100</td>
<td>20</td>
<td>120</td>
<td>51.9</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Redwood (Sequoia sempervirens)</td>
<td>June 22, 1921</td>
<td>100</td>
<td>115</td>
<td>300</td>
<td>36.8</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Apr. 4, 1912</td>
<td>110</td>
<td>60</td>
<td>480</td>
<td>35.9</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sept. 12, 1917</td>
<td>100</td>
<td>15</td>
<td>270</td>
<td>37.8</td>
<td>07</td>
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<td></td>
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<tr>
<td></td>
<td>Oct. 13, 1917</td>
<td>100</td>
<td>25</td>
<td>435</td>
<td>35.8</td>
<td>06</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>June 21, 1921</td>
<td>105</td>
<td>65</td>
<td>300</td>
<td>30.7</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>June 20, 1921</td>
<td>105</td>
<td>75</td>
<td>300</td>
<td>30.0</td>
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<tr>
<td></td>
<td>Sept. 6, 1921</td>
<td>102</td>
<td>70</td>
<td>300</td>
<td>35.4</td>
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</table>

1 Chips extracted three times in warm water, soaking 72 hours each time.
<table>
<thead>
<tr>
<th>Species</th>
<th>Ship-</th>
<th>Cook</th>
<th>Date</th>
<th>Quantity of wood used</th>
<th>Cooking liquor</th>
<th>Cooking period</th>
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<tbody>
<tr>
<td></td>
<td>ment</td>
<td>No.</td>
<td></td>
<td>Moist weight</td>
<td>Oven-</td>
<td>Dry weight</td>
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<tr>
<td></td>
<td>No.</td>
<td></td>
<td></td>
<td>Pounds</td>
<td>per cent</td>
<td>Pounds</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspen (Populus tremuloides)</td>
<td>364</td>
<td></td>
<td>Nov. 25, 1917</td>
<td>50.4</td>
<td>52.2</td>
<td>4.15</td>
</tr>
<tr>
<td>Balsam poplar (Populus balsamifera)</td>
<td>460</td>
<td></td>
<td>Sept. 20, 1920</td>
<td>78.0</td>
<td>55.6</td>
<td>3.83</td>
</tr>
<tr>
<td>Norway poplar (Populus canadensis eugenii)</td>
<td>796</td>
<td>462</td>
<td>Sept. 22, 1920</td>
<td>81.8</td>
<td>54.2</td>
<td>4.36</td>
</tr>
<tr>
<td>Largetooth aspen (Populus grandidentata)</td>
<td>307</td>
<td>463</td>
<td>Sept. 23, 1920</td>
<td>86.5</td>
<td>52.2</td>
<td>4.51</td>
</tr>
<tr>
<td>Yellow poplar (Liriodendron tulipifera)</td>
<td>750</td>
<td></td>
<td>May 1, 1921</td>
<td>73.0</td>
<td>51.6</td>
<td>3.40</td>
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<tr>
<td>Basswood (Tilia glabra)</td>
<td>301</td>
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<td>June 2, 1921</td>
<td>64.6</td>
<td>50.6</td>
<td>5.00</td>
</tr>
<tr>
<td>Black willow (Salix nigra)</td>
<td>368</td>
<td></td>
<td>Nov. 22, 1917</td>
<td>67.4</td>
<td>56.6</td>
<td>4.37</td>
</tr>
<tr>
<td>Sandbar willow (Salix longifolia)</td>
<td>681</td>
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<td>July 29, 1919</td>
<td>62.0</td>
<td>57.2</td>
<td>5.34</td>
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<tr>
<td>Red maple (Acer rubrum)</td>
<td>492</td>
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<td>Oct. 19, 1920</td>
<td>76.0</td>
<td>64.4</td>
<td>3.57</td>
</tr>
<tr>
<td>Sugar maple (Acer saccharum)</td>
<td>535</td>
<td></td>
<td>Oct. 19, 1920</td>
<td>84.6</td>
<td>70.0</td>
<td>5.55</td>
</tr>
<tr>
<td>Paper birch (Betula papyrifera)</td>
<td>514</td>
<td></td>
<td>June 17, 1921</td>
<td>74.8</td>
<td>64.1</td>
<td>5.55</td>
</tr>
<tr>
<td>Paper birch (Betula pubescens)</td>
<td>556</td>
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<td>Jan. 10, 1921</td>
<td>95.0</td>
<td>83.1</td>
<td>5.27</td>
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<tr>
<td>Yellow birch (Betula lutea)</td>
<td>600</td>
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<td>Mar. 22, 1921</td>
<td>79.7</td>
<td>71.2</td>
<td>5.18</td>
</tr>
<tr>
<td>Black gum (Nyssa sylvatica)</td>
<td>590</td>
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<td>Oct. 19, 1920</td>
<td>86.3</td>
<td>72.8</td>
<td>5.04</td>
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<tr>
<td>Tupelo gum (Nyssa aquatica)</td>
<td>577</td>
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<td>Apr. 29, 1921</td>
<td>57.9</td>
<td>51.8</td>
<td>4.54</td>
</tr>
<tr>
<td></td>
<td>578</td>
<td></td>
<td>May 17, 1921</td>
<td>90.0</td>
<td>78.8</td>
<td>5.44</td>
</tr>
<tr>
<td>----------------------------------------------</td>
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<td>-----</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Red gum (Liquidambar styraciflua)</td>
<td>317</td>
<td>2</td>
<td>45.0</td>
<td>32.8</td>
<td>2.82</td>
<td>3.82</td>
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<tr>
<td>Cucumber magnolia (Magnolia acuminata)</td>
<td>380</td>
<td>1</td>
<td>50.0</td>
<td>40.0</td>
<td>30.0</td>
<td>20.0</td>
</tr>
<tr>
<td>Sweet bay (Magnolia virginiana australis)</td>
<td>385</td>
<td>1</td>
<td>100.0</td>
<td>90.0</td>
<td>80.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Sycamore (Platanus occidentalis)</td>
<td>392</td>
<td>2</td>
<td>100.0</td>
<td>90.0</td>
<td>80.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Butternut (Juglans cinerea)</td>
<td>411</td>
<td>1</td>
<td>100.0</td>
<td>90.0</td>
<td>80.0</td>
<td>70.0</td>
</tr>
<tr>
<td>Ohio Buckeye (Aesculus glabra)</td>
<td>803</td>
<td>2</td>
<td>100.0</td>
<td>90.0</td>
<td>80.0</td>
<td>70.0</td>
</tr>
</tbody>
</table>

1 Impregnation used.
Table 14.—Cooking and strength data: Hardwoods—Diffuse porous—Sulphate process—Continued

<table>
<thead>
<tr>
<th>Species</th>
<th>Cooking data—Continued</th>
<th>Strength data</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Yields based on oven-dry weight of chips charged</td>
<td>Bleach required (35 per cent available chlorine per 100 pounds oven-dry pulp)</td>
</tr>
<tr>
<td></td>
<td>Crude pulp</td>
<td>Screenings</td>
</tr>
<tr>
<td>Aspen (Populus tremuloides)</td>
<td>50.5</td>
<td>0.05</td>
</tr>
<tr>
<td>Balsam poplar (Populus balsamifera)</td>
<td>49.6</td>
<td>0.09</td>
</tr>
<tr>
<td>Large tooth aspen (Populus grandidentata)</td>
<td>570</td>
<td>Apr. 19, 1920</td>
</tr>
<tr>
<td>Norway poplar (Populus canadensis eugenei)</td>
<td>469</td>
<td>Oct. 19, 1920</td>
</tr>
<tr>
<td>Yellow poplar (Kiriodendron tulipifera)</td>
<td>425</td>
<td>Mar. 19, 1920</td>
</tr>
<tr>
<td>Basswood (Tilia glabra)</td>
<td>501</td>
<td>May 31, 1920</td>
</tr>
<tr>
<td>Black willow (Salix nigra)</td>
<td>368</td>
<td>July 29, 1919</td>
</tr>
<tr>
<td>Sandbar willow (Salix longifolia)</td>
<td>481</td>
<td>Oct. 19, 1920</td>
</tr>
<tr>
<td>Red maple (Acer rubrum)</td>
<td>821</td>
<td>Oct. 19, 1920</td>
</tr>
<tr>
<td>Sugar maple (Acer saccharum)</td>
<td>514</td>
<td>Jan. 10, 1921</td>
</tr>
<tr>
<td>Paper birch (Betula papyrifera)</td>
<td>794</td>
<td>Oct. 29, 1920</td>
</tr>
<tr>
<td>Yellow birch (Betula Grovesii)</td>
<td>500</td>
<td>Sept. 29, 1917</td>
</tr>
<tr>
<td>Black gum (Nyssa sylvatica)</td>
<td>821</td>
<td>Oct. 19, 1921</td>
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<tr>
<td>Unnamed</td>
<td>577</td>
<td>Apr. 29, 1921</td>
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<td>578</td>
<td>578</td>
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</tr>
<tr>
<td>2</td>
<td>2</td>
<td>Feb. 5, 1907</td>
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<td>401</td>
<td>317</td>
<td>Dec. 5, 1916</td>
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<td>363</td>
<td>Nov. 23, 1917</td>
<td>46.7</td>
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<td>380</td>
<td>July 30, 1919</td>
<td>45.8</td>
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<td>385</td>
<td>Aug. 6, 1919</td>
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<td>Nov. 28, 1919</td>
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<td>563</td>
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<td>543</td>
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<td>46.0</td>
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<td>545</td>
<td>Mar. 3, 1921</td>
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<tr>
<td>606</td>
<td>Oct. 4, 1921</td>
<td>48.9</td>
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<tr>
<td>618</td>
<td>Nov. 16, 1921</td>
<td></td>
</tr>
</tbody>
</table>

1 Pulp very shivy.
2 Soft, uniformly cooked pulp, light colored and free from shive or specks.
3 Yield data lost. Probably 45 to 50 per cent.
Table 15.—Cooking and strength data: Hardwoods—Diffuse-porous—Soda or sulphate process

<table>
<thead>
<tr>
<th>Species</th>
<th>Ship. No.</th>
<th>Cook No.</th>
<th>Date</th>
<th>Moist weight lbs.</th>
<th>Oven-dry weight lbs.</th>
<th>Impregnating liquor</th>
<th>Penetration</th>
<th>Cooking liquor</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td>Before penetration</td>
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<td>After penetration</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Volume</td>
<td>Concentration</td>
<td>Per 100 pounds bone-dry chips</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Gallons</td>
<td>NaOH</td>
<td>Grams per liter</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Grams per liter</td>
<td>NaS</td>
<td>Grams per liter</td>
</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Gallons</td>
<td>NaOH</td>
<td>Grams per liter</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Grams per liter</td>
<td>NaS</td>
<td>Grams per liter</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Minutes</td>
<td></td>
<td>Pressure per square inch</td>
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<td>Temperature</td>
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<td></td>
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<td>Concentration</td>
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<td></td>
<td></td>
<td></td>
<td>Lbs.</td>
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<td></td>
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<td></td>
<td></td>
<td></td>
<td>Grams per liter</td>
</tr>
</tbody>
</table>

- Aspen (Populus tremuloides) 454 37 Dec. 28, 1916 76.0 68.7
- Balsam Poplar (Populus balsamana) 501 210 Nov. 22, 1917 71.0 63.2
- Eastern cottonwood (Populus deltoides) 796 282 Oct. 1, 1920 77.8 61.2
- Larjetoth aspen (Populus grandidentata) 747 Apr. 19, 1921 44.9 39.1
- Norway poplar (Populus canadensis eugenei) 807 708 Nov. 30, 1920 100.7 57.7
- Yellow poplar (Liriodendron tulipfera) 750 286 Oct. 6, 1920 69.6 62.5
- Basswood (Tilia glabra) 501 116 June 7, 1917 74.1 61.0
- Black willow (Salix nigra) 368 7 63 July 26, 1917 75.7 60.0
- Sandbar willow (Salix longifolia) 129 20 Oct. 20, 1920 73.3 63.0
- Red alder (Alnus rubra) 885 838 Feb. 21, 1922 131.0 73.0
- Balsa (Ochroma lagopus) 792 Aug. 25, 1921 145.2 41.7
- Boxelder (Acer negundo) 790 Aug. 12, 1921 64.8 55.2
- Red maple (Acer rubrum) 14 2 July 25, 1921 25.0 22.3

92 BULLETIN 1485, U. S. DEPARTMENT OF AGRICULTURE
<table>
<thead>
<tr>
<th>Date</th>
<th>Species Description</th>
<th>Month</th>
<th>Year</th>
<th>Suitability</th>
<th>Growth Rate</th>
<th>Diameter</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>29 Apr. 1912</td>
<td>Sugar maple (Acer saccharum)</td>
<td>May</td>
<td>1912</td>
<td>71.6</td>
<td>54.5</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>3 May 1912</td>
<td>Paper birch (Betula papyrifera)</td>
<td>June</td>
<td>1912</td>
<td>106.2</td>
<td>54.5</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>18 May 1912</td>
<td>Yellow birch (Betula lutea)</td>
<td>July</td>
<td>1912</td>
<td>104.2</td>
<td>82.9</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>5 July 1912</td>
<td>Beech (Fagus grandifolia)</td>
<td>Aug</td>
<td>1912</td>
<td>102.0</td>
<td>82.9</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>19 Dec. 1920</td>
<td>Black gum (Nyssa sylvatica)</td>
<td>Dec</td>
<td>1920</td>
<td>134.8</td>
<td>79.2</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>1 Apr. 1921</td>
<td>Tupelo gum (Nyssa aquatica)</td>
<td>Apr</td>
<td>1921</td>
<td>87.9</td>
<td>73.6</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>30 Mar. 1921</td>
<td>Red gum (Liquidambar styraciflua)</td>
<td>Mar</td>
<td>1921</td>
<td>153.4</td>
<td>73.6</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>4 Feb. 1921</td>
<td>Cucumber magnolia (Magnolia acuminata)</td>
<td>Feb</td>
<td>1921</td>
<td>122.4</td>
<td>58.5</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>23 Dec. 1920</td>
<td>Sweet bay (Magnolia virginiana)</td>
<td>Dec</td>
<td>1920</td>
<td>71.0</td>
<td>57.4</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>2 Jan. 1921</td>
<td>Sycamore (Platanus occidentalis)</td>
<td>Jan</td>
<td>1921</td>
<td>74.1</td>
<td>64.5</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>16 Nov. 1920</td>
<td>Butternut (Juglans cinerea)</td>
<td>Nov</td>
<td>1920</td>
<td>91.5</td>
<td>80.5</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>16 Nov. 1920</td>
<td>Ohio Buckeye (Aesculus glabra)</td>
<td>Nov</td>
<td>1920</td>
<td>105.6</td>
<td>92.8</td>
<td>25</td>
<td>30.6</td>
</tr>
<tr>
<td>19 Oct. 1921</td>
<td>Mangrove (Rhizophora mangle)</td>
<td>Oct</td>
<td>1921</td>
<td>40.9</td>
<td>35.6</td>
<td>25</td>
<td>30.6</td>
</tr>
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</table>

1 Shavings used.
### Table 15.—Cooking and strength data: Hardwoods—Diffuse-porous—Soda or sulphate process—Continued

<table>
<thead>
<tr>
<th>Species</th>
<th>Date</th>
<th>Steam</th>
<th>Yields based on oven-dry weight of chips charged</th>
<th>Strength data</th>
<th>Conditions during tests</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Steady state period</td>
<td>Create pulp</td>
<td>Oil per ton bleached dry chips</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Lbs.</td>
<td>Minutes</td>
<td>Per cent</td>
</tr>
<tr>
<td>Aspen (Populus tremuloides)</td>
<td>Dec. 28, 1916</td>
<td>100</td>
<td>45</td>
<td>300</td>
<td>49.5</td>
</tr>
<tr>
<td>Balsam poplar (Populus balsamifera)</td>
<td>Nov. 22, 1917</td>
<td>100</td>
<td>15</td>
<td>210</td>
<td>50.9</td>
</tr>
<tr>
<td>Eastern cottonwood (Populus deltoides)</td>
<td>Oct. 1, 1920</td>
<td>112</td>
<td>60</td>
<td>300</td>
<td>46.4</td>
</tr>
<tr>
<td>Largtooth aspen (Populus grandidentata)</td>
<td>Apr. 19, 1921</td>
<td>70</td>
<td>70</td>
<td>300</td>
<td>37.2</td>
</tr>
<tr>
<td>Norway poplar (Populus canadensis eugenei)</td>
<td>Nov. 30, 1920</td>
<td>102</td>
<td>85</td>
<td>300</td>
<td>44.0</td>
</tr>
<tr>
<td>Yellow poplar (Liriodendron tulipifera)</td>
<td>Oct. 6, 1920</td>
<td>100</td>
<td>60</td>
<td>300</td>
<td>45.2</td>
</tr>
<tr>
<td>Basswood (Tilia glabra)</td>
<td>June 7, 1919</td>
<td>100</td>
<td>20</td>
<td>245</td>
<td>49.7</td>
</tr>
<tr>
<td>Black willow (Salix nigra)</td>
<td>July 26, 1916</td>
<td>150</td>
<td>30</td>
<td>350</td>
<td>48.3</td>
</tr>
<tr>
<td>Sandbar willow (Salix longifolia)</td>
<td>Oct. 20, 1920</td>
<td>100</td>
<td>60</td>
<td>300</td>
<td>45.7</td>
</tr>
<tr>
<td>Red alder (Alnus rubra)</td>
<td>Apr. 19, 1921</td>
<td>70</td>
<td>70</td>
<td>300</td>
<td>37.2</td>
</tr>
<tr>
<td>Balsam (Ochroba laqueus)</td>
<td>Aug. 1921</td>
<td>105</td>
<td>150</td>
<td>300</td>
<td>48.4</td>
</tr>
<tr>
<td>Boxelder (Acer negundo)</td>
<td>Aug. 1921</td>
<td>100</td>
<td>60</td>
<td>300</td>
<td>36.2</td>
</tr>
<tr>
<td>Red maple (Acer rubrum)</td>
<td>July 28, 1919</td>
<td>110</td>
<td>15</td>
<td>480</td>
<td>44.6</td>
</tr>
<tr>
<td>Code</td>
<td>Seed Year</td>
<td>Boys</td>
<td>95</td>
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<td>62</td>
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<td>------</td>
<td>-----------</td>
<td>------</td>
<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>821</td>
<td>May 25, 1921</td>
<td>100</td>
<td>60</td>
<td>360</td>
<td>40.8</td>
</tr>
<tr>
<td>837</td>
<td>May 26, 1921</td>
<td>100</td>
<td>60</td>
<td>360</td>
<td>41.1</td>
</tr>
<tr>
<td>799</td>
<td>Oct. 7, 1921</td>
<td>100</td>
<td>90</td>
<td>300</td>
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</tr>
<tr>
<td>800</td>
<td>Oct. 10, 1921</td>
<td>103</td>
<td>60</td>
<td>360</td>
<td>40.2</td>
</tr>
<tr>
<td>794</td>
<td>Oct. 27, 1930</td>
<td>100</td>
<td>70</td>
<td>420</td>
<td>42.7</td>
</tr>
<tr>
<td>796</td>
<td>Nov. 1, 1920</td>
<td>100</td>
<td>75</td>
<td>300</td>
<td>37.6</td>
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<tr>
<td>765</td>
<td>Nov. 12, 1917</td>
<td>100</td>
<td>15</td>
<td>180</td>
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</tr>
<tr>
<td>952</td>
<td>July 2, 1917</td>
<td>120</td>
<td>50</td>
<td>245</td>
<td>49.7</td>
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<td>626</td>
<td>Jan. 8, 1918</td>
<td>100</td>
<td>45</td>
<td>325</td>
<td>44.5</td>
</tr>
<tr>
<td>754</td>
<td>July 9, 1909</td>
<td>110</td>
<td>30</td>
<td>450</td>
<td>50.7</td>
</tr>
<tr>
<td>818</td>
<td>Dec. 4, 1920</td>
<td>100</td>
<td>75</td>
<td>360</td>
<td>37.9</td>
</tr>
<tr>
<td>745</td>
<td>Apr. 14, 1921</td>
<td>100</td>
<td>60</td>
<td>360</td>
<td>40.5</td>
</tr>
<tr>
<td>746</td>
<td>Apr. 18, 1921</td>
<td>100</td>
<td>75</td>
<td>360</td>
<td>36.9</td>
</tr>
<tr>
<td>729</td>
<td>Feb. 4, 1921</td>
<td>100</td>
<td>120</td>
<td>300</td>
<td>39.3</td>
</tr>
<tr>
<td>742</td>
<td>Apr. 11, 1921</td>
<td>102</td>
<td>75</td>
<td>300</td>
<td>40.3</td>
</tr>
<tr>
<td>512</td>
<td>Jan. 17, 1918</td>
<td>100</td>
<td>25</td>
<td>310</td>
<td>48.9</td>
</tr>
<tr>
<td>777</td>
<td>June 3, 1921</td>
<td>102</td>
<td>90</td>
<td>300</td>
<td>28.5</td>
</tr>
<tr>
<td>774</td>
<td>June 6, 1921</td>
<td>100</td>
<td>60</td>
<td>360</td>
<td>45.3</td>
</tr>
<tr>
<td>775</td>
<td>June 7, 1921</td>
<td>102</td>
<td>75</td>
<td>360</td>
<td>26.9</td>
</tr>
<tr>
<td>814</td>
<td>Aug. 16, 1900</td>
<td>110</td>
<td>15</td>
<td>450</td>
<td>43.4</td>
</tr>
<tr>
<td>18</td>
<td>Jan. 30, 1920</td>
<td>80</td>
<td>135</td>
<td>450</td>
<td>48.1</td>
</tr>
<tr>
<td>737</td>
<td>Apr. 4, 1921</td>
<td>100</td>
<td>70</td>
<td>300</td>
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<tr>
<td>735</td>
<td>Mar. 28, 1921</td>
<td>100</td>
<td>115</td>
<td>360</td>
<td>51.2</td>
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<tr>
<td>736</td>
<td>Mar. 29, 1921</td>
<td>100</td>
<td>75</td>
<td>300</td>
<td>43.4</td>
</tr>
<tr>
<td>863</td>
<td>Oct. 5, 1921</td>
<td>100</td>
<td>70</td>
<td>360</td>
<td>43.4</td>
</tr>
<tr>
<td>798</td>
<td>Oct. 6, 1921</td>
<td>102</td>
<td>60</td>
<td>360</td>
<td>43.9</td>
</tr>
</tbody>
</table>
Table 16.—Cooking and strength data: Hardwoods—ring-porous, miscellaneous (palmetto)—Sulphite process

<table>
<thead>
<tr>
<th>Species</th>
<th>Ship-</th>
<th>Cook</th>
<th>Date</th>
<th>Quantity of wood used</th>
<th>Cooking liquor</th>
<th>Cooking period</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>ment No.</td>
<td>No.</td>
<td></td>
<td>Moist weight</td>
<td>Oven-dry weight</td>
<td>Composition</td>
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<tr>
<td>RING POROUS</td>
<td></td>
<td></td>
<td></td>
<td>Pounds</td>
<td>Pounds</td>
<td>Per cent</td>
</tr>
<tr>
<td>Common catalpa (Catalpa bignoni-</td>
<td>802</td>
<td>490</td>
<td>Nov. 8, 1920</td>
<td>90.9</td>
<td>69.2</td>
<td>5.40</td>
</tr>
<tr>
<td>oldes)</td>
<td></td>
<td>495</td>
<td>Nov. 15, 1920</td>
<td>87.6</td>
<td>65.0</td>
<td>3.84</td>
</tr>
<tr>
<td>Chestnut (Castanea dentata)</td>
<td>4</td>
<td>568</td>
<td>Apr. 15, 1921</td>
<td>61.9</td>
<td>45.5</td>
<td>5.32</td>
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<tr>
<td>Hackberry (Celtis occidentalis)</td>
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<td>582</td>
<td>May 23, 1921</td>
<td>89.5</td>
<td>76.0</td>
<td>5.50</td>
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<tr>
<td>Sassafras (Sassafras varifolium)</td>
<td>802</td>
<td>607</td>
<td>Oct. 6, 1921</td>
<td>92.2</td>
<td>67.2</td>
<td>5.32</td>
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<tr>
<td>Rock elm (Ulmus racemosa)</td>
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<td>564</td>
<td></td>
<td>151.6</td>
<td>107.8</td>
<td>5.30</td>
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<td>Makery elm (Ulmus fulva)</td>
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<td>May 30, 1921</td>
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<td>85.5</td>
<td>5.15</td>
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<td>355</td>
<td>Nov. 28, 1921</td>
<td>80.5</td>
<td>65.8</td>
<td>5.19</td>
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<tr>
<td>Red oak (Quercus borealis maxima)</td>
<td>531</td>
<td>368</td>
<td>Dec. 5, 1917</td>
<td>145.7</td>
<td>102.7</td>
<td>4.30</td>
</tr>
<tr>
<td>White oak (Quercus alba)</td>
<td>531</td>
<td>387</td>
<td>Aug. 11, 1919</td>
<td>84.4</td>
<td>74.3</td>
<td>4.34</td>
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<td>Mockernut hickory (Hicoria alba)</td>
<td>791</td>
<td>560</td>
<td>Mar. 29, 1921</td>
<td>116.4</td>
<td>91.4</td>
<td>5.08</td>
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<tr>
<td>Black locust (Robinia pseudoacacia)</td>
<td></td>
<td>567</td>
<td>Apr. 14, 1921</td>
<td>103.1</td>
<td>85.4</td>
<td>5.43</td>
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<tr>
<td></td>
<td></td>
<td>571</td>
<td>Apr. 30, 1921</td>
<td>93.3</td>
<td>80.9</td>
<td>5.05</td>
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<tr>
<td>MISCELLANEOUS</td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Cabbage palmetto (Sabal palmetto)</td>
<td></td>
<td>573</td>
<td>Apr. 32, 1921</td>
<td>155.4</td>
<td>84.0</td>
<td>5.40</td>
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<tr>
<td>Species</td>
<td>Shipment No.</td>
<td>Cook No.</td>
<td>Date</td>
<td>Per cent Crude pulp</td>
<td>Per cent Screenings</td>
<td>Yields based on oven-dry weight of chips charged (Pounds)</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>--------------</td>
<td>----------</td>
<td>---------------</td>
<td>---------------------</td>
<td>---------------------</td>
<td>----------------------------------------------------------</td>
</tr>
<tr>
<td>Common catalpa (Calapum bignonioides)</td>
<td>302</td>
<td>490</td>
<td>Nov. 8, 1920</td>
<td>45.1</td>
<td>0.06</td>
<td>136</td>
</tr>
<tr>
<td>Chestnut (Castanea dentata)</td>
<td>388</td>
<td>495</td>
<td>Nov. 13, 1920</td>
<td>49.7</td>
<td>1.26</td>
<td>43.6</td>
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<tr>
<td>Elm (Ulmus americana)</td>
<td>382</td>
<td>508</td>
<td>May 23, 1921</td>
<td>43.4</td>
<td>0.05</td>
<td>10</td>
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<tr>
<td>Sassafras (Sassafras varifolium)</td>
<td>367</td>
<td>507</td>
<td>June 1, 1921</td>
<td>36.4</td>
<td>1.36</td>
<td>12</td>
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<td>Rock elm (Ulmus racemosa)</td>
<td>416</td>
<td>314</td>
<td>Jan. 26, 1920</td>
<td>47.4</td>
<td>0.31</td>
<td>17</td>
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<td>Slimy elm (Ulmus fulva)</td>
<td>381</td>
<td>579</td>
<td>May 18, 1921</td>
<td>44.8</td>
<td>1.60</td>
<td>5.3B</td>
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<td>White ash (Fraxinus americana)</td>
<td>380</td>
<td>341</td>
<td>Nov. 28, 1917</td>
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<td>0.07</td>
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<tr>
<td>Red oak (Quercus borealis maxima)</td>
<td>555</td>
<td>367</td>
<td>Apr. 18, 1921</td>
<td>45.6</td>
<td>1.24</td>
<td>23</td>
</tr>
<tr>
<td>White oak (Quercus alba)</td>
<td>416</td>
<td>381</td>
<td>May 23, 1921</td>
<td>44.0</td>
<td>0.40</td>
<td>24</td>
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<td>Mockernut hickory (Hicoria alba)</td>
<td>567</td>
<td>566</td>
<td>Mar. 29, 1921</td>
<td>42.0</td>
<td>0.49</td>
<td>18</td>
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<tr>
<td>Black locust (Robinia pseudoacacia)</td>
<td>571</td>
<td>567</td>
<td>Apr. 14, 1921</td>
<td>49.9</td>
<td>1.48</td>
<td>10.6</td>
</tr>
</tbody>
</table>

1 Unbleached pulp pink.  
2 Unbleached pulp clear but green.  
3 Unbleached pulp dark colored and specky.  
4 Unbleached pulp very dark colored and raw.  
5 Unbleached pulp specky.  
6 Unbleached pulp of fair color but specky.  
7 Unbleached pulp dark colored, raw, and brash.
<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity of wood used</th>
<th>Impregnating liquor</th>
<th>Penetration</th>
<th>Cooking liquor</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Moist weight</td>
<td>Before penetration</td>
<td>After penetration</td>
<td>Per 100 pounds bone-dry chips</td>
</tr>
<tr>
<td></td>
<td>Open-dry weight</td>
<td>Volume</td>
<td>Concentration</td>
<td>Grams per liter</td>
</tr>
<tr>
<td>Common catalpa (Catalpa bignonioides)</td>
<td>802</td>
<td>82.9</td>
<td>82.9</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Chestnut (Castanea dentata)</td>
<td>206</td>
<td>65.0</td>
<td>65.0</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Haack cherry (Celtis occidentalis)</td>
<td>702</td>
<td>80.3</td>
<td>80.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Sassafras (Sassafras trifolium)</td>
<td>801</td>
<td>81.3</td>
<td>81.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Rock elm (Ulmus racemosa)</td>
<td>504</td>
<td>80.3</td>
<td>80.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Slippery elm (Ulmus fulva)</td>
<td>7</td>
<td>70.0</td>
<td>70.0</td>
<td>Lbs.</td>
</tr>
<tr>
<td>American elm (Ulmus americana)</td>
<td>786</td>
<td>80.3</td>
<td>80.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>White ash (Fraxinus americana)</td>
<td>805</td>
<td>80.3</td>
<td>80.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Red oak (Quercus borealis maxima)</td>
<td>531</td>
<td>81.3</td>
<td>81.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>White oak (Quercus alba)</td>
<td>531</td>
<td>82.2</td>
<td>82.2</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Mockernut hickory (Hicoria alba)</td>
<td>791</td>
<td>81.3</td>
<td>81.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Black locust (Robinia pseudoacacia)</td>
<td>792</td>
<td>80.3</td>
<td>80.3</td>
<td>Lbs.</td>
</tr>
<tr>
<td>Allanthus (Allanthus altissima)</td>
<td>588</td>
<td>80.3</td>
<td>80.3</td>
<td>Lbs.</td>
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<tr>
<td>Species</td>
<td>Shipment No.</td>
<td>Cook No.</td>
<td>Date</td>
<td>Maximum pressure</td>
</tr>
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<td>------------------------------</td>
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<tr>
<td>RING POROUS</td>
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<tr>
<td>Common catalpa (Catalpa bignoniioides)</td>
<td>1902</td>
<td>1902</td>
<td>Nov. 4, 1920</td>
<td>100</td>
</tr>
<tr>
<td>Chestnut (Castanea dentata)</td>
<td>226</td>
<td>226</td>
<td>July 29, 1916</td>
<td>120</td>
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<tr>
<td>Hackberry (Celtis occidentalis)</td>
<td>7</td>
<td>7</td>
<td>June 13, 1917</td>
<td>100</td>
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<tr>
<td>Sassafras (Sassafras salicifolium)</td>
<td>86</td>
<td>86</td>
<td>May 18, 1921</td>
<td>100</td>
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<tr>
<td>Rock elm (Ulmus racemosa)</td>
<td>564</td>
<td>564</td>
<td>Jan. 26, 1920</td>
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<tr>
<td>Slippery elm (Ulmus fulva)</td>
<td>7</td>
<td>7</td>
<td>Sept. 30, 1920</td>
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<tr>
<td>American elm (Ulmus americana)</td>
<td>750</td>
<td>750</td>
<td>May 23, 1921</td>
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<tr>
<td>White ash (Fraxinus americana)</td>
<td>508</td>
<td>508</td>
<td>June 24, 1921</td>
<td>100</td>
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<tr>
<td>Red oak (Quercus borealis maxima)</td>
<td>831</td>
<td>831</td>
<td>Sept. 29, 1921</td>
<td>100</td>
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<tr>
<td>White oak (Quercus alba)</td>
<td>531</td>
<td>531</td>
<td>Nov. 23, 1917</td>
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<tr>
<td>Mockernut hickory (Hicoria alba)</td>
<td>791</td>
<td>791</td>
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<tr>
<td>Black locust (Robinia pseudoacacia)</td>
<td>888</td>
<td>888</td>
<td>Apr. 7, 1921</td>
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<tr>
<td>Ailanthus (Ailanthus altissima)</td>
<td>2042</td>
<td>2042</td>
<td>Mar. 3, 1924</td>
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</table>

1 Extracted chips retained on screen.  
2 Extracted chips unscreened.  
3 Unextracted chips.
<table>
<thead>
<tr>
<th>Species</th>
<th>Quantity of wood used</th>
<th>Impregnating liquor</th>
<th>Penetration</th>
<th>Cooking liquor</th>
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<tr>
<td></td>
<td></td>
<td>Before penetration</td>
<td>After penetration</td>
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<tr>
<td></td>
<td></td>
<td>Concentration</td>
<td>Concentration</td>
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<tr>
<td></td>
<td></td>
<td>Volume</td>
<td>Grams per liter</td>
<td>Grams per liter</td>
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<tr>
<td>MISCELLANEOUS</td>
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<tr>
<td>Soapweed (Yucca elata)</td>
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<tr>
<td>213</td>
<td>3 Oct. 31, 1912</td>
<td>1 Lbs</td>
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<td>0.8</td>
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<tr>
<td>4 Nov. 6, 1912</td>
<td>2 Lbs</td>
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<td>Cabbage palmetto (Sabal palmetto)</td>
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<td>754</td>
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<td>July 19, 1921</td>
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<td>1.0</td>
<td>66.0</td>
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<td>711</td>
<td>Feb. 16, 1910</td>
<td>1.0</td>
<td>1.0</td>
<td>69.9</td>
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<tr>
<td>Cane (Arundinaria macrosp-era)</td>
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<td>7</td>
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<tr>
<td>CHILEAN WOODS</td>
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<tr>
<td>Olivillo</td>
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<td>Mar. 23, 1915</td>
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<td>90.0</td>
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<tr>
<td>Laurel (Laurelia aromatica)</td>
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<tr>
<td>14</td>
<td>Mar. 21, 1915</td>
<td>0.8</td>
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<td>80.0</td>
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<tr>
<td>Colgue (Nothofagus dombeyi)</td>
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<tr>
<td>15</td>
<td>Mar. 25, 1915</td>
<td>0.8</td>
<td>40.0</td>
<td>90.0</td>
</tr>
<tr>
<td>Lingue (Persa lingue)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Mar. 26, 1915</td>
<td>1.0</td>
<td>40.0</td>
<td>90.0</td>
</tr>
<tr>
<td>Roble-pellin (Nothofagus obliqua)</td>
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<td></td>
<td></td>
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<tr>
<td>11</td>
<td>Mar. 22, 1915</td>
<td>0.8</td>
<td>38.6</td>
<td>100.0</td>
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<tr>
<td>Quillai (Quillaja saponaria)</td>
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<td></td>
<td></td>
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<tr>
<td>18</td>
<td>Mar. 30, 1915</td>
<td>0.8</td>
<td>20.0</td>
<td>98.0</td>
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<tr>
<td>Species</td>
<td>Cooking data—Continued</td>
<td>Strength data</td>
<td>Conditions during tests</td>
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<td>---------------------------------</td>
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<td></td>
<td><strong>Steam</strong></td>
<td><strong>Weight per 24 x 36—500</strong></td>
<td><strong>Calendered</strong></td>
<td><strong>Relative humidity</strong></td>
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<tr>
<td></td>
<td><strong>Pressure Pressured Period</strong></td>
<td><strong>Duration at Maximum Pressure</strong></td>
<td><strong>Crude pulp</strong></td>
<td><strong>% per ton bone-dry chips</strong></td>
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<tr>
<td>MISCELLANEOUS</td>
<td><strong>Lbs</strong></td>
<td><strong>Minutes</strong></td>
<td><strong>Minutes</strong></td>
<td><strong>%</strong></td>
</tr>
<tr>
<td>Soapweed (Yucca elata)</td>
<td>3 Oct. 31, 1912</td>
<td>50</td>
<td>60</td>
<td>300</td>
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<tr>
<td>Cabbage palmetto (Sabal palmetto)</td>
<td>3 Nov. 6, 1912</td>
<td>50</td>
<td>45</td>
<td>315</td>
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<tr>
<td>Cane (Arundinaria macrosperrna)</td>
<td>5 Feb. 16, 1909</td>
<td>100</td>
<td>30</td>
<td>420</td>
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<td>CHILEAN WOODS</td>
<td>7 Feb. 24, 1909</td>
<td>100</td>
<td>15</td>
<td>540</td>
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<tr>
<td>Olivillo</td>
<td>13 Mar. 23, 1915</td>
<td>100</td>
<td>90</td>
<td>330</td>
</tr>
<tr>
<td>Laurel (Laurelia aromatica)</td>
<td>14 Mar. 24, 1915</td>
<td>100</td>
<td>90</td>
<td>330</td>
</tr>
<tr>
<td>Coigue (Nothofagus dombeyi)</td>
<td>15 Mar. 25, 1915</td>
<td>100</td>
<td>90</td>
<td>330</td>
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<tr>
<td>Lingue (Persia lingue)</td>
<td>16 Mar. 26, 1915</td>
<td>100</td>
<td>90</td>
<td>330</td>
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<tr>
<td>Roble-pellin (Nothofagus obliqua)</td>
<td>11 Mar. 22, 1915</td>
<td>100</td>
<td>90</td>
<td>330</td>
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<tr>
<td>Quillai (Quillia saponaria)</td>
<td>18 Mar. 30, 1915</td>
<td>100</td>
<td>90</td>
<td>330</td>
</tr>
</tbody>
</table>

1 Only bark used.
2 Leaves.
3 Stalks.
4 Bleached and run with 25 per cent bleached spruce sulphite into excellent book paper.
5 Excellent pulp.
6 Bleaching action slower than usual.
7 Unbleached pulp light colored and of good average fiber length.
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April 25, 1927

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