# HOLOCELLULOSE RESEARCH IN COOPERATION WITH THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY

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# HOLOCELLULOSE[1] RESEARCH IN COOPERATION WITH THE TECHNICAL ASSOCIATION OF THE PULP AND PAPER INDUSTRY[2]

By

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Research on holocellulose has been conducted at the Forest Products Laboratory during the last 5 years in cooperation with the Technical Association of the Pulp and Paper Industry. Under the cooperative agreement the Technical Association has contributed yearly financial grants for the employment, on a half-time basis, of a graduate student from the University of Wisconsin. The financial grants were increased for the last 2 years $400 and $600, respectively, as partial reimbursement to this Laboratory for expenses in connection with the research. The grants were obtained through recommendations from the TAPPI Fibrous Materials Testing Committee for the first 2 years and through recommendations from the TAPPI Fundamental Research Committee for the remaining 3 years of the cooperation. This report covers the accomplishments of the research up to date.

The types of experimental work conducted under the cooperative agreement are indicated by five main headings appearing in the body of this report. Since the results of the first 4 years have been published, they will be discussed briefly, whereas those of the current year will be discussed more fully.

## 1. Rapid Methods for the Determination of Holocellulose and Hydrolyzed Holocellulose

Work during the first year of cooperation was confined to the development of an improved method for the determination of holocellulose and for hydrolyzed holocellulose which is comparable to Cross and Bevan cellulose. The time required for the holocellulose determination by the improved method is about 2.5 hours as compared with 2.5 days by the method used previously (2). Reduction in the time required for the determination is attributed [illegible]

[1]Holocellulose as employed in this report is composed of the hemicellulose and the cellulose in wood.

[2]Presented before the TAPPI meeting in Ann Arbor, Michigan, September [illegible]-[illegible], 1941. Published in the Paper Trade Journal, Vol. 113, September [illegible], [illegible].

the technique employed for chlorinating the wood sample and to the use of alcohol-monoethanolamine for the extraction of the chlorinated lignin. The method has been published in the Paper Trade Journal (1).

The improved method for the holocellulose determination was applied to sawdust from white spruce, red spruce, jack pine, balsam fir, Eastern hemlock, aspen, white oak, maple, and willow. Its accuracy, which is well within 1.0 percent of the theoretical value, may be seen from an examination of table 1 in which are recorded the holocellulose and the lignin values of the nine preceding woods which were previously freed of materials other than holocellulose and lignin.

The method for the preparing of hydrolyzed holocellulose which is comparable to Cross and Bevan cellulose, involves the hydrolysis of holocellulose for 2 hours with 1.3 percent sulfuric acid at the temperature of the boiling water bath. A comparison of the values for the two cellulose materials from the preceding nine woods shows good agreement in table 2. The method has also been published (1).

## 2. Composition of Holocellulose, Hydrolyzed Holocellulose, and Cross and Bevan Cellulose (2)

During the second year of cooperation the composition of the holocellulose, hydrolyzed holocellulose, and Cross and Bevan cellulose was determined for comparison. The three cellulose materials were prepared from aspen, balsam fir, Eastern hemlock, jack pine, red spruce, and white spruce. They were then analyzed according to the methods described in the citations for each of the following constituents and substituent groups: alpha cellulose (4), pentosans (5), uronic acid (6), acetyl (7), methoxyl (8). The holocellulose and Cross and Bevan cellulose were also analyzed for lignin (9) although none was found.

Data obtained by the preceding analyses of the three cellulose materials are recorded in table 3. It may be noted that the holocellulose has a lower alpha cellulose content than has the other two cellulose materials. Conversely, its pentosan, uronic acid, acetyl, and methoxyl values are greater than those of the other two materials from the corresponding woods.

Table 4 shows that, on the basis of the wood, the alpha cellulose content of holocellulose is greater than that of the other two materials. And, further, on the same basis, holocellulose contains from 8.0 to 13.4 percent more alpha cellulose than do the commercial pulps. These data suggest the possibility of developing pulping procedures for retaining in the pulp increased amounts of the alpha cellulose present in the wood and thereby increase the pulp yields.

## 3. Yield and Viscosity of Holocellulose and Some of Its Cellulose Fractions (10)

The fact that the holocellulose contains, on the basis of the wood, more alpha cellulose than does hydrolyzed holocellulose or Cross and Bevan cellulose can be explained on the basis that the holocellulose had undergone less degradation than the other two cellulosic materials. In order to test the soundness of this explanation, viscosity measurements in cuprammonium solution (11) were made on each of the three materials and also on their alpha celluloses. The relative viscosity so obtained is a rough measure of the relative degree to which the cellulose chains have been shortened in the cellulosic materials by degrading agents.

Viscosity data of the six celluloses from the woods employed under the preceding heading are listed in table 5. It is shown in table 5 that the viscosity of the holocellulose is greater than that of the Cross and Bevan cellulose or that of the hydrolyzed holocellulose. Further, the viscosity of the alpha cellulose from holocellulose is higher than that of the alpha celluloses from the other two cellulosic materials. The preceding data indicated that holocellulose and its alpha cellulose are less degraded than the other corresponding materials. Hydrolyzed holocellulose and its alpha cellulose have lower viscosities than Cross and Bevan cellulose and its alpha cellulose, which is undoubtedly due to the acid treatment employed in the preparation of the hydrolyzed material.

## 4. Conversion of Holocellulose to Pulp Suitable for White Paper (12)

Experiments during the fourth year of the cooperative research were directed (a) to the preparation of pulps from white spruce Asplund fiber,[3] and (b) to the properties of the pulps and of the test sheets made from the pulps.

### Isolation of Holocellulose for Pulp

Holocellulose was prepared in 1-pound batches according to the procedure of Van Beckum and Ritter (1) from white spruce Asplund fiber. It constituted 68.0 percent of the fiber, had an alpha cellulose content of 52.0 percent on the basis of the fiber, and a viscosity in cuprammonium solution (11) of 40.4 centipoises.

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[3]The white spruce Asplund fiber was kindly furnished by the Wood Conversion Company of Cloquet, Minnesota.

## Conversion of Holocellulose to Pulp

A pulp consisting of 59.4 percent of the Asplund fiber was prepared by extracting the holocellulose with 5.0 percent sodium hydroxide solution at the temperature of the boiling-water bath for 2 hours. It is designated in table 6 as unbleached pulp from holocellulose.

A portion of the unbleached pulp was bleached to 87 parts blue (Ives) by means of 0.5 percent bleaching powder having 35.0 percent available chlorine. This pulp is designated in table 6 as bleached pulp from holocellulose. It is 58.1 percent of the Asplund fiber, has a viscosity of 37.4 centipoises, and contains 52.0 percent of alpha cellulose on the basis of the Asplund fiber.

## Physical Properties of Pulps and Test Sheets

The physical properties of the two pulps and of test sheets made from them after various periods of treatment in a 1.5-pound beater were determined by standard TAPPI methods. Results of the tests are shown in figure 1 in which the freeness of the two pulps and also of a bleached sulfite pulp are plotted against the physical properties of the test sheets. The graphs indicate that in most instances the test sheets made from the holocellulose are superior to those made from the bleached sulfite pulp which is only 43.0 percent of the wood.

## 5. A Procedure for the Preparation of Refined Pulps in High Yields

In the 4 preceding years' work described in this report the amount of chemical and the conditions employed for the preparation of holocellulose approximated those prescribed for the quantitative determination of the material. The cost of producing a cellulose material under these conditions for conversion to pulps suitable for white papers or to high-alpha pulps suitable for cellulose derivatives is higher than that for producing bleached sulfite pulp. Therefore the development of a more economical procedure for the production of refined pulps in high yields was undertaken.

Some preliminary work was done during the year of 1939-40 on semichemical pulp as a source for refined pulps in high yields. When the moist semichemical pulp was treated with gaseous chlorine, followed by an extraction with alcohol-monoethanolamine the refined pulp yield was approximately 65 percent of the wood. When the semichemical pulp was treated with chlorine water, followed by an extraction with aqueous 2 percent sodium sulfite solution the refined pulp yield was approximately 60 percent of the wood.

Semichemical pulps were prepared as sources for the refined pulps from aspen, shortleaf pine, and white spruce by the Division of Pulp and

Paper of this Laboratory. Their yields and lignin content are recorded in table 7. Experiments were made to determine the amount of chemical necessary for refining these semichemical pulps.

## Chlorine Requirement

The weight of chlorine taken up when wood is suspended in chlorine water is approximately 1-1/3 times the weight of the lignin in the wood. A ton of aspen semichemical pulp having a lignin content of 13.1 percent would contain 262 pounds of lignin. The chlorine requirement for chlorination would be 349 pounds (262 x 1-1/3 = 349). At 2 cents a pound the cost of chlorine would be $6.98.

## Chemical-base Requirement

The chemical-base requirement for removing the chlorinated lignin from the semichemical pulp was considered on the basis of (1) concentration of base in the liquor, and (2) ratio of liquor to the chlorinated semichemical pulp.

Chemicals used for dissolving the chlorinated lignin in the Cross and Bevan method for cellulose is at least five times the weight of the wood sample. It was found in the present study that satisfactory results could be obtained when the amount of chemical was reduced to 10 percent of the weight of the lignin in the semichemical pulp sample. Thus a ton of aspen semichemical having 13.1 percent lignin would contain 262 pounds of lignin. It would require 26.2 pounds of chemical base, such as sodium sulfite, or sodium hydroxide for the removal of the chlorinated lignin. At 2 cents a pound the chemical base would cost 53 cents.

The ratio of lignin chloride solvent to the semichemical pulp was reduced from 50/1 to 12/1. Semichemical pulps, properly chlorinated, which can be done in one step, and extracted according to the procedure described below, can easily be bleached to an acceptable whiteness by means of calcium hypochlorite.

## Hypochlorite Requirement

Approximately 1 percent of available chlorine applied in the form of calcium hypochlorite is required to produce the desired whiteness. This would require about 60 pounds of bleaching powder containing 35 percent of available chlorine per ton of pulp. At 2 cents a pound the bleach powder would cost $1.20.

## Procedure for Refining Semichemical Pulp

The semichemical pulp was suspended in approximately a 3 percent consistency in chlorine water while being stirred at room temperature.

When the pulp had turned to a pinkish yellow color it was drained on a screen and washed free of chlorine water. During constant stirring the washed chlorinated pulp was extracted at 80° C. for about 40 minutes with approximately 12 parts by weight of an aqueous solution of sodium hydroxide or sodium sulfite solution or with 12 parts of an alcohol-monoethanolamine solution to 1 part of pulp. The amount of base in either the aqueous or the alcoholic solution was equivalent to approximately 10 percent of the weight of the lignin in the pulp sample. The extracted pulp was then drained on a screen and washed with water until neutral. It was then bleached with approximately 1 percent of available chlorine applied in the form of calcium hypochlorite and washed.

The cost of refining a semichemical pulp according to the preceding procedure will depend largely upon its lignin content. An estimation of the cost of preparing a ton of refined aspen pulp, such as listed in column 2, table 8, may be computed as follows: the aspen semichemical pulp contains 13.1 percent lignin and the refined pulp yield is 83.5 percent. Therefore, approximately 2,400 pounds of semichemical pulp are required per ton of refined pulp. This amount of semichemical pulp contains 315 pounds of lignin. The following itemized account shows the distribution of cost for producing 1 ton of refined aspen pulp:

| | | |
|---|---|---|
| 2,400 pounds of aspen semichemical pulp at $25 per ton | | $30.00 |
| 420 pounds chlorine (315 x 1-1/3) at $0.02 per pound | 8.40 | |
| 31.5 pounds alkali (315 x 1/10) at $0.02 per pound | .63 | |
| Hypochlorite | 1.20 | |
| Cost of chemicals | 10.23 | 10.23 |
| Labor for chemically refining the semichemical pulp | | 5.00 |
| Approximate cost per ton of refined pulp | | $45.23 |

Data on the yield and properties of the refined pulps, which were prepared from the three semichemical pulps, are listed in table 8.

It may be noted in table 8 that the yields of refined pulp prepared from the semichemical pulps range from 72.9 to 83.5 percent. On the basis of the wood they range from 59.5 to 63.0 percent.

The alpha-cellulose content of the refined pulp ranges from 78.0 to 82.9 percent. The remainder of the refined pulp may be considered hemicellulose. The alpha cellulose content is from 46.4 to 52.1 percent on the basis of the wood, being lowest in shortleaf pine. These alpha cellulose values on the basis of the wood are considerably higher than the corresponding values for alpha cellulose from commercial pulps.

The pentosan value of the refined aspen pulp is 19.2 percent whereas those for the softwood refined pulps are from 9.9 to 11.6 percent. They are approximately 0.5 of the hemicellulose values except in the case of the aspen refined pulp in which out of 20.8 parts of hemicellulose there are 19.2 parts of pentosans.

Solubilities of the alpha celluloses from the refined pulps in 7.14 percent sodium hydroxide range from 4.1 to 13.2 percent.

Viscosity values of the alpha celluloses vary from 40.9 to 112 centipoises.

## Pulp for White Paper

The two white spruce pulps listed in columns 4 and 6, table 8, were extracted with 2 percent sodium hydroxide solution at 80° C. for 2 hours so as to reduce their hemicellulose content and make them better suited for white papers. The residual pulps after the alkali extraction are listed as pulps A and B in table 9.

Pulp A is 57.2 percent of the wood and has an alpha cellulose content of 85.8 percent. Pulp B is 57.0 percent of the wood and has an alpha cellulose content of 86.5 percent. Viscosities of the two pulps are 54.5 and 53.1 centipoises, respectively.

Pulps A and B were separately treated in a 1.5 beater and test sheets were made from samples removed after various periods of beating. Physical properties of the pulps and the test sheets were determined by Standard TAPPI methods. The values are recorded in table 10.

Pulps A and B, before beating, had a freeness of 855 cc. and 860 cc., respectively. Both pulps lost their freeness rather rapidly with beating, dropping to 525 cc. and 520 cc. in 40 minutes, respectively. Test sheets prepared from a sample of pulp A beaten 40 minutes have a burst of 1.67 points per pound per ream, tear of 1.35 grams per pound per ream, double folds 1,229, tensile 13,400 pounds per square inch, solid fraction 0.52, stretch 8.00 percent, and opacity 57.0 percent. Test sheets prepared from samples of pulp B beaten for 40 minutes have the following properties: burst 1.83 points per pound per ream, tear 1.36 grams per pound per ream, double folds 879, tensile 12,250 pounds per square inch, stretch 6.5 percent, opacity 55.0 percent, and solid fraction 0.53.

## Production of High-alpha Pulp

The refined aspen pulp listed in column 2, table 8, was converted to a high-alpha pulp which was tested for its suitability for cellulose derivatives. The high-alpha pulp was 49 percent of the wood, had an alpha cellulose content of 98.7 percent, and a viscosity in cuprammonium solution of 112 centipoises according to the Standard TAPPI method. Tests by a commercial laboratory showed that the pulp acetylated readily.

Amounts of chemicals and conditions employed for preparing the high-alpha pulp were similar to those prescribed for the determination of alpha cellulose. They would, undoubtedly, be too costly for commercial operations. The development of an economical procedure for the production of high-alpha pulp from refined semichemical pulp has been reserved for next year.

## Summary


Results on the holocellulose research may be summarized as follows:

A practical method for the determination of holocellulose was developed. It was applied to nine woods. A method was also developed for converting the holocellulose by a dilute acid hydrolysis to a cellulose fraction closely approximating Cross and Bevan cellulose in yield.

The chemical composition of the holocellulose, the hydrolyzed holocellulose, and the Cross and Bevan cellulose from six pulpwoods were determined. Hydrolyzed holocellulose and Cross and Bevan cellulose are similar in composition and yields. Holocellulose differs from the other two cellulose fractions in that it is composed of the cellulose and the hemicellulose in the wood, contains all the acetyl groups and from 10 to 15 percent of the methoxyls in the wood. Holocellulose contains from 47 to 52 percent of alpha cellulose by weight on the basis of the wood.

The relative states of degradation of holocellulose, hydrolyzed holocellulose, and Cross and Bevan cellulose were found by a determination of their viscosities when dispersed in cuprammonium solution. Holocellulose was the least degraded, Cross and Bevan cellulose was degraded more than the holocellulose, and the hydrolyzed holocellulose was degraded the most. The alpha cellulose recovered from the holocellulose had higher viscosities than did the alpha cellulose from the other two wood fractions.

A pulp appearing to have excellent properties for white paper was made by extracting white spruce holocellulose by means of dilute alkali. The residual bleached pulp so obtained constituted 58.1 percent of the wood. Strength properties of test sheets made from samples of the pulp at different beating intervals indicated the pulp to be comparable with sulfite pulp suitable for the manufacture of white bond paper.

Semichemical pulps appear to be suitable for the production of refined pulps in yields of 57 to 60 percent of the wood. An economical procedure for converting semichemical pulps to refined pulps in high yields seems feasible.

A high-alpha pulp constituting 49 percent of the wood and having an alpha cellulose content of 98.7 percent was prepared from a refined aspen semichemical pulp. The high-alpha pulp was found to acetylate readily.

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Table 1.--Results indicating the accuracy of the holocellulose determination

(Results based on oven-dry (105° C.) weight of the extractive-free wood)

| Wood | Holocellulose by new method (1) | Lignin by sulfuric acid method (2) | Holocellulose and lignin (Col. 1 + 2) (3) |
|---|---|---|---|
| | Percent | Percent | Percent |
| White spruce | 73.3 | 26.6 | 99.9 |
| Red spruce | 72.9 | 26.6 | 99.5 |
| Jack pine | 72.5 | 27.2 | 99.7 |
| Balsam fir | 69.9 | 30.1 | 100.0 |
| Eastern hemlock | 68.5 | 31.5 | 100.0 |
| Aspen | 82.5 | 17.3 | 99.8 |
| White oak | 75.4 | 24.1 | 99.5 |
| Maple | 76.3 | 23.5 | 99.8 |
| Willow | 78.3 | 22.0 | 100.3 |

Table 2.--Results indicating the accuracy of the method for converting holocellulose to a cellulose fraction comparable in yield to Cross and Bevan cellulose

(Results based on oven-dry (105° C.) weight of extractive-free wood)

| Wood | Cross and Bevan cellulose | |
|---|---|---|
| | By hydrolysis of: holocellulose | By Cross and Bevan method (7) applied on wood |
| | Percent | Percent |
| White spruce | 61.0 | 61.2 |
| Red spruce | 60.5 | 60.3 |
| Jack pine | 59.1 | 58.3 |
| Balsam fir | 55.3 | 56.4 |
| Eastern hemlock | 55.4 | 56.0 |
| Aspen | 63.7 | 64.1 |
| White oak | 60.2 | 59.6 |
| Maple | 57.9 | 57.9 |
| Willow | 61.5 | 61.5 |

Table 3.--Results of analyses of holocellulose, hydrolyzed holocellulose, and Cross and Bevan cellulose

| Material | Basis oven-dry wood, yield | Results based on oven-dry (105° C.) material | | | | |
|---|---|---|---|---|---|---|
| | | Alpha cellulose | Pentosan: Tollen's method | Uronic acid anhydride: ($CO_2$ x 4) | Acetyl | Methoxyl |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| | Percent | Percent | Percent | Percent | Percent | Percent |
| Aspen holocellulose | 82.5 | 61.4 | 28.2 | 5.04 | 5.53 | 1.13 |
| Hydrolyzed holocellulose | 63.7 | 74.3 | 15.9 | 2.60 | 3.07 | .70 |
| Cross and Bevan cellulose | 64.1 | 76.3 | 19.9 | 2.64 | 1.61 | .52 |
| Balsam fir holocellulose | 69.9 | 63.0 | 10.3 | 4.28 | 3.18 | .58 |
| Hydrolyzed holocellulose | 55.3 | 70.9 | 7.1 | 1.96 | 2.06 | .53 |
| Cross and Bevan cellulose | 56.4 | 70.7 | 6.0 | 1.92 | 1.40 | .54 |
| Eastern hemlock holocellulose | 68.5 | 70.4 | 8.9 | 4.88 | 2.70 | 1.23 |
| Hydrolyzed holocellulose | 55.4 | 75.2 | 5.5 | 1.92 | 1.76 | .48 |
| Cross and Bevan cellulose | 56.0 | 77.1 | 4.6 | 1.88 | 1.94 | .33 |
| Jack pine holocellulose | 72.5 | 68.3 | 15.0 | 4.00 | 2.68 | 1.04 |
| Hydrolyzed holocellulose | 59.1 | 73.0 | 8.8 | 1.84 | 1.60 | .69 |
| Cross and Bevan cellulose | 58.3 | 74.1 | 6.8 | 1.88 | 1.76 | .73 |
| Red spruce holocellulose | 72.9 | 66.2 | 13.0 | 4.36 | 3.21 | 1.25 |
| Hydrolyzed holocellulose | 60.5 | 71.6 | 7.6 | 2.00 | 1.40 | .49 |
| Cross and Bevan cellulose | 60.3 | 72.0 | 6.7 | 2.04 | 1.51 | .42 |
| White spruce holocellulose | 73.3 | 67.5 | 12.2 | 3.64 | 3.19 | .96 |
| Hydrolyzed holocellulose | 61.0 | 71.7 | 6.9 | 1.84 | 1.59 | .45 |
| Cross and Bevan cellulose | 61.2 | 72.9 | 6.2 | 1.92 | 1.61 | .43 |

Table 4.--Alpha cellulose content of cellulose fractions

(Percentages expressed on weight of oven-dry (105° C.) extractive-free wood)

| Species | Holocellulose | Cross and Bevan cellulose | Hydrolyzed holocellulose | Pulp |
|---|---|---|---|---|
| (1) | (2) | (3) | (4) | (5) |
| | Percent | Percent | Percent | Percent |
| Aspen............. | 50.7 | 48.3 | 47.3 | 42.3 (Bleached soda) |
| Balsam fir......... | 44.0 | 39.8 | 39.3 | .................... |
| Eastern hemlock... | 48.2 | 43.2 | 41.7 | 34.8 (Sulfite) |
| Jack pine.......... | 49.5 | 43.2 | 43.1 | 36.1 (Sulfate) |
| Red spruce......... | 48.3 | 43.4 | 43.3 | .................... |
| White spruce....... | 49.5 | 44.6 | 43.7 | 39.8 (Bleached sulfite) |

Table 5.--Yield and viscosity of cellulosic materials from various woods

| Cellulosic materials | Aspen | | White spruce | | Red spruce | | Jack pine | | Balsam fir | | Eastern hemlock | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Yield | Viscosity | Yield | Viscosity | Yield | Viscosity | Yield | Viscosity | Yield | Viscosity | Yield | Viscosity |
| Holocellulose | 82.5 | 40.2 | 73.3 | 32.7 | 72.9 | 35.4 | 72.5 | 50.1 | 69.9 | 20.1 | 68.5 | 23.0 |
| Cross and Bevan cellulose | 64.1 | 28.9 | 61.2 | 17.2 | 60.3 | 18.8 | 58.3 | 26.9 | 56.4 | 19.7 | 56.0 | 20.3 |
| Hydrolyzed holocellulose | 63.7 | 11.2 | 61.0 | 13.7 | 60.5 | 11.6 | 59.1 | 15.8 | 55.3 | 6.4 | 55.4 | 8.5 |
| Alpha from holocellulose | 50.7 | 72.3 | 49.5 | 68.2 | 48.3 | 56.7 | 49.5 | 77.7 | 44.0 | 39.2 | 48.2 | 36.1 |
| Alpha from Cross and Bevan cellulose | 48.3 | 39.6 | 44.6 | 23.8 | 43.4 | 30.1 | 43.2 | 29.2 | 39.8 | 24.0 | 43.2 | 23.5 |
| Alpha from hydrolyzed holocellulose | 47.3 | 18.0 | 43.7 | 21.1 | 43.3 | 18.4 | 43.1 | 21.1 | 39.3 | 19.3 | 41.7 | 20.9 |

**Note: Percentage yield based on weight of oven-dry wood; viscosities expressed in centipoises in cuprammonium solution.**

Table 6.--Yield and viscosity of cellulosic materials from white spruce

(Percentage yield based on weight of moisture-freed wood; viscosities expressed in centipoises in cuprammonium solution.)

| Cellulosic materials | Holocellulose and pulps | | Alpha cellulose | |
|---|---|---|---|---|
| | Yield | Viscosity | Yield | Viscosity |
| (1) Holocellulose (prepared in 1-pound batches) and its alpha cellulose...................... | 68.0 | 40.4 | 52.0 | 48.8 |
| (2) Unbleached pulp (prepared from (1)) and its alpha cellulose.... | 59.4 | 41.9 | 52.4 | 47.3 |
| (3) Bleached pulp (prepared from (2)) and its alpha cellulose.... | 58.1 | 37.4 | 52.0 | 43.2 |

Table 7.--Yield and lignin content of semichemical pulps

| Semichemical pulp | Yield on basis of wood | Lignin content on basis of pulp |
|---|---|---|
| | Percent | Percent |
| Aspen................ | 73.0 | 13.1 |
| Shortleaf pine....... | 81.5 | 16.6 |
| White spruce......... | 80.0 | 21.2 |

Table 8.--Yields and properties of refined pulps prepared from semichemical pulps

| Material | Treatment for producing refined pulp from semichemical pulp from -- | | | | | |
|---|---|---|---|---|---|---|
| | Aspen | Shortleaf pine | White spruce | | | |
| | Two chlorinations plus two sulfite extractions | Two chlorinations plus two sulfite extractions | Two chlorinations plus two alcoholic ethanolamine extractions | Two chlorinations plus two sulfite extractions | Two chlorinations plus two aqueous NaOH extractions | One chlorinations plus one aqueous NaOH extraction |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) |
| Refined pulp (Percent) | | | | | | |
| of semichemical pulp | 83.5 | 72.9 | 78.8 | 77.5 | 76.8 | 76.0 |
| of wood | 61.0 | 59.5 | 63.0 | 62.0 | 61.4 | 60.8 |
| Alpha cellulose (Percent) | | | | | | |
| of refined pulp | 79.2 | 78.0 | 82.8 | 82.0 | 82.7 | 82.9 |
| of wood | 48.3 | 46.4 | 52.1 | 51.0 | 50.7 | 50.3 |
| Pentosans (Percent) | | | | | | |
| in refined pulp | 19.2 | 9.9 | 11.1 | 10.0 | 10.7 | 11.6 |
| in alpha cellulose | 3.8 | 3.3 | 1.8 | 1.7 | 1.6 | 1.9 |
| Ash (Percent) | | | | | | |
| in refined pulp | .8 | .5 | .7 | .8 | 1.1 | .5 |
| in alpha cellulose | .1 | .2 | .2 | .2 | .2 | .2 |
| 7.14 percent NaOH soluble (Percent) | | | | | | |
| of refined pulp | 19.9 | 20.8 | 22.1 | 18.4 | 23.6 | 22.8 |
| of alpha cellulose | 4.1 | 13.2 | 12.1 | 7.6 | 11.4 | 10.7 |
| Viscosity (Centipoises) | | | | | | |
| refined pulp | 78.4 | 23.1 | 48.7 | 65.4 | 45.1 | 49.2 |
| alpha cellulose | 112.0 | 40.9 | 48.6 | 57.1 | 44.2 | 48.2 |

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Table 9.--Some properties of alkali-extracted refined white spruce pulp

| Material | Yield on basis of wood | Alpha cellulose on basis of -- | | Viscosity | |
|---|---|---|---|---|---|
| | | Pulp | Wood | Pulp | Alpha cellulose |
| | Percent | Percent | Percent | Centipoises | Centipoises |
| Pulp A....... | 57.2 | 85.8 | 49.1 | 45.7 | 54.5 |
| Pulp B....... | 57.0 | 86.5 | 49.3 | 45.5 | 53.1 |

Table 10.--Beater test values of pulps and test sheets

| Material | Beating time | Freeness S.-R. | Burst | Tear | Double folds | Tensile | Stretch | Opacity | Solid fraction |
|---|---|---|---|---|---|---|---|---|---|
| | Minutes | Cc. | Points per lb. per ream | Grams per lb. per ream | | Lbs. per sq. in. | Percent | Percent | |
| Pulp A... | 0 | 855 | 0.82 | 2.75 | 382 | 4,060 | 5.25 | 80 | 0.40 |
| | 20 | 775 | 1.70 | 1.66 | 945 | 9,680 | 5.75 | 69 | .47 |
| | 30 | 660 | 1.65 | 1.59 | 1,191 | 10,650 | 8.00 | 67 | .49 |
| | 40 | 525 | 1.67 | 1.35 | 1,229 | 13,400 | 8.00 | 57 | .52 |
| | 50 | 405 | 1.72 | 1.25 | 1,112 | 14,000 | 7.50 | 48 | .55 |
| | 60 | 295 | 1.68 | 1.19 | 1,781 | 13,130 | 8.00 | 40 | .60 |
| Pulp B... | 0 | 860 | .94 | 2.53 | 568 | 4,230 | 5.25 | 81 | .41 |
| | 20 | 765 | 1.69 | 1.63 | 1,037 | 10,170 | 6.25 | 69 | .47 |
| | 30 | 640 | 1.69 | 1.52 | 797 | 9,780 | 6.25 | 65 | .52 |
| | 40 | 520 | 1.83 | 1.36 | 879 | 12,250 | 6.50 | 55 | .53 |
| | 50 | 405 | 1.73 | 1.14 | 1,357 | 13,770 | 6.75 | 46 | .57 |
| | 60 | 290 | 1.74 | .93 | 1,552 | 13,100 | 6.75 | 36 | .59 |

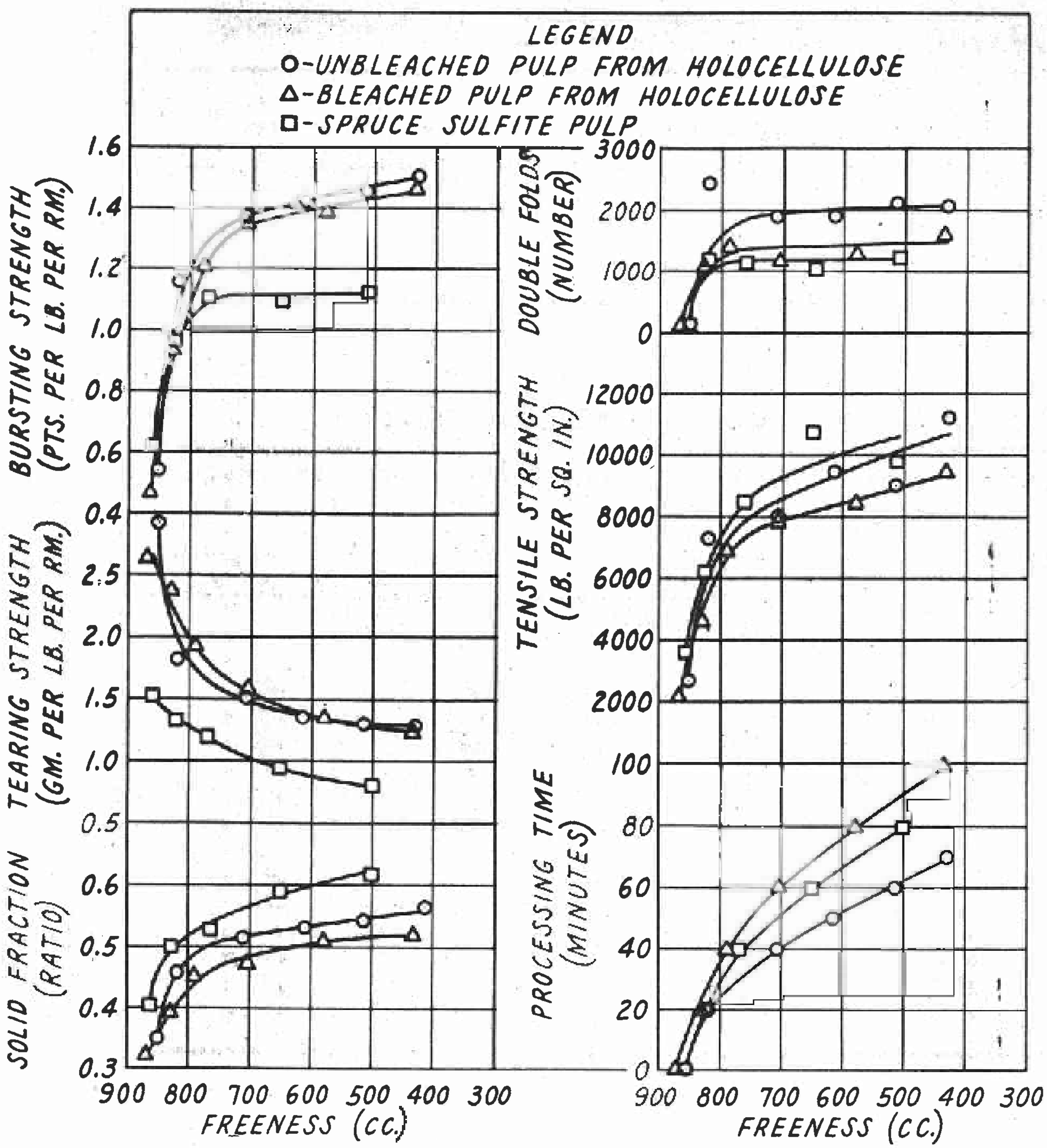


FIG. 1
BEATER-TEST VALUES OF PULPS AND TEST SHEETS

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