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CHEMIMECHANICAL PULPS FROM VARIOUS SOFTWOODS AND HARDWOODS

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CHEMIMECHANICAL PULPS FROM VARIOUS SOFTWOODS AND HARDWOODS[1]

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SUMMARY

The results of experiments on the making of high-yield chemimechanical[4] pulps from hardwoods and softwoods by several cooking techniques are discussed in this report. In one method of neutral sulfite chemimechanical pulping a conventional procedure was followed, while in another

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[3]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[4]Chemimechanical pulps are defined in this report as pulps produced from wood in any form or shape by using a mild chemical treatment in which there is no major change in the lignin, followed by a mechanical treatment to separate the fibers. Usually these pulps fall within the yield range of 80-95 percent.

method a hot-liquor impregnation procedure was followed. Another chemimechanical pulp was made using a two-stage acid alkaline process. Aspen, western hemlock, and a mixture of hardwoods were pulped by the conventional neutral sulfite chemimehcanical method at yields ranging from 87 to 92 percent. Balsam fir and western hemlock were impregnated and cooked with a preheated neutral sulfite liquor to yields ranging from 90 to 97 percent. Western hemlock was also pulped by the two-stage acid-alkaline chemimechanical process. The effect of varying the pH of the cooking liquors by the use of various buffers was determined.

The various types of chemimechanical pulp are compared in regard to properties and energy consumptions.

Selected pulps were bleached and used in papermaking experiments. Newsprint papers were made by substituting high-yield hardwood neutral sulfite chemimechanical pulp for softwood groundwood pulp, and also by substituting high-yield softwood two-stage acid-alkaline and neutral sulfite chemimechanical pulps for softwood sulfite pulp. Magazine-grade papers were made by substituting high-yield softwood neutral sulfite chemimechanical pulps for part of both the softwood groundwood and sulfite components.

INTRODUCTION

The possibility of producing useful pulps in the yield range of about 90 percent or more by refining chips softened by a mild chemical treatment has attractive possibilities for better wood utilization. Pulps of this type made from many hardwood species, which produce groundwood pulp too weak for general use, have properties approaching those of softwood-groundwood pulps. Pulps made from some softwoods in a similar way generally have the high bulk and opacity characteristics of groundwood pulp and have, in addition, higher strengths that justify their consideration as partial substitutes for softwood chemical pulps in some blends.

CHEMIMECHANICAL PULPING

Two cooking techniques were used to make the high-yield neutral sulfite chemimechanical pulps. In one method a conventional procedure was followed; that is, presteaming, liquor addition, gradual temperature rise, and a time at maximum temperature followed by blowdown. To obtain high yields of pulp by this method, less chemical was dissolved in the cooking liquor than for normal semichemical pulping, and the maximum cooking temperature was reduced to between 130° and 140° C. These temperatures were comparable to those recommended for securing bright pulps by the chemigroundwood process.

Hot-liquor impregnation cooks were made by heating the neutral sulfite liquor in a pressure reservoir connected to the digester, before introducing it to the chips. During the impregnation periods, which lasted from 10 to 40 minutes, a hydrostatic pressure of 100 pounds per square inch gage was maintained in the digester. Preheating the impregnating solution to temperatures between 170° and 190° C. produced equilibrium temperatures in the digester of from 125° to 135° C. At the end of the impregnation, the liquor was blown back into the reservoir, where it was measured and sampled for analysis.

To make the two-stage acid-alkaline chemimechanical pulp, the chips were presteamed, followed by an evacuation of the digester to about 20 inches of mercury. A sodium bisulfite liquor at room temperature was then added, followed by the injection of liquid sulfur dioxide. The temperature was raised to 114° C., where it was held for 35 minutes. After blowdown, the treated chips were passed through a screw press and then returned to the digester, where they were boiled at atmospheric pressure for 3 hours in a solution of sodium bicarbonate.

Aspen, western hemlock, and a mixture of hardwoods consisting of 50 percent red maple and 10 percent each of red oak, white oak, yellow birch, ash, and elm were pulped by the conventional-type process in a yield range of about 87 to 92 percent. Hot-impregnation cooks were made on balsam fir and western hemlock at yields ranging from about 90 to 97 percent. Western hemlock was the only wood pulped by the two-stage acid-alkaline chemimechanical process at a yield of about 81 percent.

Conventional-Type Cooks

Effect of Cooking and Species

There was very little difference between the amounts of sodium sulfite required for cooking the aspen and the hardwood mixture by the conventional procedure, although the mixture did require a longer cooking time.

Table 1 shows that the amount of cooking, as measured by the yield, is critical, since opacity, as well as strength, is sensitive in this respect. The loss in opacity on cooking to lower yields is accompanied by a reduction in the amount of energy required for refining, as well as by a marked increase in pulp strength. Considering pulp brightness, strength, and energy consumption in refining, aspen is indicated to be better than the mixture of denser hardwoods. The density of the aspen test sheets was considerably greater than that of the sheets made of the mixed hardwoods, which suggests that the strength difference could be reduced by increased wet pressing of the latter. The lower density of the mixed hardwood pulp sheets is probably due to the oaks, since these species are known to give bulky pulps. Because of the differences in brightness between the aspen and mixed hardwood pulps, conclusions cannot be drawn as to comparative opacity.

Bleaching

The mixed hardwood chemimechanical pulp was bleached in order to estimate the chemical requirement and also the opacity at a brightness suitable for use in printing papers. The pulp responded readily to moderate amounts of bleach in a single-stage application of either calcium hypochlorite or sodium hydrosulfite. As shown in table 2, applying 8 percent available chlorine as calcium hypochlorite for 30 minutes at a temperature of 36° C. and a consistence of 10 percent gave a brightness of 69.5 percent. Using these same conditions and extending the duration 15 minutes, with a slight rise in pH, gave approximately the same final brightness. Using a consistence of 3 percent and a temperature of 60° C., the application of 1.5 percent sodium hydrosulfite for 30 and 60 minutes gave brightness values of 60.8 and 61.6 percent, respectively.

It is shown in table 3 that the strength of the pulp was not significantly changed by bleaching to a brightness of 69.6 percent, although the opacity dropped 10 percentage points to an unsatisfactory level of 81.8 percent.

Impregnation-Type Cooks

From the standpoint of pulp color and brightness, hot-impregnation sodium sulfite treatments, using sodium bisulfite as the buffer, were found to be more satisfactory than those buffered with either sodium carbonate or bicarbonate in producing high-yield pulps from balsam fir. As shown in table 4, lowering the pH from 10.4 to 7.6 during a series of 10-minute treatments at 135° C. increased the brightness of the pulp from 47.6 to 52.5 percent, and decreased the yellow cast noticeably without significantly affecting pulp strength. The highest yield of pulp was produced when the pH value was the lowest, and the lowest yield of pulp was produced when the pH value was highest.

PAPERMAKING

Substitution of High-Yield Neutral Sulfite Chemimechanical Hardwood Pulp for Softwood Groundwood

An experimental newsprint paper was made on a 13-inch Fourdrinier paper machine from a furnish consisting of 20 percent southern pine sulfate pulp beaten to a freeness of 320 milliliters (Canadian Standard), and 80 percent high-yield (91 percent) neutral sulfite chemimechanical aspen pulp processed to a freeness of 440 milliliters. The experimental paper (table 5) had more strength and a higher brightness when compared with a sample of commercial Canadian newsprint. The opacity of the experimental newsprint is somewhat lower than the Canadian newsprint, although Laboratory experiments have shown that disk-mill refining of the neutral sulfite chemimechanical pulp to a lower freeness or the addition of a small amount of clay could have increased this value. Refining to a lower freeness also might have increased the density of the experimental newsprint.

Substitution of High-Yield Neutral Sulfite Chemimechanical Softwood Pulp for Both Groundwood and Sulfite Pulps

The substitution of high-yield balsam fir pulp, in the amount of 25 percent for part of both the groundwood and the sulfite components of a magazine stock, decreased the density somewhat and slightly increased the opacity of the papers without significantly affecting the strength properties (table 6). Other papers made from 60 percent bleached groundwood, 25 percent bleached sulfite, and 15 percent of the bleached balsam fir neutral sulfite chemimechanical pulp compared very closely with the experimental reference standard paper, which consisted of a 60-40 mixture of groundwood and sulfite pulps.

Experimental newsprint papers made by substituting western hemlock two-stage acid-alkaline and neutral sulfite chemimechanical pulps at two yield levels for all of the sulfite components were not as strong as the reference standard paper, which was made from a pulp furnish consisting of 75 percent western hemlock groundwood and 25 percent western hemlock sulfite pulp (table 7). The papers containing the lower yield neutral sulfite (86.9 percent) and the two-stage acid-alkaline chemimechanical pulps were somewhat stronger than the one containing the higher yield pulp (93.4 percent), although the opacity of the paper containing the higher yield pulp was distinctly higher than either the reference standard paper or the experimental papers containing the lower yield neutral sulfite and the two-stage acid-alkaline chemimechanical pulps. The brightness values of the reference standard paper and the paper containing the higher yield neutral sulfite chemimechanical pulp were about the same, while the brightness value of the papers containing the lower yield neutral sulfite and the two-stage acid-alkaline chemimechanical pulps were about 5 and 3 percentage points higher, respectively.

COMPARISON OF VARIOUS KINDS OF HIGH-YIELD PULPS

Included in table 1 are data for typical high-yield pulps, ranging from 88 to 97 percent in yield, made by different processes from aspen and a mixture of denser hardwoods, and also from balsam fir and western hemlock. It is recognized that, for any given process, yield, and species, pulps varying in properties are obtainable because of variations in fiber processing, grinder operation, wood quality, and other factors. Therefore, while comparison of single pulps selected as representative types may indicate fairly definite trends, the comparisons must not be considered as strict generalizations or final answers. The comparisons are made on the unbleached pulp basis. If these points are kept in mind, the following comparison of different kinds of high-yield pulps may afford some indication of general trends.

Opacity

High opacity was obtained in aspen and mixed hardwood pulps produced in yields above 90 percent by the neutral sulfite, and bisulfite chemimechanical, and the the groundwood processes. Aspen cold soda and chemigroundwood pulps of 88 and 89 percent yield, respectively, were relatively low in this important property.

Regardless of yield, the balsam fir and western hemlock neutral sulfite, cold soda, and bisulfite chemimechanical pulps were low in opacity. The two-stage acid-alkaline chemimechanical pulp also had a low opacity, about the same as the commercial western hemlock sulfite pulp. The only exception to this was a western hemlock neutral sulfite chemimechanical pulp of 93 percent yield, which had an opacity of 91 percent. Western hemlock groundwood pulp had an opacity of 95 percent and, though not available, the opacity of the balsam fir groundwood could be expected to be similarly high.

The opacity of pulp is influenced by its brightness and also by the fiber characteristics and size distribution. Pulps in this yield range that have high opacity are often low in brightness.

Brightness

Pulps made in this yield range by mild chemical treatment are generally low in brightness regardless of the method of preparation. At yields above 90 percent, the brightness of aspen neutral sulfite, cold soda, and chemigroundwood chemimechanical pulps are fairly comparable to the brightness of unbleached groundwood pulps from aspen and the softwoods. The brightness of all the aspen pulps below 90 percent yield is less than that of the groundwood pulps. The brightness of the mixed hardwood pulps, regardless of yield or process, is also less than the brightness of the aspen and softwood-groundwood pulps.

Of the softwood pulps, only the balsam fir chemigroundwood pulp was relatively close to the softwood-groundwood pulps in brightness. Those softwood high-yield pulps that could, because of their strength, be considered as partial substitutes for unbleached sulfite pulp were as good as, or better than, the spruce and western hemlock sulfite pulps in brightness.

If the unbleached pulps are restricted in usefulness because of their low brightness, they may be readily bleached by the processes used for bleaching groundwood. However, bleaching invariably reduces opacity, so the pulps with high initial opacity are most likely to have the advantage for bleaching treatments. Although the yellowness of the various pulps produced was not measured quantitatively, it was observed visually that the cold soda pulps, even after bleaching, had more of a yellow cast than any of the other pulps.

Strength

The association of higher strength with lower yield was noticeable in even the narrow range of 88 to 92 percent yield for both the neutral sulfite and cold soda chemimechanical pulps. At the same yield levels, the hardwood cold soda pulps had better strength than the hardwood neutral sulfite and hardwood bisulfite pulps. The aspen chemigroundwood pulps were stronger than the aspen neutral sulfite and cold soda pulps at the same yield and freeness levels. Both the aspen and mixed hardwood cold soda pulps at 92 percent yield were comparable to softwood groundwoods in strength.

The balsam fir bisulfite, the neutral sulfite, and the chemigroundwood chemimechanical pulps made at 90, 91, and 97 percent yields, respectively, were comparable in strength. However, the freeness of the chemigroundwood was very much lower than the other two. The balsam fir cold soda pulp was similar to balsam fir groundwood pulp in strength.

The most noticeably comparable strength value between certain of the softwood high-yield pulps and the acid sulfite pulps made from the respective species was their tear factor. The tearing strength of the balsam fir bisulfite pulp was higher than that of the spruce sulfite pulp, and the neutral sulfite pulps (at 91 and 92 percent yield) were almost as high. Similarly comparable tear values are noted for the western hemlock neutral sulfite, two-stage acid alkaline and sulfite pulps.

Fiber-Size Distribution

The physical character, the chemical composition, and the size distribution of the fibers of which a pulp is composed influence its strength, opactiy, freeness, and other properties. The screen classification of a pulp gives an idea of the amounts of the fibers and particles of different lengths or sizes, independent of their physical and chemical characteristics. A few screen classification tests are shown in table 1.

Groundwood pulps generally contain large amounts of material that will pass a 200-mesh screen, and consequently their average fiber length, as indicated by the fiber-length index, is lower than most other high-yield pulps. Pulps in this yield range containing the higher amounts of fines are often higher in opacity and bulkiness of the sheet. For example, in table 1 a mixed-hardwood bisulfite chemimechanical pulp, an aspen groundwood pulp, and a western hemlock groundwood pulp have similar screen fractionation values--relatively high amounts of fines and low amounts of long fibers--and are also high in opacity and low in density. The extent to which the fines contribute to these two properties, as well as the strength, depends on whether they are flourlike or are hydrated, and the degree of hydration. Flourlike fines are more likely to give high opacity and bulk than hydrated fines. This may explain why a balsam fir bisulfite pulp and a western hemlock neutral sulfite pulp, which have screen classifications similar to that of a western hemlock sulfite pulp, are higher than the sulfite pulp in both opacity and bulk, but not as good in bursting and tensile strengths.

The stronger high-yield pulps generally contain more long material and have higher fiber-length indexes than the weaker ones.

Density

The aspen neutral sulfite, cold soda, and chemigroundwood chemimechanical pulps all had density values much higher than either the aspen or softwood groundwoods. The only exception to this was a neutral sulfite pulp made at 92 percent yield, which had a density value only slightly higher than the groundwoods.

It appears that, to produce pulps by the neutral sulfite process from the mixed hardwoods that have density values comparable to those of the groundwoods, the yield must be near 90 percent, whereas pulps made by the cold soda process must be greater than 92 percent in yield. A pulp made from the mixed hardwoods by the bisulfite process at 90 percent yield had a density value actually less than those of the groundwoods.

The softwood chemimechanical pulps, regardless of process or yield, all had density values similar to those of the groundwoods.

Freeness

Hardwood pulps produced by mild chemical treatments with strength and fiber-distribution properties satisfactory for groundwood pulp substitution are generally much freer than the groundwood pulps. On the other hand, if these pulps are strong enough for substitution for softwood sulfite pulp, they are usually lower in freeness than the sulfite pulp.

Energy Consumption

Most of the chemimechanical pulps can be prepared for groundwood pulp substitution with about the same or even less energy consumption than that required for making groundwood pulp. With respect to aspen, the neutral sulfite pulps appear, in table 1, to require somewhat more energy than the cold soda and chemigroundwood pulps at the same yield or the same freeness levels. Energy consumptions for refining the softwood pulps are generally moderate regardless of process.

CONCLUSIONS

Pulps in this high-yield range can be made by several processes with properties varying with the woods used and the conditions used in their preparation.

Their value lies in the fact that in some instances the hardwood pulps can be substituted for softwood pulps, and in other instances the high-yield pulps can be substituted for low-yield pulps.

Table 1.--Properties of unbleached chemimechanical pulps from various hardwoods and softwoods, pulped by different processes

Pulping process	Yield [1]	Energy consumed[2]	Freeness (Canadian Standard)	Burst factor	Tear factor	Breaking length	Density	Opacity [3]	Brightness (G. E. equivalent)	Screen classification: on 28-mesh	Retained between 28- and 48-mesh	Retained between 48- and 100-mesh	Retained between 100- and 200-mesh	Passing 200-mesh	Fiber length index
	Percent	Hp.-days	Ml.			Meters	G. per cc.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	
ASPEN															
Neutral sulfite	88	69	180	23	52	4,250	0.61	88	49						
Neutral sulfite	92	99	180	12	33	2,960	.46	94	51						
Cold soda	88	33	250	36	63	6,350	.62	75	....						
Cold soda	92	36	335	19	60	3,600	.61	....	54	24	29	25	8	14	0.153
Chemigroundwood	[4]89	38	185	54	70	8,580	.75	75	40	22	33	19	7	19	.159
Chemigroundwood	[4]91	41	245	31	78	5,710	.60	....	55	16	42	16	8	18	.133
Groundwood	[5]97	99	70	13	44	3,050	.40	94	59	3	19	27	20	31	.082
Groundwood[6,7]	[5]97	....	60	11	39	2,400	.38	....	60	8	16	22	16	38	.083
MIXED HARDWOODS[8]															
Neutral sulfite	87	95	180	20	55	3,440	.46	95	41						
Neutral sulfite	92	104	180	6	26	1,530	.34	98	38						
Cold soda	90	....	180	26	53	4,400	.57	....	42						
Cold soda	92	....	180	14	42	3,040	.44	....	44						
Bisulfite	90	143	170	8	27	2,030	.36	98	38	2	11	34	15	38	.073
BALSAM FIR															
Neutral sulfite[9]	91	78	325	26	92	4,640	.44	85	51						
Neutral sulfite[9]	92	97	260	31	94	5,260	.47	87	50						
Neutral sulfite[9]	95	71	320	22	85	2,940	.43	83	53						
Cold soda[10]	....	49	245	17	49	3,080	.44	86	47						
Bisulfite	90	57	380	26	113	4,230	.34	88	46	60	18	11	4	7	.266
Chemigroundwood	[4]96	82	45	26	85	4,850	.44	86	56	37	14	14	11	24	.112
Groundwood	[5]97	56	113	15	51	3,100	.40	....	59	16	17	24	14	29	.093
WESTERN HEMLOCK															
Neutral sulfite[9]	87	73	310	35	95	5,520	.49	83	42	57	13	6	3	21	.138
Neutral sulfite[9]	93	77	260	24	101	4,060	.37	91	47	37	25	15	7	16	.151
Two-stage acid-alkaline: [11]	81	41	400	25	103	4,150	.50	68	53	53	17	9	4	17	.156
Groundwood	[5]97	....	100	13	54	2,575	.43	95	54	8	21	23	16	32	.083
Sulfite[6]	[12]46	....	620	49	93	7,380	.73	67	42	56	17	13	3	11	.203
WHITE SPRUCE															
Sulfite[6]	[12]48	....	450	39	100	7,250	.72	78	53						

[1] Moisture-free weight basis.

[2] Per ton of air-dry pulp.

[3] Sheet weight 37 pounds per ream, 500 sheets, 25 by 40 inches.

[4] Based on change in specific gravity of wood before and after treatment.

[5] Assumed water soluble loss of 3 percent.

[6] Commercial pulp.

[7] Made from a mixture of 25 percent aspen, 65 percent spruce, and 10 percent balsam.

[8] Mixture consisted of 50 percent red maple, and 10 percent each of red oak, white oak, yellow birch, ash, and elm.

[9] Hot liquor impregnation treatment with sodium bicarbonate buffer.

[10] Continuous.

[11] Chips first cooked in an acid sulfite solution and then in an alkaline solution before mechanical fiberization.

[12] Yield assumed for bleachable pulp.

Table 2.--One-stage bleaching of mixed hardwood neutral sulfite chemi-mechanical pulp at 87.0 percent yield

Bleaching chemical: Formula	Bleaching chemical: Amount	Temperature	Consistence	Duration	pH	Brightness (G. E. equivalent)
	Percent	°C.	Percent	Min.		Percent
[1] $Ca(OCl)_2$	10.0	36	10	60	11.6-9.6	74.0
[1] $Ca(OCl)_2$	8.0	36	10	30	11.8-10.4	69.5
[1] $Ca(OCl)_2$	8.0	37	10	45	12.2-12.0	69.6
[2] $Na_2S_2O_4$	1.5	60	3	30	6.5-6.7	60.8
[2] $Na_2S_2O_4$	1.5	60	3	60	6.9	61.6

[1] Calcium hypochlorite buffered with 4 percent sodium silicate solution and 4 percent sodium hydroxide. Percentages are in terms of available chlorine.

[2] Sodium hydrosulfite stabilized with 0.5 percent trisodium salt of ethylene diamine tetra-acetic acid.

Table 3.--Effect of bleaching a mixed hardwood neutral sulfite chemimechanical pulp at 87 percent yield

Properties	Unbleached pulp	Bleached pulp
Freeness (Canadian Standard)................ml.	140	155
Burst factor..................................	21.5	20.4
Tear factor...................................	49.2	51.6
Breaking length..........................m.	3,840	3,750
Density............................g. per cc.	0.50	0.52
Opacity (37-lb. ream)..................percent	91.8	81.8
Brightness (G. E. equivalent)..............do.	46.7	69.6

Table 4.--Effect of pH in producing high-yield neutral sulfite chemimechanical pulps from balsam fir[1]

Impregnating liquor: Buffer	Impregnating liquor: pH	Na_2SO_3 used[2]	Yield[2]	Brightness (G. E. equivalent)
		Percent	Percent	Percent
Na_2CO_3	10.4	9.0	90.3	47.6
$NaHCO_3$	8.8	13.2	92.1	49.7
$NaHCO_3$	8.3	11.7	91.0	51.2
$NaHSO_3$	7.6	10.0	94.8	52.5

[1]Constant impregnating conditions: 10 minutes at 135° C. with a liquor having a Na_2SO_3 concentration of 60 grams per liter.

[2]Moisture-free wood basis.

Table 5.--Substitution of aspen high-yield neutral sulfite chemimechanical pulp for softwood groundwood in newsprint paper

Properties	Experimental[1] paper	Commercial[2] paper
Ream weight (500 sheets, 25 by 40 inches)....lb.:	39.4	37.2
Thickness....................................mils:	3.9	2.9
Density...........................g. per cc.:	.56	.72
Bursting strength..................pts. per lb.:	.25	.20
Tearing resistance...................g. per lb.:	.74	.65
Tensile strength...............lb. per in. width:	10.2	7.2
Folding endurance..................double folds:	5	2
Opacity.....................................percent:	87.1	90.2
Brightness (G. E. equivalent)..............do..:	62.3	60.5

[1] Furnish consisting of 20 percent southern pine sulfate pulp and 80 percent aspen neutral sulfite chemimechanical pulp (91 percent yield). Headbox freeness--305 milliliters.

[2] Standard furnish of softwood sulfite and groundwood pulps.

Table 6.--Substitution of balsam fir high-yield neutral sulfite chemimechanical pulp for part of both groundwood and sulfite pulps in magazine-base papers

Machine run No.	4943	4948	4950
Pulp furnish:			
Bleached spruce-aspen groundwood......percent	60	50	60
Bleached western hemlock sulfite.........do..	40	25	25
Bleached balsam fir neutral sulfite chemimechanical (92.9 percent yield)...do..	......	25	15
Headbox freeness (Canadian Standard).........ml.	130	145	140
Ream weight (500 sheets, 25 by 40 inches)....lb.	31.8	33.2	32.0
Density.............................g. per cc.	0.61	0.54	0.54
Thickness.....................................mils	2.9	3.4	3.3
Bursting strength...................pts. per lb.	0.21	0.24	0.24
Average tearing resistance...........g. per lb.	0.75	0.72	0.70
Average folding endurance..........double folds	3	3	2
Average tensile strength.......lb. per in. width	6.1	6.2	6.4
Opacity...............................percent	83.2	84.6	84.7
Brightness (G. E. equivalent)..............do..	78.4	77.0	76.7

Table 7.--Substitution of western hemlock high-yield chemimechanical pulps for sulfite pulp in newsprint papers

Machine run No.	5331	5333	5332	5334
Western hemlock pulp furnish:				
Commercial groundwood...percent	75	75	75	75
Commercial sulfite...do	25	.....	.....	.....
Experimental neutral sulfite chemimechanical:				
93 percent yield...do	.....	25	.....	.....
87 percent yield...do	.....	.....	25	.....
Bleached chemimechanical[1] (81 percent yield)...do	.....	.....	.....	25
Headbox freeness (Canadian Standard)...ml.	200	200	170	200
Ream weight (500 sheets, 25 by 40 inches)...lb.	37.9	38.1	37.0	39.4
Density...g. per cc.	0.70	0.57	0.62	0.61
Thickness...mils	3.0	3.7	3.3	3.6
Bursting strength...pts. per lb.	0.19	0.12	0.15	0.11
Average tearing resistance...g. per lb.	0.66	0.44	0.51	0.48
Average folding endurance...double folds	6	3	3	2
Average tensile strength...lb. per in. width	7.9	5.8	6.3	5.8
Opacity...percent	89.3	93.2	89.2	89.5
Brightness (G. E. equivalent)...do	51.7	50.1	55.5	53.3

[1] Made by a two-stage, acid-alkaline process.

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