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MILK CARTON BOARDS FROM CERTAIN LAKE STATES SOFTWOODS AND HARDWOODS

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MILK CARTON BOARDS FROM CERTAIN LAKE STATES SOFTWOODS AND HARDWOODS

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Digest of Results

An investigation was made to determine the possibility of manufacturing milk carton stock from certain hardwoods and softwoods that had grown in upper Michigan but common to the Lake States in general. A hardwood mixture made up of two parts of aspen, two parts of maple, and one part of beech by weight was pulped by the sulfate and neutral sulfite semichemical processes. A softwood mixture consisting of two parts of jack pine, two parts of eastern hemlock, and one part of balsam fir was pulped by the sulfate and the neutral sulfite processes. These pulps were bleached by the conventional multistage bleaching process to brightnesses in the range of 80 to 83 percent for the sulfate pulps and 85 to 87 percent for the neutral sulfite pulps.

The estimated yield of the mixed hardwood unbleached sulfate pulp was 50.4 percent and that of the mixed softwood sulfate pulp was 41.5 percent. The softwood mixture produced a higher strength sulfate pulp than the hardwood mixture. The softwood sulfate pulp was more difficult to bleach than the hardwood sulfate pulp, but no more difficult than is usual for softwood sulfate pulps.

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The hardwood mixture was cooked to a yield of about 69 percent by the neutral sulfite semichemical procedure. The strength of this pulp increased with bleaching, resulting in a strength level higher than that for the bleached hardwood sulfate pulp.

A fully cooked unbleached softwood neutral sulfite pulp, with a bursting strength slightly higher than the softwood sulfate pulp, was made at a yield of 44.5 percent. The bleaching requirements for this pulp were about the same as those of the softwood sulfate pulps of the same yield.

Experimental milk carton stock was made from various blends of the softwood and hardwood pulps. For comparative purposes, boards were made from commercial southern pine sulfate pulp. The results of these board runs are as follows:

(1) The mixed softwood sulfate boards, which were considered as the reference boards, had strength properties similar to the boards made from commercial southern pine sulfate pulp.

(2) Up to 50 percent hardwood pulp made by the neutral sulfite semichemical process was added to the mixed softwood sulfate furnish without altering the strength properties of the boards. Boards with 75 and 100 percent of hardwood semichemical pulp were lower in tearing resistance and folding endurance but similar in other strength properties to the all-softwood sulfate board.

(3) Up to 50 percent hardwood pulp made by the sulfate process was added to the softwood sulfate furnish with relatively little effect on properties of the board, except for folding endurance. Hardwood sulfate pulp contents greater than 50 percent significantly lowered the board strength.

(4) The mixed softwoods pulped by the neutral sulfite process gave boards with strength properties equal to, or greater than, those obtained on the mixed softwood sulfate boards.

(5) Boards made from hardwood neutral sulfite semichemical pulp blended (a) with softwood neutral sulfite pulp and (b) with softwood sulfate pulp had similar properties.

Performance tests on milk cartons fabricated from the boards indicated that those made from board containing hardwood neutral sulfite semichemical pulp bulged less, when filled with milk, than those made from board containing softwood sulfate pulp only or combinations of hardwood and softwood sulfate pulp. The filled cartons made from hardwood sulfate containing board were equivalent to those made from softwood sulfate board in a rough handling test, but cartons made from hardwood neutral sulfite semichemical containing board were less resistant.

Introduction

The experiments described in this report were conducted to evaluate the suitability of several common Lake States hardwood and softwood species for use in the manufacture of milk carton stock. The work was conducted with the cooperation of the Michigan College of Mining and Technology, Houghton, Mich., who, prior to this work, had made a survey to determine the species of wood available in upper Michigan and the approximate ratio of their growth in the forest of that area.

The work included pulping and bleaching a mixture of the three predominant softwood species and a mixture of the three predominant hardwood species in the ratio in which they were available. The mixtures were pulped by both the sulfate process and neutral sulfite process. The softwood neutral sulfite pulp was fully cooked. The hardwood neutral sulfite pulp was of the semichemical type. The neutral sulfite process differs from the neutral sulfite semichemical process, principally in the temperature and cooking time used and in the production of a lower yield of pulp. From softwoods it gives stronger pulps than can be obtained by the neutral sulfite semichemical process. Milk carton stock was made from blends of these softwood and hardwood pulps, with the object of determining the maximum amount of hardwood pulp that could be added to the softwood pulp without significantly affecting the strength of the milk carton.

The Wood

Aspen, sugar maple, eastern hemlock, and balsam fir were received from the vicinity of Mass, Mich. Jack pine was obtained from the vicinity near Rapid River, Mich., and American beech from Munising, Mich.

Each wood was converted to chips that were screened to remove material smaller than 1/4 by 1/4 inch and larger than 1-1/4 by 1-1/4 inches. The nominal chip size was 5/8 inch.

The mixture of softwoods consisted of 40 percent jack pine, 40 percent eastern hemlock, and 20 percent balsam fir, based on ovendry weights. The hardwood mixture comprised 40 percent aspen, 40 percent maple, and 20 percent beech, also based on ovendry weights.

Sulfate Pulping Experiments

Sulfate pulping experiments were designed to produce bleachable sulfate pulps. First, a series of digestions were made in small-scale digesters with a capacity of 0.8 cubic foot to determine the most suitable chemical-wood ratio for pulping the mixtures. Then large-scale digestions to produce pulps for board-making experiments were made in a 225-cubic-foot digester. Details of the cooking conditions used and the yield data obtained for all the digestions are given in table 1.

The softwood mixture was more difficult to pulp than the hardwood mixture. As expected, pulp from the hardwood mixture was higher in yield and lower in permanganate number than pulp from the softwood mixture. Comparing the two large-scale pulps after beating samples to a freeness value of 450 milliliters in the standard beater test,[3] the hardwood mixture gave unbleached pulp 52 percent lower in bursting strength, 23 percent lower in tearing strength, and 38 percent lower in breaking length than the softwood mixture. Strength data are given in table 2.

Neutral Sulfite Pulping Experiments

The neutral sulfite process uses sodium sulfite as the pulping agent with a small amount of sodium bicarbonate for buffering. The hardwood mixture was given a mild digestion in order to obtain a semichemical pulp. The softwood mixture was subjected to more drastic cooking conditions to produce a fully cooked neutral sulfite pulp.

[3] Freeness values in this report are expressed in Canadian Standard units.

As with the sulfate pulping, preliminary small-scale experiments were made in autoclaves to establish pulping conditions for larger digestions to be made in the 225-cubic-foot digester. General pulping conditions and details of the individual digestions are provided in table 3. In every case, the digester charge was heated indirectly.

Mixed Hardwood Semichemical Pulp

Chips from digestion No. 1-5615N were passed through a 36-inch, double-rotating disk mill to convert them to pulp. Preliminary milling trials on the chips indicated that there are rather narrow limits of fiberizing conditions for achieving optimum results. Although the freeness of the pulp was lower than desirable, a small change in the disk setting resulted in a substantial increase in number and size of shives.

The pulp, after milling, was screened, passed through 3-inch centrifugal cleaners, and wet lapped.

The strength of the unbleached neutral sulfite pulp, at a freeness of 450 milliliters, was somewhat lower than the sulfate pulp produced from the same mixture (table 2).

Mixed Softwood Neutral Sulfite Pulp

One of the small-scale neutral sulfite digestions, made on the mixture of softwoods (digestion No. 1350Y), gave a yield of 44.6 percent of fully cooked pulp, but digestion No. 1351Y made to a yield of 53.8 percent required milling to convert the chips to pulp.

The conditions selected for the large digestion (1-5619N) were similar to those used in producing the fully cooked pulp in small-scale experiments. The pulp yield was estimated to be about 44.5 percent, which is slightly higher than that obtained in the large sulfate digestion on the same mixture.

The neutral sulfite pulp was screened, passed through 3-inch centrifugal cleaners, and wet lapped. The bursting strength and breaking length values for this pulp equaled those of the unbleached sulfate pulp, but it was lower in tearing resistance and folding endurance (table 2).

Bleaching Experiments

Procedures

Procedures used for bleaching the sulfate pulps.--In preliminary tests, the suitability of a one-stage hypochlorite treatment and a three-stage, chlorination-caustic soda extraction-hypochlorite, treatment were compared for bleaching the sulfate pulp from the hardwood mixture (digestion No. 1-4173). Conditions in these and subsequent bleaching treatments were in accord with the usual mill practice. Because of the high alkalinity of the water supply at the U.S. Forest Products Laboratory, the pulp was acidified slightly before adding the chlorine to promote chlorination of the lignin without degrading the cellulose. The pulp consistence and temperature were high during extraction to aid removal of chlorinated lignin, and a moderate temperature and alkalinity was maintained during the hypochlorite treatments to preserve pulp strength.

A three-stage process was also used for bleaching the sulfate pulp from the softwood mixture. In bleaching pulp to be used for the board-making experiments, however, an oxidative extraction consisting of a mixture of caustic soda and calcium hypochlorite at a moderate temperature was used in place of the usual caustic soda extraction.

The total chlorine requirements of the sulfate pulps were estimated from the permanganate numbers to about 4.0 percent for the hardwood and 6.5 percent for the softwood pulp. About 70 percent of these amounts were applied in the chlorination stage. Bleaching tests were made on samples of the extracted pulps, and the amounts of hypochlorite applied in the final bleach were adjusted accordingly. Further adjustments in chlorine and hypochlorite were made, when necessary, in subsequent bleaches.

Procedures used for bleaching the neutral sulfite pulps.--The mixed hardwood and mixed softwood neutral sulfite pulps were bleached by a sequence of chlorination, caustic soda extraction, and hypochlorite treatments. The bleaching conditions and procedure were essentially the same as those for bleaching the mixed hardwood sulfate pulp. Estimates of total chlorine requirements, however, were based on the modified Tingle number of the pulps, using the factors 1.2 for the mixed hardwood and 1.5 for the mixed softwood neutral sulfite pulps.

Details of the bleaching treatments are given in table 4.

Results of Bleaching Experiments

Bleach requirements of the sulfate pulps.--The mixed hardwood sulfate pulp was bleached to about 75 percent brightness in one stage with calcium hypochlorite, using 4.2 percent available chlorine (table 4). This bleaching treatment did not lower pulp strength. Although a brightness of 75 percent is adequate for some types of foodboard, the bleached pulp contained too many off-color shives for this use. It is likely that this difficulty could be overcome by increasing the amount of hypochlorite somewhat and with use of centrifugal cleaning.

As would be expected, the three-stage bleaching process produced a clean pulp. With 17 percent less total chlorine equivalent (3.3 to 3.5 percent) than was applied in the one-stage process, brightness values of 81.7 to 82.6 percent were obtained. This level of brightness is adequate for a wide variety of foodboards and other papers.

As expected, the mixed softwood sulfate pulp required more chlorine (about twice as much) for bleaching than did the mixed hardwood sulfate pulp. The ratio of its chlorine requirement to permanganate number was 0.44 compared to 0.36 for the mixed hardwood pulp. However, the bleach requirement of the softwood pulp was normal.

The results for bleaches Nos. 3785 and 3786 (table 4) show that the softwood sulfate pulp could be bleached to about 65 percent brightness with about 1 percent less chlorine (based on pulp) than would be required to bleach to 80 percent brightness. The shives were not bleached satisfactorily with the lower amount of chlorine, however.

Bleach requirements for the neutral sulfite pulps.--In past experience, the total chlorine requirement for bleaching hardwood neutral sulfite semichemical pulps ranged from about 1.1 to 1.3 times the modified Tingle number* of the unbleached pulp. Thus, the results in table 4 show that the chlorine requirement for the mixed hardwood neutral sulfite semichemical pulp (1.2 times its Tingle number) is within the range for pulp of its type and yield. It also appears that the brightness of the pulp would be satisfactory with somewhat lower chemical dosage, but possibly the shives and dirt would not be bleached completely.

The results for bleach No. 3848 (table 4) show the high bleach requirement typical of softwood neutral sulfite semichemical pulps. However, the bleach requirements of these pulps decrease rapidly with increased

*Tappi 36, No. 3:123-6 (March 1953).

pulping and are about equal for neutral sulfite and sulfate pulps of the same yield. Thus, because of the higher yield of the unbleached softwood neutral sulfite pulp (digestion No. 1-5619N), the total dosage of chlorine in bleaches Nos. 3862 and 3882 was made higher than that used on the softwood sulfate pulp. However, this increase was partially offset by the higher yield of bleached neutral sulfite pulp.

Cleanliness of the bleached pulps. --As expected, there was no difficulty in bleaching the shives in the fully cooked sulfate and neutral sulfite pulps with a three-stage treatment. The shives in the sulfate pulps were well bleached at 82 percent brightness, and the bleached softwood neutral sulfite was exceptionally clean.

The unbleached hardwood neutral sulfite semichemical pulp contained an unusual amount of dark shives, which possibly originated in the beech wood and were not removed by a 3-inch centrifugal cleaner. These dark shives were only partially bleached, despite the high brightness of the bleached pulp. Shives like these, however, can be completely removed, as was demonstrated with a 6-inch cleaner after the bleaching and board-making experiments were completed.

Brightness stability of the bleached pulps. --Previous experience has shown that both hardwood and softwood pulps, bleached with hypochlorites in either one-stage or multistage processes, are somewhat unstable in brightness. Accelerated aging by heating air-dried test sheets decreased the brightnesses of the bleached neutral sulfite pulps about 4 to 6.5 points. This is about equal to the brightness decrease for sulfate pulps bleached by the same process. Losses of these amounts in the accelerated aging test indicate there will be about a 1- to 3-point decrease on the paper machine. Brightness recession can be reduced about 50 percent by adding a final peroxide treatment to the bleaching process. The peroxide stage would also increase brightness about 3 to 5 points.

Yield and strength of the bleached pulps. --Yield data for the bleached pulps used in the papermaking experiments are given in table 4. The data agree within ±0.5 percent of values obtained in duplicate, small-scale tests, in which the entire samples were dried and weighed. They are also in the range usually expected for the pulps tested.

The strengths of the bleached pulps at 450 milliliters freeness are given in table 2. The tests show that upon bleaching the mixed hardwood sulfate pulp with the three-stage process on a small scale there was essentially no strength loss at a brightness of 82 percent but in the pilot plant bleaching there was a 25 percent loss in bursting and tearing strengths. Other similar instances have occurred. The minimum average strength loss in bleaching the mixed softwood sulfate pulp in the pilot plant was 11 percent. Presumably, strength retention would have been better in small-scale bleaching had it been done. The strength of both bleached softwood pulps, however, except in tearing resistance, was higher than that of a commercial-bleached southern pine sulfate pulp.

The bleached mixed softwood neutral sulfite pulp bleached in the pilot plant was actually better in overall strength balance than the unbleached pulp.

The data in table 2 also show the usual strength increase upon bleaching the hardwood semichemical pulp, which brought its strength to a higher level than that of the bleached hardwood sulfate pulp.

Papermaking Experiments

Milk carton stock was made from blends of the bleached hardwood and softwood pulps on the experimental 13-inch-wide Fourdrinier paper machine operating at a speed of 19 feet per minute. The blends included (1) softwood and hardwood sulfate, (2) softwood sulfate and hardwood neutral semichemical, and (3) softwood neutral sulfite and hardwood neutral sulfite semichemical. The softwood and hardwood pulps in each of these blends were used in the ratios of 1:1, 1:2, and 2:1. Carton stock was also made from 100 percent of the two experimental softwood pulps and the hardwood neutral sulfite semichemical pulp. Surface-sized boards were made from each of the pulp furnishes. A starch mixture, with a concentration of 0.6 pound per gallon, was prepared by cooking a high viscosity substituted starch to 190° F. and maintaining this temperature for at least 15 minutes. The mixture was cooled to between 130° and 140° F. before it was applied to the board.

Generally, only one run was made with a given pulp furnish. Although optimum sheet properties are not likely to be obtained in a single run, an attempt to accomplish this was made by varying the pulp processing and machine operating conditions from run to run in the series.

The pulps for a given furnish were processed individually and then blended in the beater or in the paper machine chest. In all runs, 2 percent of fortified rosin size was added to the pulp stock. The pH value was adjusted to about 6.0 with sulfuric acid and further to 5.0 with alum. Rolls of the coated stock were supplied to commercial concerns for printing trials and conversion into 1-quart milk bottles for the evaluation of their characteristics and qualities as milk containers.

A commercial southern pine semibleached sulfate pulp (shipment No. 4242) was obtained for comparison purposes. This pulp had been processed before shipment, and indications were that it had been removed at the wet press section during commercial boardmaking operations. When received, it had a moisture content of 66 percent. The strength of the pulp is given in table 2. For the experimental run (machine run No. 4736), the pulp was not subjected to any further processing. No rosin size was added, as it was assumed to have been sized previously. Properties of the board made on the experimental machine, compared with those obtained on a commercial southern pine board, showed the experimental board was somewhat higher than the commercial board in all strength properties except tearing resistance. The commercial board had a smoother surface and appeared less porous than the experimental board.

The properties of the boards are given in table 5. All tests were made in accordance with TAPPI standards.

Boards From Combinations of the Softwood Sulfate and Hardwood Sulfate Pulps

These tests were made to determine the effect of the addition of hardwood pulp prepared by the sulfate process to the softwood sulfate pulp on board properties. Machine run No. 4802 (table 5) was made from a furnish comprising 100 percent of the mixed softwood sulfate pulp. The board had bursting and tensile strength values similar to those obtained on the experimental-coated board made from the southern pine pulp,(machine run No. 4736) but the tearing resistance and folding endurance were lower.

In this series, the experimental softwood sulfate pulp was processed to a freeness varying from 550 milliliters for the all-softwood board to 590 milliliters for the pulp used in the board containing 50 percent hardwood. Because the original freeness of the hardwood bleached sulfate was low, it was subjected to relatively little processing before blending with the softwood. The hardwood pulps were not beaten in the first runs. These pulp furnishes drained well on the wire, however, and indicated additional processing would be feasible. Therefore, in the run involving 50 percent of the hardwood pulp, this portion of the furnish was beaten to a freeness of 530 milliliters before blending with the softwood pulp.

Twenty-five percent hardwood sulfate pulp was added to the softwood mixture (machine run No. 4740) with relatively little effect on the bursting and tensile strength of the board, but the folding endurance was decreased somewhat with this amount of hardwood in the pulp furnish. The board containing 50 percent of the hardwood pulp (machine run No. 4745) had strength properties, except folding endurance, equal to the board containing the 25 percent of hardwood pulp. When the hardwood content was increased to 75 percent, a substantial loss in all strength properties resulted.

As the hardwood sulfate pulp content increased, the density of the boards decreased. To obtain boards with comparable thickness and density, the wet press pressure and calendering pressure were increased as the hardwood portion was increased.

All blends of these two pulps ran well on the machine and presented no operating difficulties. It was possible to jordan some of the blends with no drainage or crushing at the wet press section. This, as has been mentioned, indicated that the hardwood portion could have been processed to a lower freeness with the possibility of developing more strength in the pulp and resulting finally in the production of better milk cartons.

In the printing of the board from machine run No. 4742 (75 percent hardwood), there was excessive picking of the surface of the sheet. Another machine run was made (machine run No. 4804) using more wet press pressure and less calendering pressure to obtain the desired thickness. This board was slightly higher in bursting strength than machine run No. 4742, and it ran well in the printing test with no observed picking tendencies.

Boards From Combinations of the Softwood Sulfate and Hardwood Neutral Sulfite Semichemical Pulps

In this series, hardwood neutral sulfite semichemical pulp was substituted for the hardwood sulfate pulp used in the previous series. The hardwood content was varied from 25 to 100 percent.

In a study of this type where it is desired to observe the effect of additions of hardwood pulp on sheet properties, it is generally well to maintain constant processing conditions for the softwood component. However, since the initial freeness of the hardwood semichemical pulp was somewhat lower than the freeness of the sulfate pulp after processing, it was believed desirable to process the sulfate less as its content in the furnish decreased. This kept the freeness of the furnishes more in balance and minimized drainage problems on the paper machine. In the run using 75 percent of the softwood pulp (machine run No. 4786), the softwood pulp was processed to a freeness of 570 milliliters as compared to a freeness of 625 milliliters in the run using 25 percent (machine run No. 4790). Therefore, the bursting strength level for the sulfate pulp was lower in the boards that were higher in hardwood pulp content.

A good appearing all-hardwood carton stock (machine run No. 4800) was made entirely from the semichemical pulp. Although this board was somewhat low in most strength properties, it was more uniform in formation, higher in brightness, and appeared to have a better finish than the all-softwood board. The all-hardwood board was 12 percent lower in bursting strength, 63 percent lower in tearing resistance, and over 95 percent lower in folding endurance than the all-softwood board (machine run No. 4802).

A substantial amount of the hardwood semichemical pulp was added to the softwood sulfate pulp without appreciably affecting the physical properties of the board. Milk carton stock containing 25 and 50 percent of the hardwood pulp had strength properties equal to the all-softwood sulfate board. When the hardwood content was increased to 75 percent, a decrease in tearing resistance and folding endurance was noted, with no appreciable change in bursting and tensile strengths.

Boards From Combinations of Softwood Neutral Sulfite and Hardwood Neutral Sulfite Semichemical Pulps

In the third series, the softwood pulp used was a fully cooked neutral sulfite, and the hardwood pulp was neutral sulfite in the semichemical yield range.

The neutral sulfite pulp was processed to the same freeness level for all runs, so the pulp freeness in the headbox varied with the amounts used. The freeness of the combinations decreased from 550 to 375 milliliters as the hardwood pulp content was increased. In two runs, jordaning was tried with no obvious improvement in bursting strength or formation. With an appreciable amount of jordaning, the drainage on the wire became too slow for satisfactory running.

The softwood neutral sulfite was used as 100 percent of the furnish in one run (machine run No. 4792). Comparing this board with the all-softwood sulfate board (machine run No. 4802), the neutral sulfite pulp gave a board with equal or greater strength properties than the sulfate pulp. Its formation was also better, and it was higher in brightness. The neutral sulfite pulp had given strength properties at a higher freeness level than the sulfate pulp. Thus, the neutral sulfite pulp required less processing for a given strength. The pulp freeness at the headbox for the all neutral sulfite pulp run was 550 milliliters as compared to 510 milliliters for the all sulfate run.

The strength of the board decreased as the percent of hardwood semichemical pulp in the furnish increased. However, the properties of the boards were comparable to those in the previous series in which the sulfate pulp was used in place of the neutral sulfite pulp.

Performance Tests on Milk Containers

Quart-size milk containers were fabricated from the various boards on commercial converting equipment. All boards performed satisfactorily in the converting operation. When filled with milk, the cartons made from the hardwood neutral sulfite semichemical boards generally seemed to bulge less than those made from all-softwood sulfate boards, or combinations of softwood and hardwood sulfate pulps. This should be an advantage, both in transportation and storage of the filled cartons. The filled containers were subjected to a rough handling test. In this test, it was observed that cartons made from board containing the hardwood sulfate pulp were usually equivalent in resistance to that of containers made entirely from softwood sulfate pulp, but cartons made of boards containing hardwood neutral sulfite semichemical pulp were less resistant than the all-softwood sulfate cartons.

Table 1.--Cooking conditions used and yield data obtained in producing sulfate pulps from hardwood and softwood mixtures

Digestion No.	Weight of wood charged (moisture-free)[1]	Chemicals charged: Concentration: Sodium hydroxide	Chemicals charged: Concentration: Sodium sulfide	Chemicals charged: Amount (moisture-free wood basis): Total chemical	Chemicals charged: Amount (moisture-free wood basis): Active alkali	Chemicals consumed	Yield of unbleached pulp (moisture-free wood basis): Screened pulp	Yield of unbleached pulp (moisture-free wood basis): Screenings	Permanganate number of pulp
	Lb.	G. per l.	G. per l.	Percent	Percent	Percent	Percent	Percent	
HARDWOOD MIXTURE[2]									
3347X	7.0	32.81	10.94	17.5	13.65	90.1	52.4	1.9	13.0
3348X	7.0	37.50	12.50	20.0	15.60	85.8	52.5	.3	12.2
1-4173	2,098.0	37.50	12.50	20.0	15.60	82.2	50.4	.3	9.1
SOFTWOOD MIXTURE[3]									
3353X	6.0	42.19	14.06	22.5	17.55	71.6	46.4	.4	21.9
3354X	6.0	46.88	15.62	25.0	19.50	67.1	45.1	.2	19.8
1-4174	1,831.0	46.88	15.62	25.0	19.50	66.4	41.5	1.4	15.3

[1] Small-scale digestions were made in steam-jacketed, cylindrical, tumbling digesters heated indirectly with steam. Large-scale digestions were made in a stationary digester with an outside circulation system for heating the cooking liquor. The cooking conditions other than those shown were as follows: liquor-wood ratio, 4:1; sulfidity (based on active alkali), 25.5 percent; maximum temperature, 170° C.; temperature-pressure increase period, 90 minutes; duration at maximum temperature, 90 minutes.

[2] Mixture containing 40 percent of aspen, 40 percent of maple, and 20 percent of beech by weight.

[3] Mixture containing 40 percent of eastern hemlock, 40 percent of jack pine, and 20 percent of balsam fir by weight.

Table 2.--Strength and other data on unbleached and bleached sulfate and neutral sulfite pulps made from hardwood and softwood mixtures

Condition	Digestion or bleach No.[1]	Bleaching data: Number of stages	Bleaching data: Total chlorine	Unbeaten pulp[2]: Bursting strength	Unbeaten pulp[2]: Tearing resistance	Unbeaten pulp[2]: Folding endurance	Unbeaten pulp[2]: Breaking length	Unbeaten pulp[2]: Density	Unbeaten pulp[2]: Freeness (Canadian Standard)	Unbeaten pulp[2]: Brightness (G.E. equivalent)	Pulp beaten to a 450-milliliter freeness (Canadian Standard)[3]: Bursting strength	Beaten: Tearing resistance	Beaten: Folding endurance	Beaten: Breaking length	Beaten: Density
				Pts. per lb. per rm.[4]	G. per lb. per rm.[4]	Double folds	M.	G. per cc.	Ml.	Percent	Pts. per lb. per rm.[4]	G. per lb. per rm.[4]	Double folds	M.	G. per cc.
MIXED HARDWOOD SULFATE PULP[5]															
Unbleached	1-4173	.....	.....	0.31	1.01	4	4,050	0.54	[6]560	40.2	0.72	1.20	40	7,050	0.69
Bleached	3777	1	4.2	.27	.84	3	2,460	.53	620	75.3	.71	1.22	45	6,550	.69
	3780	3	3.5	.28	.85	3	3,080	.54	610	81.7	.69	1.20	25	6,400	.68
	3784	3	3.3	.31	.97	4	3,270	.56	570	82.6	.55	1.20	25	5,200	.68
	3787	3	3.3	.33	.93	4	3,060	.54	570	82.4	.62	1.15	35	5,700	.68
MIXED HARDWOOD NEUTRAL SULFITE SEMICHEMICAL PULP[5]															
Unbleached	1-5615N	.....	.....	.20	.77	2	2,480	.44	680	50.0	.64	1.05	50	6,250	.65
Bleached	3832	3	13.7	.89	1.35	137	7,120	.73	305	87.5	.....	.....	.....	.....	.....
	3842	3	13.2	.69	1.27	43	6,020	.66	445	87.5	.....	.....	.....	.....	.....
	3883	3	13.0	.74	1.28	60	6,120	.67	440	87.1	.....	.....	.....	.....	.....
MIXED SOFTWOOD SULFATE PULP[7]															
Unbleached	1-4174	.....	.....	.92	2.72	619	7,090	.53	[6]670	34.6	1.50	1.56	1,600	11,400	.79
Bleached	3790	3	6.5	.58	3.44	96	4,370	.52	680	82.2	1.40	1.47	1,350	9,100	.77
	3793	3	6.7	.52	3.13	40	3,830	.51	670	82.2	1.22	1.44	950	8,000	.76
	3820	3	6.7	.63	3.13	115	4,430	.55	665	81.2	1.38	1.52	1,150	9,820	.78
	3821	3	6.7	.60	2.95	72	4,250	.54	665	80.9	1.31	1.30	1,170	9,040	.81
MIXED SOFTWOOD NEUTRAL SULFITE PULP[7]															
Unbleached	[8]1350Y	.....	.....	.68	2.45	201	5,860	.44	710	48.1	1.48	1.32	730	11,800	.75
	[9]1351Y	.....	.....	.93	2.07	274	6,960	.45	690	43.0	1.48	1.15	540	11,250	.72
	[8]1-5619N	.....	.....	.93	2.12	532	6,610	.49	680	54.2	1.54	1.30	860	11,200	.77
Bleached	[10]3862	3	10.8	.99	2.26	318	5,800	.58	650	86.5	1.59	1.13	1,075	9,650	.78
	[10]3882	3	10.5	1.02	2.48	431	6,120	.58	655	86.1	1.55	1.30	1,200	10,000	.78
COMMERCIAL SOUTHERN PINE BLEACHED SULFATE PULP[11]															
Bleached	.....	.....	.....	.60	2.02	112	4,910	.58	555	85.6	.95	1.62	475	7,100	.70

[1]Digestion No. for unbleached pulps, bleach No. for bleached pulps.

[2]Unless otherwise noted.

[3]Values interpolated from standard beater test curves.

[4]Ream of 500 sheets, 25 by 40 inches.

[5]40 percent aspen, 40 percent maple, and 20 percent beech.

[6]After beating 5 minutes in standard beater test. This applies also to the strength data

[7]40 percent jack pine, 40 percent eastern hemlock, and 20 percent balsam fir.

[8]Fully cooked pulp.

[9]Semichemical pulp.

[10]Digestion No. 1-5619N.

[11]Shipment No. 4242. Pulp processed before shipment.

Table 3.--Preparation of the neutral sulfite pulps from the softwood and hardwood mixtures

Digestion No.	Yield of unbleached pulp	Cooking liquor applied[1]			Chemical applied as		Cooking schedule		
		Volume	Na_2SO_3	$NaHCO_3$	Sulfur	Soda ash	Temperature	Time to temperature	Time at temperature
	Percent	Gal. per 100 lb. of wood[2]	Lb. per 100 lb. of wood[2]	Lb. per 100 lb. of wood[2]	Lb. per ton of pulp[3]	Lb. per ton of pulp[3]	°C.	Hr.	Hr.
MIXED SOFTWOOD[4] NEUTRAL SULFITE PULPS									
1350Y	44.6	48	37.5	3.1	385	1,350	180	2.5	7.4
1351Y	53.8	48	31.9	2.3	270	950	180	2.5	6.0
1-5619N	[5]44.5	48	37.0	3.4	[5]380	[5]1,340	180	2.75	8.0
MIXED HARDWOOD[6] NEUTRAL SULFITE SEMICHEMICAL PULPS									
1368Y	66.3	48	22.9	7.1	160	645	175	2.5	4.0
1369Y	70.4	48	18.2	6.8	120	500	175	2.5	2.4
1-5615N	[5]69	46.5	19.2	6.5	[5]125	[5]525	175	2.5	2.6

[1]Chips were lightly steamed in the digester before adding the cooking liquor.

[2]Based on moisture-free wood.

[3]Per ton of unbleached air-dry pulp.

[4]Two parts jack pine, two parts eastern hemlock, and one part balsam fir chips by weight.

[5]Estimated.

[6]Two parts aspen, two parts maple, and one part beech chips by weight.

Table 4.--Bleaching experiments on sulfate and neutral sulfite pulps from hardwood and softwood mixtures

Pulp			Chemicals applied[1]						Bleached pulp		
Bleach No.	Digestion No.	Amount	Stage 1		Stage 2		Stage 3 $Ca(OCl)_2$	Total chlorine[2]	Yield		Brightness
			Chemical	Amount	Chemical	Amount			Basis unbleached pulp	Basis moisture-free wood	
		Lb.		Percent		Percent	Percent	Percent	Percent	Percent	Percent
MIXED HARDWOOD[3] SULFATE, PERMANGANATE NUMBER 9.1, YIELD 50.4 PERCENT											
3777	1-4173	2.0	$Ca(OCl)_2$	4.2	...	...	...	4.2	97.7	...	75.3
3778	1-4173	0.2	Cl_2	2.5	NaOH	2.0	1.0	3.5	...	...	83.6
3779	1-4173	0.2	do.	2.5	do.	2.0	1.5	4.0	...	...	84.6
3780	1-4173	2.5	do.	2.5	do.	2.0	1.0	3.5	95.2	48.0	81.7
3784	1-4173	220.0	do.	2.3	do.	1.8	1.0	3.3	96.0	48.4	82.6
3787	1-4173	203.0	do.	2.3	do.	2.0	1.0	3.3	95.6	48.2	82.4
MIXED SOFTWOOD[4] SULFATE, PERMANGANATE NUMBER 15.3, YIELD 41.5 PERCENT											
3785	1-4174	0.1	Cl_2	4.5	NaOH	2.0	1.0	5.5	...	...	63.8
3786	1-4174	.1	do.	4.5	do.	2.0	2.0	6.5	...	...	79.7
3790	1-4174	160.0	do.	4.7	NaOH+	2.0	1.3	6.5	94.7	39.3	82.2
					$Ca(OCl)_2$	0.5					
3793	1-4174	165.0	do.	4.7	do.	2.0	1.5	6.7	95.0	39.4	82.8
						0.5					
3820	1-4174	172.0	do.	4.7	do.	2.0	1.5	6.7	93.4	38.8	81.2
						0.5					
3821	1-4174	157.0	do.	4.7	do.	2.0	1.5	6.7	94.0	39.0	80.9
						0.5					
MIXED HARDWOOD[3] NEUTRAL SULFITE SEMICHEMICAL PULP, TINGLE NUMBER 10.6, YIELD 69 PERCENT											
3832	1-5615N	205.0	Cl_2	13.0	NaOH	2.0	0.7	13.7	85.8	59.2	87.5

Table 4.--Bleaching experiments on sulfate and neutral sulfite pulps from hardwood and softwood mixtures (Continued)

Pulp			Chemicals applied[1]						Bleached pulp		
Bleach No.	Digestion No.	Amount	Stage 1		Stage 2		Stage 3 $Ca(OCl)_2$	Total chlorine[2]	Yield		Brightness
			Chemical	Amount	Chemical	Amount			Basis unbleached pulp	Basis moisture-free wood	
		Lb.		Percent		Percent	Percent	Percent	Percent	Percent	Percent
3842	1-5615N	204.0	Cl_2	12.5	NaOH	2.5	0.7	13.2	86.1	59.4	87.5
3883	1-5615N	184.0	....do....	12.0	....do....	2.0	1.0	13.0	87.0	60.0	87.1
MIXED SOFTWOOD[4] NEUTRAL SULFITE PULP											
3847	[5]1350Y	0.1	Cl_2	9.0	NaOH	2.0	2.5	11.5	....	....	84.3
3848	[6]1351Y	.1	....do....	20.0	....do....	2.0	4.0	24.0	....	....	84.6
3862	[7]1-5619N	186.0	....do....	9.5	....do....	2.0	1.3	10.8	92.3	41.1	86.5
3882	[7]1-5619N	168.0	....do....	9.2	....do....	2.0	1.3	10.5	94.3	42.0	86.1

[1]Percentages of chemicals are based on weight of unbleached pulps, moisture free. Bleaching conditions and chemicals indicated by formulas are: Cl_2 (chlorine) 1 to 1.5 hours at 25° C. and 2 to 3.8 percent consistence. NaOH (caustic soda) extraction 1 hour at 50° to 70° C. and 10 to 13 percent consistence; $Ca(OCl)_2$ (calcium hypochlorite) 2 to 4 hours at 38° C., 10 to 12.8 percent consistence, and pH 8.5 to 9.5; NaOH + $Ca(OCl)_2$ oxidative extraction with caustic soda and calcium hypochlorite at 45° C., 10 to 12 percent consistence, and pH 11.5 to 12.

[2]Applied as chlorine and available chlorine in the form of hypochlorite in stages 1 and 3.

[3]40 percent each of aspen and maple and 20 percent of beech.

[4]40 percent each of jack pine and eastern hemlock and 20 percent of balsam fir.

[5]Fully cooked pulp, Tingle No. 7.8, yield 44.6 percent.

[6]Semichemical pulp, Tingle No. 12.8, yield 53.8 percent.

[7]Fully cooked pulp, Tingle No. 7.7, yield 44.5 percent.

(Sheet 2 of 2)

Table 5.--Data on milk carton stock made from mixtures of softwoods and hardwoods[1]

Machine run No.	Softwood[3] Process	Softwood[3] Amount	Hardwood[4] Process	Hardwood[4] Amount	Weight, ream 25 by 40 - 500	Thickness	Density	Bursting strength	Bursting strength	Average tearing resistance	Average folding endurance (M.I.T.)	Average tensile strength	Air resistance (Gurley)	Smoothness (Bekk)	Brightness (G. E. Equivalent)
		Percent		Percent	Lb.	Mils	G. per cc.	Pts.	Pts. per lb. per rm.	G. per lb. per rm.	Double folds	P.i.w.	Sec. per 100 cc.	Seconds	Percent
Commercial bottle stock (Shipment 4254)					248.5	16.2	0.85	96.4	0.38	2.31	1,114	50.3	188	23	63.3
[5]4736					239.0	16.4	.81	131.0	.54	2.40	2,135	80.6	128	8	68.1
4802	Sulfate	100			230.0	15.9	.80	125.8	.55	1.70	960	81.0	120	7	78.1
4740	...do..	75	Sulfate	25	247.0	16.5	.83	112.3	.46	1.50	695	77.0	122	12	80.2
[6]4745	...do..	50	...do..	50	236.0	15.7	.83	98.7	.42	1.50	283	74.4	108	12	79.7
4742	...do..	25	...do..	75	251.8	16.5	.84	69.8	.28	.82	30	61.3	61	15	80.1
[6]4743	...do..	25	...do..	75	252.0	16.0	.87	82.0	.32	.72	56	70.2	119	6	79.2
[6]4804	...do..	25	...do..	75	242.0	16.3	.82	84.1	.35	.67	62	70.2	97	16	80.1
4786	...do..	75	NSSC[7]	25	240.5	16.3	.82	120.8	.51	1.60	805	81.1	114	10	78.1
4788	...do..	50	...do..	50	239.5	16.3	.81	133.4	.56	1.71	889	88.4	88	9	80.4
4790	...do..	25	...do..	75	248.5	15.9	.86	130.2	.52	1.17	310	89.9	126	9	83.2
4800			...do..	100	242.6	16.1	.83	109.7	.45	.63	14	85.6	98	11	87.8
4792	Neutral sulfite	100			240.0	15.7	.85	143.5	.60	2.00	2,111	80.7	169	13	86.6
4794	...do..	75	NSSC[7]	25	242.0	16.2	.83	128.0	.53	1.62	1,107	86.3	118	10	87.0
4796	...do..	50	...do..	50	240.0	16.4	.81	117.6	.49	1.56	816	80.4	89	10	86.6
4798	...do..	25	...do..	75	244.5	16.5	.82	119.0	.49	.99	188	89.5	94	10	86.8

[1]Coated at the size press with a solution of starch.

[2]2 percent rosin size and sulfuric acid and alum to give a pH of 5 added at beater in all furnishes except that of No. 4736. Stock processing described in test.

[3]40 percent jack pine, 40 percent eastern hemlock, and 20 percent balsam.

[4]40 percent aspen, 40 percent maple, and 20 percent beech.

[5]Pulp furnish consisted of a commercial refined southern pine semibleached sulfate pulp (wet-press broke).

[6]Pulp subjected to a jordan treatment.

[7]Neutral sulfite semichemical.

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