SULFITE PULPS FOR PAPREG:

BASE PAPERS AND LAMINATES FROM BLACK SPRUCE, BALSAM FIR, WESTERN HEMLOCK, AND GRAND FIR

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SULFITE PULPS FOR PAPREG: BASE PAPERS AND LAMINATES FROM BLACK SPRUCE, BALSAM FIR, WESTERN HEMLOCK, AND GRAND FIR[1]

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Summary

Pulping conditions previously developed for Canadian black spruce were applied to Michigan black spruce, balsam fir, and western hemlock to produce pulps with chlorine demands between 7 and 8 percent. Parallel-laminated plastics made from the slightly processed pulps had, when tested in the grain direction, the following values for tensile strength and modulus of elasticity in tension, respectively: Canadian black spruce, 37,900 and 3,240,000 pounds per square inch; Michigan black spruce, 40,500 and 3,340,000 pounds per square inch; balsam fir, 36,200 and 3,110,000 pounds per square inch; and western hemlock, 37,400 and 3,110,000 pounds per square inch. All of these values are in excess of minimum papreg requirements for these properties.

Balsam fir pulps with chlorine demands of 13 percent were also made into satisfactory laminates, but with no material increase in strength. Pulps with chlorine demands of 4 percent, on the other hand, yielded laminates of relatively low strength. A commercial balsam fir sulfite pulp with a chlorine demand of 7 percent was made into a satisfactory papreg.

A typical commercial sulfite pulp of western hemlock, in which the time of cooking was short and in which the chlorine demand was 9.9 percent, yielded a laminate somewhat below the minimum strength requirements. Three western hemlock commercial pulps that had been produced at a low maximum temperature had chlorine demands in the range of 7.6 to 13.6 percent. The lowest bleaching pulp, after slight processing, and the highest bleaching pulp, after considerable processing, were made into laminates satisfying papreg requirements, whereas that from the slightly processed intermediate pulp was close to standard.

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[1] This mimeograph is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

A typical commercial sulfite pulp of grand fir in which the time of cooking was short and in which the chlorine demand was 9 percent, was made into a laminated plastic with a tensile strength and a modulus of elasticity somewhat below minimum papreg requirements.

Introduction

In a recent Forest Products Laboratory report[2] it was shown that black spruce digested with cooking acids of varying composition and widely varying temperatures yielded pulps which could be made into papreg provided the chlorine demand of the pulp exceeded 6 percent. It was also shown that, if the chlorine demands of the pulps exceeded 8 percent, the resulting papreg was slightly lower in strength than that made from pulps with chlorine demands in the optimum range of 7 to 8 percent. Further, a set of pulping conditions was established for the production of pulps that are suitable for subsequent conversion into high-strength laminates.

The results of similar sulfite pulping experiments are given in this report for the comparison of pulps, paper and papreg of balsam fir, western hemlock, and a sample of black spruce from a different source. Several commercial sulfite pulps from balsam fir, western hemlock, and grand fir were available for comparison with the experimental pulps. The balsam fir experiments, made under the digestion conditions previously developed for black spruce, included digestions for varying times for the production of pulps ranging widely in degree of delignification. A commercially produced balsam fir pulp, made under similar conditions, also was made into paper and laminated plastics. In the western hemlock experiments also the conditions developed previously were used. The commercial western hemlock pulps had been produced by two procedures: (a) one pulp produced according to typical quick-cook procedure and having a high chlorine demand and (b) three pulps produced under varying time schedules using a low maximum temperature and having varying chlorine demands. A typical commercial grand fir pulp was likewise tested for its properties as a pulp paper, and as papreg.

Experimental Part

The balsam fir pulpwood used in these experiments was cut on the Keweenaw Peninsula of Upper Michigan. The shipment consisted of logs from trees of various growth and quality classes. The average chemical composition data (indicated by sample No. 1 in table 1) show the lot to have been normal for the species at the time of receipt. A mixture of chips made from the various wood types and not used in these experiments until after 8 months of storage had, however, a fairly high caustic soda solubility, possibly indicating the start of decay (sample No. 2, table 1).

[2] Sulfite Pulps for High-strength Laminated Paper Plastics: Pulping Variables and Properties of Black Spruce Pulps, Papers, and Plastics. FPL Mimeo. 1393, March 1943, (restricted).

The black spruce pulpwood used was obtained from the same site as the balsam fir. The data in table 1 show it to have nearly the same chemical composition as that obtained from the Algoma district of Ontario, Canada, and used in previous experiments[2]. Respective density values of 25.2 and 25.3 pounds per cubic foot and summerwood contents of 23.1 and 21.4 percent illustrate further the similar quality of the spruce from the two sources.

The pulping experiments were made with chips 5/8 inch in length, in an alloy-clad, steam-jacketed, tumbling digester of 13-cubic-foot capacity. The digestion conditions used are given in table 2. The pulps were screened through an 8-cut screen plate and tested according to Forest Products Laboratory standard methods. The commercial balsam fir pulp was made from a mixture of 75 percent balsam fir and 25 percent spruce from an eastern Canadian stand. The commercial western hemlock and grand fir pulps were made from wood representative of that ordinarily used by the pulp mill.

The pulps were made into paper either without further treatment or after a small amount of beater processing, as indicated in table 3. The paper machine was controlled to produce paper with a directional tensile-strength ratio of more than 2, a ream weight of nearly 30 pounds, and a caliper of less than 3 mils. The papers were impregnated with a noncured phenolic resin and dried. Sheets of the impregnated paper were parallel laminated and molded under a pressure of 250 pounds per square inch at 325° F. The laminated paper plastics were tested for strength and stiffness in tension and flexure, and for specific gravity and water absorption.

Discussion of Results

Balsam Fir Pulping

Experimental Pulps

In the previous experiments on black spruce[2], it had been found that the degree of delignification (as measured inversely by the chlorine demand) greatly affected the strength of papreg. The results of similar experiments with balsam fir are given in tables 2 and 3. Increasing the digestion time successively from 9 to 10.5 to 13 hours caused a decrease in pulp chlorine demand from 13.2 to 8.1 to 4.2 percent, respectively. Within this wide range, decreases in pulp yield and lignin content and increases in total and alpha cellulose contents occurred with the decreases in chlorine demand.

The total hemicellulose content of the pulps, however, did not vary greatly, since a slight decrease in pentosans was balanced by a slight increase in alkali-soluble material. The pulp with the lowest chlorine demand was also the lowest of the three in tensile and bursting strengths. The other two, although differing considerably in chlorine demand, yield, and chemical constituents, showed insignificant variations in tensile and bursting strengths. The tearing strength of all three grades was not apparently influenced by their degree of pulping.

The tensile strengths of the papers made from these pulps (table 3), both unprocessed and processed, increased with an increase in pulp chlorine demand, although the paper from the least delignified pulp (that with the highest chlorine demand) was only slightly stronger than that from the pulp of medium delignification. Processing the pulps to reduce their average initial freeness value of 850 cc. to the 840 cc. level (5 minutes processing in the beater used) caused increases in the tensile strength of the paper of 5 to 19 percent, with the exception of a decrease in the strength, in the machine direction, for the paper made from the most delignified pulp. The high porosity indices of the papers made from the three grades of pulps, both unprocessed and processed, indicated them to be less absorbent than desirable for satisfactory resin impregnation.[3] Although subsequent impregnation of the papers showed their resin content to be adequate (36 to 39 percent) they tended to become coated rather than to absorb the resin. Other properties of the papers, such as ream weight, caliper, density, and the tensile-strength ratio of machine direction to cross direction, were considered satisfactory for subsequent impregnation and laminating.

The tensile strengths of the papreg were lowest for that made from the most-delignified pulp, whereas plastics made from pulps with the medium and high chlorine demands were, like the pulps, about equal in tensile strength. This trend verified that found previously for black spruce pulps. The laminates made from the slightly processed pulps, like the papers, were higher in tensile strength than those from the unprocessed pulps. The laminate made from the low-chlorine-demand processed pulp was slightly lower in tensile strength than the minimum value of 35,000 pounds per square inch for papreg. The laminates from all the pulps, unprocessed or processed, had moduli of elasticity in tension slightly more than the minimum requirement of 3,000,000 pounds per square inch for papreg. The moduli of rupture values were approximately equal to the respective tensile strengths and the moduli of elasticity in bending were about 10 percent less than the corresponding moduli in tension. The water absorption of the plastics varied from 4 to 7 percent, and showed no relationship with the pulp or paper properties. The specific gravity was close to 1.4 in all cases.

Commercial Pulp

A commercial balsam fir pulp, produced under conditions similar to those employed in the experiments described (table 2), had higher alpha and considerably lower hemicellulose contents than the experimental pulps with the same chlorine demand. Compared on the same basis, the commercial pulp was also stronger, was made into a paper having a higher tensile strength, and was converted into a laminated plastic having a slightly higher tensile strength than the experimental pulp. The superiority of the commercial pulp may have been caused partly at least by the presence of about 25 percent of spruce in the pulpwood used at that mill.

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[3] Papers made from pulps similarly prepared from the same wood, except that it was pulped shortly after chipping, had porosity indices below 20 seconds (data not given in this report). This suggests that the carbohydrate degradation associated with decay may have influenced the absorbency characteristics of the papers described above.

Experimental Pulps

When the pulping conditions previously developed for black spruce were applied to western hemlock, a pulp with a chlorine demand of 8.7 percent was obtained (No. 5015, table 2). This is higher than the optimum range of 6 to 8 percent found for spruce. An increase in cooking time of 0.25 hour caused a decrease in chlorine demand of 1 percent (No. 5016-5017, table 2). No significant change in yield or chemical composition of the pulps, which were characteristically low in pentosans content, resulted from this small change in chlorine demand. Although a moderate increase in the tensile strength of the more delignified pulp was noted, papers made from the two pulps after the same amount of processing were approximately equal in tensile strength as well as in other properties (table 3). The papers had rather low tensile strengths, densities, and porosity indices but had a high ratio of machine direction to cross direction tensile strengths. Since slight processing of the pulp with lower chlorine demand improved tensile strength considerably without decreasing absorbency, the possibility that additional processing for the production of yet higher strength without appreciably destroying absorbency is indicated.

The tensile strengths of papreg made from the two slightly processed pulps (table 3) were reasonably close in value, 36,260 and 37,370 pounds per square inch. They thus exceeded slightly the minimum tensile-strength requirement for papreg. The improvement in the paper strength caused by the slight processing of pulp No. 5016-5017 was reflected in the laminate, indicating further that additional processing seems beneficial. The fact that relatively high tensile-strength papreg was made from relatively low-strength papers may possibly be explained by the high tensile-strength ratio in the papers. The moduli of elasticity in tension for all the laminates made from papers of experimental pulps slightly exceeded the minimum requirement for papreg. The values for moduli of rupture and elasticity in bending were slightly less than the respective values in tension. The laminates were low in density, and fairly high in water absorbency.

Commercial Pulps

A typical commercial western hemlock sulfite pulp with a rather high chlorine demand of 9.9 percent (No. 1750, table 2) had physical properties similar to one of the experimental pulps with a chlorine demand of 8.7 percent (No. 5015, table 2). The papers made from the two pulps were also fairly similar in properties, except for a low tensile-strength ratio for No. 1750. However, the strength value of the laminated plastic made from the commercial pulp (see table 3) did not reach the minimum strength value for papreg.

Three special commercial western hemlock sulfite pulps made under moderate cooking conditions with respect to maximum temperature, and particularly with respect to the time to reach the maximum temperature (Nos. 1772, 1812, and 1842, table 2) had normal increasing lignin and decreasing cellulose contents in relation to the increase in chlorine demand which ranged from 7.6 to 13.6 percent. The pentosans were characteristically low for pulps from this species. Significant decreases in tensile, bursting, and tearing strengths of the pulps were also observed with increase in chlorine demand from the lowest to the highest value; the pulp with the medium chlorine demand had strength properties intermediate to the other two. This trend verified the previous experience of the mill supplying the pulps and it was also in fair agreement with the previous Laboratory experiments on black spruce.

The differences in the average tensile strengths between the papers made from these pulps were caused mainly by differences in density. The specific tensile-strength values (tensile strength divided by density) for Nos. 1772, 1812, and 1842 were 10,170, 9960, and 10,060 pounds per square inch, respectively, indicating very little difference in the papers from this standpoint. If the pulp with the highest chlorine demand (No. 1842, table 3) had, like the others, been processed only 5 minutes instead of 25 minutes it is possible that the paper from it would have had a lower tensile strength than actually obtained, and the trend of decreasing tensile strength with increasing chlorine demand observed in the pulps might also have been observed in the papers. The papers had uniformly low porosity indices.

The laminated plastic from the most delignified pulp (No. 1772) exceeded the minimum tensile-strength requirements for papreg, whereas those from the two less delignified pulps (Nos. 1812 and 1842) had tensile strengths close to this standard. The laminate from the least delignified pulp (No. 1842) possibly benefited from the extra processing given the pulp, and for the resons previously mentioned it is possible that additional processing of the other hemlock pulps might also have resulted in papers and laminates with higher strengths than those obtained in these experiments.

Comparison of experimental and commercial pulps having the same chlorine demand (Nos. 5016-5017 and 1772, respectively) showed them to be similar in their pulp, paper, and papreg properties. The laminates from all of the commercial pulps had specific gravities of 1.4, which were appreciably higher than the laminates from the experimental pulps.

Grand Fir Pulp

A commercially produced grand fir sulfite pulp (No. 1753) that had been made under the same conditions as the commercial western hemlock pulp No. 1750 had similar strength properties. Similarity also existed in the strength properties of the base papers, and papreg made from the pulps from the two species. The grand fir laminate also was somewhat lower in strength than the minimum requirement for papreg.

Comparison of Species

A comparison is given in table 4 of the physical properties and chemical constituents of Canadian black spruce, Michigan black spruce, Michigan balsam fir, and western hemlock sulfite pulps produced under similar conditions and having approximately the same chlorine demand. Slightly longer cooking times were required for the fir and hemlock in order to attain the same degree of delignification as the spruce. The chemical constituents in the pulps varied characteristically with the species. The cellulose contents of the western hemlock pulp were higher and those of the balsam fir lower than the two spruce pulps. The content of pentosans was highest in the two spruce pulps and lowest in the hemlock. Differences in the amounts of alkali-soluble material were inappreciable. The two black spruce pulps were nearly identical in chemical characteristics. The differences in the physical properties of the various pulps were likewise small. The tensile strength of the western hemlock pulp was slightly below that of the others and the bursting strength of the Canadian black spruce pulp was slightly superior to that of the others. Characteristically the western hemlock pulp developed a higher tearing strength at 800 cc. freeness and required a longer time of processing than the others to lower the freeness to 550 cc.

The properties of the papers from these pulps also varied somewhat between species as shown in table 5. The hemlock papers made from both unprocessed and processed pulps were, unlike the pulps, decidely lower in tensile strength than the others but the tensile-strength ratio was higher. The hemlock papers were apparently highly absorbent as indicated by the low porosity values, whereas the fir papers had high porosity indices. The impregnated papers, however, had closely agreeing resin contents and had nearly equal contents of volatile matter.

The tensile strength and modulus of elasticity in papreg data given in table 5 indicate that the spruce laminates were superior to the fir and hemlock which were nearly alike in these properties. In flexural strengths the spruce and the fir laminates were superior to the hemlock laminate. The hemlock papreg was considerably less dense than the others, but this is not considered to be a fundamental characteristic.

Table 1.--Chemical composition of balsam fir, western hemlock, and black spruce chips used for sulfite pulping experiments.

Species	Shipment No.	Lignin	Total cellulose	Alpha cellulose	Total pentosans	Pentosans in cellulose	Solubility in: Alcohol benzene	Ether	1 percent NaOH	Hot water	Ash
			Percent				Percent				
Balsam fir from Michigan:[1]											
Sample No. 1............	1661	28.5	58.6	42.2	10.8	7.7	3.5	1.0	11.1	3.5	0.5
Sample No. 2............	1661	29.1	56.6	41.6	11.4	---	2.7	.5	13.4	3.8	---
Western hemlock..........	1560	30.4	62.1	44.7	8.1	5.1	2.2	.2	9.4	2.4	.3
Black spruce from Michigan	1662	26.6	60.4	44.9	11.3	9.3	1.9	.9	10.6	2.8	.2
Black spruce from Canada[2]	1700	26.6	61.2	44.5	10.9	9.2	1.8	.7	10.6	3.1	.3

[1]Sample No. 1 -- Average properties of a mixture of progressive- and regressive-growth wood when received. Sample No. 2 -- A mixture of chips of progressive- and regressive-growth wood, used after 8 months storage.

[2]Used in previous experiments.

Table 2.--Properties of balsam fir, western hemlock, and grand fir sulfite pulps.

Species	Digestion or shipment number	Digestion conditions: Maximum temperature	Digestion conditions: Time to maximum temperature	Digestion conditions: Total time	Digestion conditions: Maximum pressure	Digestion results: Total yield	Digestion results: Chlorine demand of pulp	Chemical characteristics of pulps: Lignin	Chemical characteristics of pulps: Total cellulose	Chemical characteristics of pulps: Alpha cellulose	Chemical characteristics of pulps: Total pentosans	Chemical characteristics of pulps: 1 percent NaOH soluble	Tensile strength: 800 cc. freeness S-R	Tensile strength: 550 cc. freeness S-R	Bursting strength: 800 cc. freeness S-R	Bursting strength: 550 cc. freeness S-R	Tearing strength: 800 cc. freeness S-R	Tearing strength: 550 cc. freeness S-R	Solid fraction: 800 cc. freeness S-R	Solid fraction: 550 cc. freeness S-R	Beating time: 800 cc. freeness S-R	Beating time: 550 cc. freeness S-R
		° C.	Hours		Lb. per sq. in.	Percent		Percent					Lb. per sq. in.		Pts./lb./ream[1]		Grams/lb./ream[1]				Minutes	
Balsam fir pulping:																						
Experimental pulps	5009-5010[2,3]	130	6	13.0	80	45.3	4.2	1.2	95.6	--	4.6	9.2	6,100	9,900	0.71	0.82	1.02	0.67	0.48	0.62	9	47
	5007-5008[2,3]	130	6	10.5	80	47.2	8.1	1.7	92.8	73.5	4.8	9.0	7,500	11,600	.92	1.05	1.12	.76	.47	.60	8	32
	5011-5012[2,3]	130	6	9.0	80	50.4	13.2	4.4	88.6	71.3	5.4	8.5	8,000	10,800	.95	1.10	.96	.68	.48	.56	13	40
Commercial pulps	1773	128	-	12.5	95	--	7.2	1.2	93.6	78.2	3.3	7.8	8,900	12,400	1.23	1.27	1.25	.90	.48	.61	12	48
Western hemlock pulping:																						
Experimental pulps	5015[2,3]	130	6	10.0	80	50.2	8.7	1.4	94.1	--	3.3	9.3	6,500	9,600	.91	1.01	1.30	.82	.45	.54	10	47
	5016-5017[2,3]	130	6	10.25	80	50.2	7.7	1.2	94.7	--	3.2	9.1	7,150	10,900	1.06	1.04	1.40	.90	.48	.58	10	50
Commercial pulps	1750[4]	138	3.5	8.0	80	--	9.9	--	--	--	--	--	6,700	8,700	.90	1.05	1.25	.80	.43	.56	17	45
	1772[4]	124	3.25	13.25	80	--	7.6	1.1	95.3	77.6	3.1	8.6	7,000	11,200	.95	1.10	1.43	.85	.47	.61	13	39
	1812[4]	124	3.25	11.5	80	--	10.0	2.2	92.2	--	3.6	8.0	6,000	9,300	.90	1.03	1.37	1.00	.47	.55	18	47
	1842[4]	124	8.5	14.5	80	--	13.6	3.9	91.0	76.6	3.5	9.5	5,600	9,000	.77	.98	.98	.67	.46	.58	22	49
Grand fir:																						
Commercial pulp	1753[4]	138	3.5	8.0	80	--	9.1	--	--	--	--	--	5,700	9,300	.91	.98	1.35	.95	.47	.57	25	66

[1] 25 by 40 -- 500 ream.

[2] Gallons of cooking liquor per 100 pounds of moisture-free wood: balsam fir 62.5; western hemlock 58.0; chips steamed 0.5 hour at atmospheric pressure before charging cooking liquor.

[3] Digestion conditions: Sulphur dioxide, total 6.0 percent, combined 1.2 percent; penetration temperature 110° C.; time to reach penetration temperature, 2 hours; time at penetration temperature, 2 hours.

[4] Digestion conditions: Sulphur dioxide, total 6.5 percent, combined 1.24 percent.

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Table 3.--Properties of papers and parallel laminated plastics (papreg) made from balsam fir, western hemlock, and grand fir sulfite pulps.

Species	Digestion or shipment No.	Pulp characteristics: Chlorine demand	Pulp characteristics: Processing time	Paper properties: Tensile strength: Machine direction	Tensile strength: Cross direction	Tensile strength: Ratio	Tensile strength: Average	Ream weight	Caliper	Density	Porosity (Gurley Densometer)	Impregnating results: Resin content	Impregnating results: Volatile matter	Properties of parallel-laminated plastics[1]: Tensile strength	Modulus of elasticity in tension	Static bending: Modulus of rupture	Static bending: Modulus of elasticity	Specific gravity	Water absorption
		Percent	Minutes	Lb. per sq. in.	Lb. per sq. in.		Lb. per sq. in.	Pounds 25x40-500	Mils	Grams per cc.	Seconds 100 cc.	Percent	Percent	Lb. per sq. in.	1,000 lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.		Percent
Balsam fir pulping:																			
Experimental pulps	5009	4.2	0	11,340	4,850	2.3	8,100	32.6	2.4	0.75	74	37.4	4.3	32,590	3,126	31,470	2,767	1.41	5.1
	5010		5	10,470	5,100	2.1	7,790	31.7	2.3	.75	87	37.5	4.8	34,360	3,016	36,400	2,885	1.41	4.8
	5007	8.1	0	12,060	5,270	2.3	8,670	28.8	2.2	.72	38	36.1	4.6	35,900	3,114	35,330	2,918	1.41	6.3
	5008		5	14,350	5,610	2.6	9,980	30.8	2.3	.75	75	38.0	4.6	36,180	3,065	31,640	3,010	1.42	7.3
	5011	13.2	0	12,700	5,500	2.3	9,100	31.3	2.3	.73	37	39.2	4.6	35,420	3,049	36,720	2,913	1.39	3.7
	5012		5	14,100	6,250	2.3	10,180	33.2	2.5	.73	39	36.8	4.5	37,630	3,229	38,720	2,961	1.39	4.4
Commercial pulp	1773	7.2	0	13,100	5,360	2.4	9,230	29.6	2.2	.73	25	36.4	4.6	37,230	3,226	31,470	2,986	1.27	4.7
Western hemlock pulping:																			
Experimental pulps	5015	8.7	5	8,790	2,700	3.3	5,750	30.4	2.6	.66	2	34.0	5.5	36,260	3,012	35,050	2,983	1.35	5.2
	5016	7.7	0	6,820	1,990	3.4	4,410	29.5	2.8	.58	1	34.8	5.2	35,000	3,065	31,640	2,713	1.22	8.4
	5017		5	9,090	3,030	3.0	6,060	33.2	2.9	.64	2	34.9	5.1	37,370	3,110	34,300	2,823	1.29	6.7
Commercial pulps	1750	9.9	14	9,060	4,740	1.9	6,920	30.7	2.4	.69	11	35.9	4.6	33,690	2,482	26,900	2,619	1.42	5.5
	1772	7.6	5	10,670	4,190	2.5	7,430	31.6	2.4	.73	4	38.4	4.6	37,110	3,485	31,160	2,959	1.41	5.4
	1812	10.0	5	8,800	3,680	3.3	6,280	29.6	2.6	.63	5	35.6	4.2	34,620	2,834	39,310	2,951	1.41	5.0
	1842	13.6	25	11,360	4,540	2.5	7,950	31.3	2.2	.79	3	36.0	4.5	35,170	3,318	34,700	2,947	1.40	4.3
Grand fir																			
Commercial pulp	1753	9.1	14	9,620	3,100	3.1	6,360	29.2	2.4	.67	7	34.6	4.6	33,520	2,445	27,460	2,614	1.42	5.7

[1]All tests were made according to Federal Specifications for Plastics: Organic: General Specifications L-P-406, December 9, 1942. Strength and stiffness values are given for plastic tested in the machine (fiber) direction, only.

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Table 4.--Properties of sulfite pulps made under similar conditions from black spruce, balsam fir, and western hemlock.

Species	Digestion No.	Total digestion time[1]	Total yield	Chlorine demand	Chemical characteristics: Lignin	Chemical characteristics: Total cellulose	Chemical characteristics: Alpha cellulose	Chemical characteristics: Total pentosans	Chemical characteristics: One percent NaOH soluble	Physical properties of pulps: Tensile strength, 800 cc. freeness S. R.	Tensile strength, 550 cc. freeness S. R.	Bursting strength[2], 800 cc. freeness S. R.	Bursting strength[2], 550 cc. freeness S. R.	Tearing strength[2], 800 cc. freeness S. R.	Tearing strength[2], 550 cc. freeness S. R.	Solid fraction, 800 cc. freeness S. R.	Solid fraction, 550 cc. freeness S. R.	Beating time, 800 cc. freeness S. R.	Beating time, 550 cc. freeness S. R.
		Hours	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Lb. per sq. in.	Lb. per sq. in.	Points per lb. per rm.	Points per lb. per rm.	Grams per lb. per rm.	Grams per lb. per rm.			Minutes	Minutes
Canadian black spruce	5005) 5006)	10.0	50.1	7.5	1.0	93.1	76.6	6.0	8.7	8,800	11,300	1.10	1.22	1.22	0.86	0.48	0.59	12	36
Michigan black spruce	5013) 5014)	10.0	49.4	7.2	1.4	93.6	76.0	6.0	9.1	7,750	11,800	1.00	1.12	1.08	.76	.50	.60	14	38
Michigan balsam fir	5007) 5008)	10.5	48.2	8.1	1.7	92.8	73.5	4.8	9.0	7,500	11,600	.92	1.05	1.12	.76	.47	.60	8	32
Western hemlock	5016) 5017)	10.25	50.2	7.7	1.2	94.7	78.5	3.2	9.1	7,150	10,900	1.06	1.04	1.40	.90	.48	.58	10	50

[1]Conditions constant for all digestions: acid concentration -- 6.0 percent total with 1.2 percent combined sulphur dioxide; temperature schedule -- 2 hours from 55° C. to 110° C., 2 hours 110° C., 2 hours from 110° C. to 130° C., and hold at 130° C. to end; 80 pounds per square inch maximum pressure; 0.5 hour pre-steaming of chips at atmospheric pressure; indirect steam used during digestion period.

[2]25 x 40 -- 500 ream.

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Table 5.--Properties of papers and parallel-laminated plastics (papreg) made from black spruce, balsam fir, and western hemlock sulfite pulps.

Species	Digestion No.	Pulp characteristics: Chlorine demand	Pulp characteristics: Processing time	Paper properties: Tensile strength: Machine direction	Tensile strength: Cross direction	Tensile strength: Ratio	Tensile strength: Average	Ream weight	Caliper	Density	Porosity (Gurley Densometer)	Impregnating results: Resin content	Impregnating results: Volatile matter	Plastics[1]: Tensile strength	Plastics: Modulus of elasticity in tension	Static bending: Modulus of rupture	Static bending: Modulus of elasticity	Specific gravity	Water absorption
		Percent	Minutes	Lb. per sq. in.	Lb. per sq. in		Lb. per sq. in.	Pounds 25x40-500	Mils	Grams per cc.	Seconds 100 cc.	Percent	Percent	Lb. per sq. in.	1,000 lb. per sq. in.	Lb. per sq. in.	1,000 lb. per sq. in.		Percent
Canadian black spruce	5005	7.5	0	13,860	4,760	2.9	9,310	29.6	2.3	0.70	12	35.4	4.7	38,060	3,474	36,100	3,293	1.41	5.8
	5006		7	12,100	5,380	2.2	8,740	30.4	2.4	.70	16	36.0	4.9	37,870	3,244	33,890	3,072	1.40	5.4
Michigan black spruce	5013	7.2	0	10,870	4,780	2.3	7,875	28.3	2.2	.72	8	35.3	5.4	39,500	3,304	34,640	3,079	1.40	4.6
	5014		5	13,380	4,260	3.1	8,820	29.5	2.2	.73	12	36.3	5.2	40,540	3,343	38,500	3,261	1.42	5.0
Michigan balsam fir	5007	8.1	0	12,060	5,270	2.3	8,665	28.8	2.2	.72	38	36.1	4.6	35,900	3,008	35,990	2,918	1.41	6.3
	5008		5	14,350	5,610	2.6	9,980	30.8	2.3	.75	75	38.0	4.6	36,180	3,114	35,330	3,010	1.42	7.3
Western hemlock	5016	7.7	0	6,820	1,999	3.4	4,409	29.5	2.8	.58	1	34.8	5.2	35,000	3,065	31,640	2,713	1.22	8.4
	5017		5	9,090	3,030	3.0	6,060	33.2	2.9	.64	2	34.9	5.1	37,370	3,110	34,300	2,823	1.29	6.7

[1]All tests were made according to Federal Specifications for Plastics: Organic: General Specifications L-P-406, December 9, 1942. Strength and stiffness values are given for plastic tested in the machine (fiber) direction, only.

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