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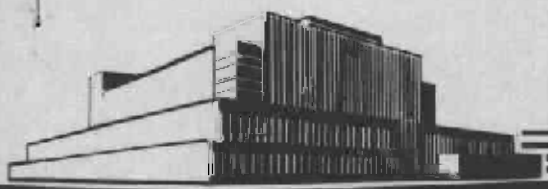

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

EXPERIMENTS ON THE GROUNDWOOD AND SULFITE PULPING OF SUBALPINE FIR[1]

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Summary and Conclusions

Groundwood pulping experiments were made on 2 lots of understory and 2 lots of mature subalpine fir (Abies lasiocarpa var. lasiocarpa)[3] from Idaho and Montana. Pulps with good strength but somewhat lower brightness than spruce and aspen groundwood pulps were made from all four lots of wood. Papermaking experiments indicated that subalpine fir groundwood pulps are suitable for book and newsprint papers.

The four types of the fir were individually pulped by the conventional sulfite process. Satisfactory yields of pulp were obtained. All had similar pulping requirements, with the mature wood showing a slight resistance. Except in tearing strength, the pulps were generally as strong as, or stronger than, a shipment of commercial western hemlock pulp; and, except in bursting strength, they were comparable to, or better than, a pulp prepared from black spruce. The brightness of the unbleached fir pulps, however, was well below that of normal spruce pulps.

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[1] This report previously issued as a Pulp and Paper Division report of limited distribution.

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

[3] The approved common name for this species according to the 1927 "Forest Service Check List of Forest Trees" was "alpine fir." This name was changed to "subalpine fir" in the 1953 "Check List of Native and Naturalized Trees."

Introduction

Subalpine fir occurs in an area extending through the Rocky Mountains from Canada to Arizona and New Mexico at elevations ranging from 2,000 to 9,500 feet. Usually associated with Engelmann spruce, it is also found with grand fir, Douglas-fir, western white pine, and western larch. Although subalpine fir has little commercial use, a small amount of it is used as construction lumber. Since the species is fairly light in weight and decays readily, it is not particularly prized for use as fuel or fence posts.

A considerable amount of subalpine fir is available in the form of thinnings in the forests of Idaho and Montana. Although a logical outlet for the thinnings would be in the manufacture of paper, information is not available on subalpine fir's pulping characteristics or the quality of the product. This investigation was undertaken in cooperation with the Forest Utilization Service, Northern Rocky Mountain Forest and Range Experiment Station.[4]

Description of the Wood

The wood consisted of 4 types and was divided into 4 lots as follows: Lot Au: Unreleased understory of a larch-Douglas-fir type from Flathead National Forest, Montana. Lot Ar: Understory of a larch-Douglas-fir type that had been released by cutting from Flathead National Forest, Montana. Lot B: Mature timber from the Coeur d'Alene National Forest, Idaho. Lot C: Mature timber from the Gallatin National Forest, Montana.

Certain physical characteristics and chemical analyses of the wood are given in table 1. The low content of summerwood and fast rate of growth in the wood of lot C combined to give a low density. Though the solid volume of wood in the cord of this wood was normal, the low density caused it to have a low weight of moisture-free wood per cord. There was practically no rot in any of the lots of wood, except for some in the butt sections of lot B. Likewise, the amount of compression wood was small. Heartwood was present, but it could not be positively distinguished from the sapwood by simple tests.

The total holocellulose and alpha-cellulose contents for the subalpine fir are slightly lower than for most of the reference species. The total content of pentosans for the subalpine fir is lower than that for the white spruce and balsam fir but about the same as that for the three western species.

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[4]Now the Intermountain Forest and Range Experiment Station.

The amount of ether-soluble material is also lower in the subalpine fir than in the reference species, but the other levels of extractives are roughly the same. The chemical analyses, therefore, revealed nothing that would prevent the use of this wood for the production of satisfactory pulps.

Groundwood Pulping and Papermaking

Equipment and Procedure

The laboratory-size grinder used in these experiments has 3 pockets 16 inches wide comparable to commercial-size hand-fed grinders, but takes blocks of wood 6 inches long. The pulpstones are 54 inches in diameter (commercial size) by 8 inches in width. Three different pulpstones were used, a sandstone and two artificial pulpstones composed of aluminum oxide grit. The three stones also differed in the sharpness of their grinding surfaces.

The grinder pit temperature was regulated at 140°, 150°, or 160° F., and the consistency in the pit ranged from 3 to 4 percent. The peripheral speed of the stone was 3,120 feet per minute. The pulps were screened through a flat-plate screen having slots 0.008 inch wide. Pulp test sheets of about 115 pounds basis weight (25 x 40--500) were made and tested by TAPPI standard methods. The screen analyses were made on an Appleton Selective screen.

Grinding Experiments

Data on the grinding characteristics and pulp properties are given in table 2.

In experiments with each of the four types of wood, attempts were made to obtain pulps covering a range of properties by adjusting grinding pressure and varying stone surface sharpness. The strongest pulps were those made on the dull stone surfaces, although in a few instances the freeness of the pulps was so low as to be out of the practical range (grinder runs Nos. 952, 954, and 955). Commercial groundwood pulps used for printing papers range in freeness from about 40 to 50 cubic centimeters up to about 150 cubic centimeters Canadian Standard and perhaps higher. The pulps made on the sharper stone surfaces generally had fairly good strength values, although they were somewhat lower than those of good-quality spruce groundwood pulps of comparable freeness.

The general level of brightness of the subalpine fir pulps was slightly lower than that of spruce and aspen groundwood pulps. Subalpine fir pulps would probably be satisfactory in newsprint papers but would have to be bleached for use in the lighter grades of book paper.

It is expected that all four types of wood can be used to produce commercially satisfactory groundwood pulps. There were no great differences in the groundwood pulping characteristics of the different types of subalpine fir tested or in the properties of the pulp obtained.

Papermaking Experiments

The data on papers made with the subalpine fir groundwood are given in table 3.

Good-quality newsprint papers containing 80 percent of subalpine fir groundwood and 20 percent of unbleached spruce sulfite were made in machine runs Nos. 3800, 3801, 3802, and 3803, representing pulps from each of the 4 types of wood. They were equal in strength and comparable in most other properties to the average of 56 commercial newsprint papers tested at the Laboratory, except for the paper that contained pulp made from the mature wood from Montana (lot C). Though that paper was somewhat lower in bursting strength than the average, it would very likely be of acceptable quality commercially. It was equal in bursting strength to newsprint paper made in machine run No. 3502 from commercial pulps and also to newsprint paper made experimentally at the Laboratory from southern pine commercial newsprint pulps.

Groundwood pulps, as prepared from the unreleased and released understory Montana wood and the mature Idaho wood, were used in making book-paper base stock for coating. This kind of paper usually contains 8 to 12 percent of clay and generally is coated. For evaluating the groundwood pulps, the clay was omitted in several of the experimental paper runs, and none of the papers was coated.

The two book papers (machine runs Nos. 3798 and 3799) made from the understory fir (lots Au and Ar) were very similar in properties, indicating that there was very little, if any, difference in the suitability of these two types of wood. Both papers were of good quality, being comparable in most properties to the reference sheet (machine run No. 3676) prepared with the same sulfite pulp and an equivalent amount of a commercial Lake States bleached groundwood of the same freeness as the subalpine fir pulp. These papers were somewhat low in brightness (58.8 and 60.4 percent) for this type of paper, but this property can be improved by the use of a bright filler or by brightening the groundwood pulp.

Three book papers were made with groundwood from the mature Idaho fir (type B) and experimental old-growth Douglas-fir sulfate pulp for the chemical pulp component. The furnishes of the papers included 12 percent of clay. This groundwood was much finer than those used in the other book papers and the newsprint papers. The groundwood portion in one of the

papers (machine run No. 3704) consisted of 45 parts of the subalpine fir groundwood and 35 parts of a red alder bleached groundwood. The finish of this paper indicated it would be a very good base sheet for coating. It was, however, somewhat low in brightness. The other two papers (machine runs Nos. 3702 and 3703), in which the groundwood was all subalpine fir, were considered to be somewhat low in both brightness and finish. Brightness and finish can be improved by increasing the amount of filler. The brightness, as mentioned above, can be also increased by brightening the groundwood pulp, a common practice in the making of groundwood book paper. The two papers containing 80 percent of groundwood and 20 percent of Douglas-fir sulfate had strength properties that would be satisfactory for newsprint paper, though for that purpose the clay would probably be omitted.

Conclusion of Groundwood Pulping Tests

The data obtained in this work indicate that good-quality groundwood pulps can be made from all of the four types of subalpine fir that were used. With the exception of the mature wood from Montana, which produced slightly weaker pulps, the strength values of the pulps from the different types of wood were generally comparable. Papermaking experiments indicated that good-quality printing papers can be made with these groundwood pulps in the furnishes. For newsprint papers, the pulps can be used in the unbleached state, but for use in the better printing grades, such as book or magazine-book papers, it might be necessary to brighten the groundwood pulps.

Sulfite Pulping

The work reported here included pulping of the mature wood from the Gallatin National Forest to produce pulps ranging from high-yield through hard-to-bleach and easily bleached ones to a dissolving pulp. The other three shipments of wood--mature wood from the Coeur d'Alene National Forest, together with released and unreleased understory thinnings from the Flathead National Forest--were investigated more briefly.

Cooking

Standard 5/8-inch chips, which had been freed from oversized material and sawdust by passage over a gyrating screen, were cooked in a small, stainless steel, tumbling digester, which was heated by means of a steam jacket. Details of the cooking conditions are included in table 4. The moisture content of the wood in 3 of the lots of wood was close to 44 percent. Chips from the other lot (unreleased understory material) had dried out; therefore, they were steamed in the digester before adding the cooking liquor in order to increase the moisture content level to about 50 percent.

For paper-grade pulp, the amount of combined sulfur dioxide charged (that is, the sulfur dioxide combined with calcium) was equivalent to 4.5 pounds of calcium oxide per 100 pounds of moisture-free wood. For the dissolving grade of pulp, the combined sulfur dioxide (combined with ammonia) was the equivalent of 3.5 pounds of calcium oxide.

The cooked material was dumped from the digester after the pressure was relieved, and then was put through an 8-cut, flat, pulsating screen. The retained material was weighed as screenings. In the case of the high-yield pulp digestions (1096y through 1100y), the wood was incompletely digested, and so it was necessary to fiberize the softened chips in a disk mill before screening the fibers. Testing of the material was in accordance with the methods of the Technical Association of the Pulp and Paper Industry.

Pulping Characteristics

With the exception of lot C, the specific gravity of the wood was average for the conifers generally cooked by the sulfite process (table 1), and so a normal production of pulp per digester charge would be expected.

The amounts of screenings suggest that the mature wood from Montana was slightly refractory to cooking with calcium-base liquor. Increasing the amount of base from 4.5 to 5.5 pounds of calcium oxide per 100 pounds of wood (data not shown in table 4) did not reduce the amount of screenings to normal. A satisfactorily low level of screenings (0.25 percent) was obtained with ammonia-base liquor.

A high-yield pulp (57 percent) resulted from use of a cooking time of 1 hour and 15 minutes at 135° C. As previously described, it was necessary to fiberize the cooked chips mechanically. To make the fully cooked pulps from lot C under these conditions, the time at 135° C. was increased by 1-1/2 and 2-3/4 hours, respectively.

Although the four types of pulpwood showed only minor differences in cooking time for a given bleachability as measured by the permanganate number, there was a significant difference in total yield. At an interpolated permanganate number of 18, the total yield would range from 48.4 for the mature wood from Montana to 52.1 for the unreleased understory thinnings.

Pulp Properties

The low content of ether extractives in the pulps (table 5) indicated that pitch trouble would be unlikely in the paper mill. The content of pentosans was a little less than had been previously found at the Forest Products Laboratory in spruce sulfite pulps. The pulps from the four woods were quite uniform in chemical composition.

The sulfite pulps made from mature Montana wood were the weakest of the four samples (table 6). Among the remaining three samples, there is little difference from the standpoint of strength. The slightly higher strength values of the unreleased understory pulp cannot be considered significant.

In general, the unbleached pulps showed good strength properties and could be substituted for spruce, except in cases where brightness is critical. Compared with the commercial western hemlock pulp shown in table 6, the subalpine fir product was weaker in tearing resistance but otherwise as strong or stronger. The fir pulps were also comparable with, or superior to, a black spruce pulp, except in bursting strength.

An attempt to produce a high alpha-cellulose pulp by reducing the amount of combined sulfur dioxide (digestions Nos. 1093-4y and 1103-4y, tables 4 and 5) was not successful. The viscosity of the pulp was sufficiently high, however, to suggest the use of more drastic cooking conditions to remove a greater proportion of the hemicelluloses. Further purification could be done in the course of the bleaching.

Table 1.--Certain physical characteristics and principal chemical constituents[1] of four types of subalpine fir

Summerwood by volume	Average age	Rings per inch	Specific gravity[2]	Holocellulose	Alphacellulose	Lignin	Total pentosans	Solubility in: Ether	Solubility in: 1-percent caustic soda	Solubility in: Hot water	Solubility in: Alcohol-benzene	Ash
Percent	Years			Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
UNRELEASED UNDERSTORY, LOT Au, FLATHEAD NATIONAL FOREST, MONTANA												
24.3	61	19.1	0.376	69.7	46.9	28.0	8.1	0.3	11.0	2.0	2.1	0.5
RELEASED UNDERSTORY, LOT Ar, FLATHEAD NATIONAL FOREST, MONTANA												
27.0	66	18.0	.380	67.4	46.5	28.6	8.5	.3	11.6	2.9	2.1	.5
MATURE TIMBER, LOT B, COEUR D'ALENE NATIONAL FOREST, IDAHO												
19.4	89	20.1	.359	66.5	44.8	27.9	8.3	.9	12.8	3.5	3.4	.5
MATURE TIMBER, LOT C, GALLATIN NATIONAL FOREST, MONTANA												
20.5	44	13.5	.308	67.1	44.2	29.6	8.9	.7	11.5	2.5	2.2	.4
TYPICAL ANALYSES FOR OTHER SPECIES												
White spruce				73	49	27	11	1.5	11	3	2.6	.2
Engelmann spruce				69	45	27	8	1.3	11	2	2.7	.2
Balsam fir				70	44	29	11	1.0	11	4	3.5	.5
Douglas-fir				69	49	27	7	1.0	12	4	3.6	.2
Western hemlock				74	52	28	9	.8	9	3	1.6	.3

[1] Based on weight when moisture-free.

[2] Based on weight when moisture-free and volume when green.

Table 2.--The groundwood pulping of subalpine fir (Abies lasiocarpa var. lasiocarpa)

Grinder run No.	Wood dryness	Grinding data[1]					Properties of pulp suspension					Properties of pulp test sheets[2]					
		Grinding surface condition	Pressure of wood on stone	Grinding rate per 24 hours[3,4]	Power input[4]	Energy consumed[3]	Freeness: Schopper-Riegler	Freeness: Canadian Standard	Screen analysis: Retained on 24-mesh	Screen analysis: Passing 150-mesh	Fiber length index	Bursting	Tearing	Tensile: Breaking length	Tensile: M.	Density	Brightness
	Percent		Lb. per sq. in.	Tons	Hp.	Hp.-days	Cc.	Cc.	Percent	Percent		Pts. per lb. per rm.	Gm. per lb. per rm.	Lb. per sq. in.	M.	Gm. per cc.	Percent
LOT Au																	
953	59.5	Dull	20	0.92	63	68	230	40				0.27	0.68	1,880	3,010	0.44	53.7
956	55.0	Dull	30	1.52	91	60	300	70	5.0	43.9	0.093	.27	.57	1,875	3,000	.44	54.2
960	47.0	Sharp	20	.79	44	56		150				.19	.66	1,255	2,320	.38	53.0
LOT Ar																	
954	56.7	Dull	20	.72	59	82	230	25				.30	.61	1,930	3,090	.44	54.3
957	49.5	Dull	30	1.74	93	54	330	80	8.6	45.0	.092	.26	.64	1,890	3,060	.43	54.6
958	42.8	Sharp	20	.94	55	58		170				.18	.66	1,418	2,540	.39	52.0
LOT B																	
955	71.0	Dull	20	.84	74	88	180	20				.30	.62	2,130	3,260	.46	58.1
951	70.4	Dull	30	1.47	85	58	265	35	7.1	45.1	.092	.28	.59	2,040	3,240	.44	58.2
940	70.2	Medium-dull	20	.61	47	77	250	45	8.2	44.4	.093	.31	.64	2,260	3,600	.44	56.2
959	54.1	Sharp	20	1.53	78	51		185				.18	.65	1,260	2,360	.38	53.6
LOT C																	
952	52.3	Dull	20	.73	57	78	200	20				.25	.50	2,020	3,160	.45	55.5
950	51.3	Dull	30	1.21	82	67	255	45	3.5	48.5	.086	.24	.51	1,805	2,895	.44	59.2
938	50.0	Medium-dull	40	1.13	80	71	320	115	9.6	43.4	.095	.22	.61	1,440	2,580	.39	58.6
961	43.5	Sharp	20	1.23	72	58		140				.16	.53	1,120	2,085	.38	55.6

[1] Three different pulpstones were used: a 90-grit aluminum oxide abrasive stone in Grinder Run Nos. 950-957, inclusive; an average 60-grit aluminum oxide abrasive stone in Grinder Run Nos. 958-961, inclusive; and a sandstone in Grinder Run Nos. 938 and 940. Burr pattern was that obtained with either 8- or 10-cut, 1-1/2-inch lead, spiral burrs. Pit temperature was 160° F. in all runs except in Grinder Run Nos. 938 and 940 in which it was 150° and 140° F., respectively. Peripheral speed of the stone was 3,120 feet per minute, and the pit consistency ranged from 3 to 4 percent.

[2] Ream size, 25 x 40 - 500.

[3] Based on tons of moisture-free wood ground.

[4] Per square foot of wood-stone contact area.

Table 3.--Papermaking data on printing papers containing subalpine fir groundwood pulps

Machine run No.	Pulp furnish[1]						Headbox freeness		Ream weight (25 x 40 - 500)	Thickness	Density	Bursting strength	Tearing strength	Tensile strength	Brightness	Opacity	Porosity	Penetration	Folds
	Douglas-fir sulfate	Commercial pulp: Unbleached sulfite[2]	Commercial pulp: Bleached sulfite	Commercial pulp: Ground-wood	Experimental groundwood pulp: Grinder run No.[3]	Experimental groundwood pulp: Lot	Schopper-Riegler	Canadian Standard											
	Percent	Percent	Percent	Percent	Percent		Cc.	Cc.	Lb.	Mils	Gm. per cc.	Pts. per lb. per rm.	Gr. per lb. per rm.	Lb. per in. with	Lb. per sq. in.	Percent	Percent	Sec.	Sec.	
NEWSPRINT PAPERS																			
3800		20			80	960	Au	435	150	36.6	3.8	0.53	0.27	0.74	9.8	2,580	58.8	91.1	26	36	10
3801		20			80	957-958	Ar	420	125	35.1	3.7	.52	.28	.63	10.3	2,785	57.1	90.4	36.2	53	3
3802		20			80	951, 959	B	355	100	36.5	3.7	.55	.31	.61	10.1	2,730	59.9	91.2	48.7	61	4
3803		20			80	961	C	425	135	36.4	3.3	.61	.20	.53	8.0	2,410	60.2	91.9	44.9	59	1
For Comparison																			
3502		20		[4]80						34.8	3.0	.64	.19	.61	6.38		60.0	87.6	26.7	37	1
Average of 56 commercial newsprint papers										38	3.3	.64	.25	.54	8.4	2,537	51	92	52	50	
BOOK PAPERS																			
3798	[5]40				60	956	Au	390	110	39.9	3.9	.57	.35	.80	13.0	3,330	58.8	88.3	73	66	11
3799	[5]40				60	957	Ar	385	130	43.0	4.0	.59	.34	.83	13.7	3,430	60.4	90.6	56	56	6
3702	[5]40				60	940	B			36.8	3.1	.66	.38	.66	12.1		69.4	89.1		115	17
3703	[6]20				80	940	B			38.6	3.4	.63	.29	.55	12.5		68.0	90		151	3
3704	[8]20				80	(9)	B			36.2	3.5	.57	.25	.98	8.5		69.2	90		82	4
For Comparison																			
3676	[5]40			[10]60			340	90		43.0	3.7	.64	.31	.79	14.6	3,950	87.7	76	83	11	

[1] Non-fibrous materials used: In Machine Run Nos. 3800-3808, inclusive, and 3502, 1/4 percent rosin size and 3 percent alum. In Machine Run Nos. 3676, 3798, and 3799, 3 percent alum. In Machine Run Nos. 3702, 3703, and 3704, 1 percent rosin size, 3 percent alum, and 12 percent clay.

[2] Commercial Canadian spruce unbleached sulfite, newsprint grade, Shipment P-3098.

[3] In Machine Run 3801, groundwood pulps from Grinder Run Nos. 957 and 958 were blended in 20:80 proportions, respectively, to give a mixture with a freeness of about 150 cc. Canadian Standard. Similarly in Machine Run 3802, pulps from Grinder Run Nos. 951 and 959 were blended in 25:75 proportions, respectively.

[4] Commercial Canadian spruce unbleached groundwood, newsprint grade, Shipment P-3097. Freeness, 165 cc. Canadian Standard.

[5] Commerical West Coast (softwood, probably western hemlock) bleached sulfite, Shipment P-3227. Brightness, 82.9 percent.

[6] Laboratory prepared bleached Douglas-fir sulfate, Bleach No. 2198.

[7] Bleached commercial Lake States softwood sulfite, Shipment 3213.

[8] Laboratory prepared semibleached Douglas-fir sulfate, Bleach No. 2413.

[9] The groundwood was a mixture of 45 parts Alpine fir groundwood (Grinder Run No. 940) and 35 parts red alder bleached groundwood (Grinder Run No. 935).

[10] Bleached commercial Lake States groundwood (60 percent spruce, 30 percent balsam fir, and 10 percent poplar), Shipment P-3227. Brightness, 62.3 percent. Freeness, 85 cc. Canadian Standard.

Table 4.--Sulfite pulping of subalpine fir[1]

Digestion No.	Time at 135° C.	Total cooking time	Final combined SO_2	Yield		Permanganate No.
				Total	Screenings	
	Hours	Hours	Percent	Percent	Percent	Ml.
MATURE WOOD, MONTANA, LOT C						
1096y 1100y	1.25	6.25	0.33	57.5	.....	[2]48.6
1090y 1099y	2.7	7.7	.25	48.7	3.4	18.7
1095y 1097y	4.0	9.0	.13	45.5	.6	9.9
[3]1093-4y 1103-4y	2.4	7.4	-.02	45.6	.25	8.6
MATURE WOOD, IDAHO, LOT B						
1141y	3.25	8.25	.27	48.6	1.4	14.2
1142y	2.7	7.7	.30	50.1	2.0	18.2
RELEASED UNDERSTORY, LOT Ar						
1137y	3.25	8.25	.32	51.3	.6	16.2
1138y	2.9	7.9	.36	53.1	.8	20.0
UNRELEASED UNDERSTORY, LOT Au						
1139y	3.7	8.7	.33	48.8	.4	14.7
1140y	4.0	9.0	.39	48.9	.4	13.1

[1]Conditions common to all digestions. Liquor-to-wood ratio, including moisture in the chips, 60 gallons per 100 pounds of moisture-free wood. Temperature rise; 0.5 hour to 80° C., 0.5 hour at 80° C., 0.5 hour to 110° C., 1.5 hours at 110° C., and 2 hours to 135° C. Initial liquor concentration in the digester, allowing for chip moisture, was 5.2 percent total and 1.03 percent combined sulfur dioxide, except as otherwise noted. All cooks with calcium base except as otherwise noted.

[2]60 milliliters of 0.1 $KMnO_4$ used.

[3]Ammonia-base digestions. Initial concentration of combined sulfur dioxide was 0.8 percent.

Table 5.--Chemical properties of subalpine fir sulfite pulps

Digestion No.	Chlorine demand[1]	Lignin	Holocellulose	Alphacellulose	Total pentosans	Ether solubility
	Percent	Percent	Percent	Percent	Percent	Percent
MATURE WOOD, MONTANA, LOT C						
1096y 1100y		13.6	79.8	65.0	4.6	0.4
1090y 1099y	9.7	2.5	92.9	77.6	4.5	.5
1095y 1097y	4.7	1.3	96.3	82.2	4.4	.4
[2]1093-4y 1103-4y	4.0	1.2	96.2	79.9	4.2	.5
MATURE WOOD, IDAHO, LOT B						
1141y	7.0	1.1	94.0	77.0	4.1	.3
1142y	9.4	2.0	92.2	74.5	4.3	.4
RELEASED UNDERSTORY, LOT Ar						
1137y	8.2	1.7	93.7	75.8	4.0	.3
1138y	10.5	2.1	91.8	73.9	4.2	.4
UNRELEASED UNDERSTORY, LOT Au						
1139y	7.3	1.0	93.8	78.2	4.7	.3
1140y	6.4	.8	94.5	77.9	4.4	.3

[1]Calculated from permanganate number by formula given in TAPPI Method T-214 m-50.

[2]Ammonia-base pulp. Beta cellulose is 6.2 percent, gamma cellulose is 12.0 percent, viscosity is 46 at 0.5 percent concentration in cupriethylenediamine.

Table 6.--Strength properties of subalpine fir sulfite pulps

Digestion No.	Chlorine demand	Bursting strength		Tearing strength		Breaking length		Folding endurance		Density		Beating time		Brightness (G.E. equivalent)
		At freeness[1] of--		At freeness[1] of--		At freeness[1] of--		At freeness[1] of--		At freeness[1] of--		At freeness[1] of--		
		500 ml.	250 ml.	500 ml.	250 ml.	500 ml.	250 ml.	500 ml.	250 ml.	500 ml.	250 ml.	500 ml.	250 ml.	
	Percent	Pts. per lb. per rm.[2]	Pts. per lb. per rm.[2]	Gm. per lb. per rm.[2]	Gm. per lb. per rm.[2]	Meters	Meters	Double folds	Double folds	Gm. per cc.	Gm. per cc.	Min.	Min.	Percent
MATURE WOOD, MONTANA, LOT C														
1096y 1100y		0.87	0.94	0.87	0.66	8,900	9,350	550	1,050	0.78	0.85	10	23	38.7
1090y 1099y	9.7	1.00	1.02	.97	.77	9,500	9,800	800	1,000	.81	.95	10	22	44.7
1095y 1097y	4.7	.93	.96	1.04	.74	8,400	9,200	700	1,100	.82	.90	10	22	50.7
MATURE WOOD, IDAHO, LOT B														
1141y	7.0	1.08	1.13	1.00	.83	9,600	9,800	800	1,500	.84	.91	15	26	50.1
1142y	9.4	1.09	1.19	.96	.80	9,700	10,500	875	1,375	.88	.93	15	26	46.1
RELEASED UNDERSTORY, LOT Ar														
1137y	8.2	1.07	1.09	1.15	.94	9,400	10,400	750	1,250	.81	.92	16	28	47.9
1138y	10.5	1.08	1.20	1.10	.90	10,000	10,700	750	1,500	.78	.82	16	28	48.9
UNRELEASED UNDERSTORY, LOT Au														
1139y	7.3	1.15	1.23	1.04	.87	9,800	10,400	875	1,450	.81	.93	14	26	49.5
1140y	6.4	1.09	1.18	1.00	.87	10,000	10,600	1,000	1,630	.83	.96	13	26	51.2
COMMERCIAL WESTERN HEMLOCK SULFITE, SHIPMENTS 1750 AND 1812														
.....	10.0	.94	1.07	1.25	.90	7,300	8,300	.....	.....	.72	.83	25	46	.....
BLACK SPRUCE SULFITE, DIGESTIONS 3977-I, 3978-I, 3997-I														
.....	6.4	1.19	1.24	.96	.75	9,100	9,180	.....	.....	.78	.88	14	42	.....

[1] Canadian Standard freeness. Freeness and other values interpolated from standard beater test curves.

[2] Ream size: 500 sheets 25 by 40 inches in size.

SUBJECT LISTS OF PUBLICATIONS ISSUED BY THE

FOREST PRODUCTS LABORATORY

The following are obtainable free on request from the Director, Forest Products Laboratory, Madison 5, Wisconsin:

List of publications on Box and Crate Construction and Packaging Data

List of publications on Chemistry of Wood and Derived Products

List of publications on Fungus Defects in Forest Products and Decay in Trees

List of publications on Glue, Glued Products, and Veneer

List of publications on Growth, Structure, and Identification of Wood

List of publications on Mechanical Properties and Structural Uses of Wood and Wood Products

Partial list of publications for Architects, Builders, Engineers, and Retail Lumbermen

List of publications on Fire Protection

List of publications on Logging, Milling, and Utilization of Timber Products

List of publications on Pulp and Paper

List of publications on Seasoning of Wood

List of publications on Structural Sandwich, Plastic Laminates, and Wood-Base Aircraft Components

List of publications on Wood Finishing

List of publications on Wood Preservation

Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

Note: Since Forest Products Laboratory publications are so varied in subject no single list is issued. Instead a list is made up for each Laboratory division. Twice a year, December 31 and June 30, a list is made up showing new reports for the previous six months. This is the only item sent regularly to the Laboratory's mailing list. Anyone who has asked for and received the proper subject lists and who has had his name placed on the mailing list can keep up to date on Forest Products Laboratory publications. Each subject list carries descriptions of all other subject lists.