PULPING AND PAPERMAKING EXPERIMENTS ON QUAKING ASPEN FROM COLORADO

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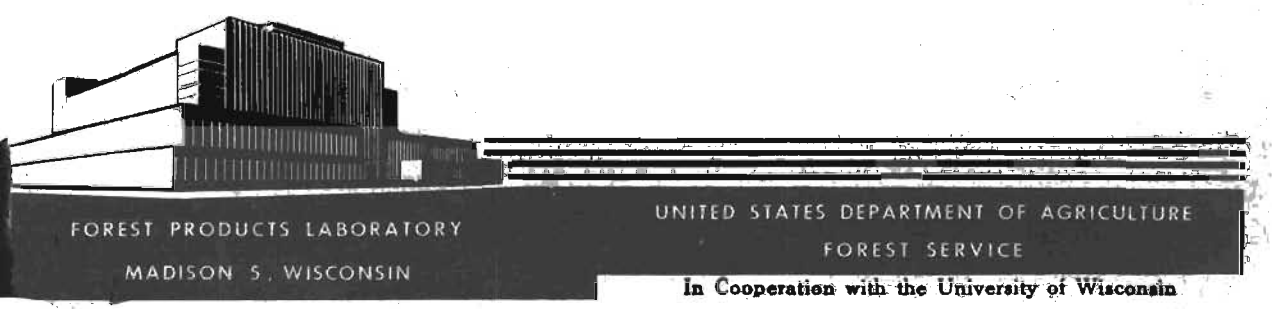

FOREST PRODUCTS LABORATORY
MADISON 5, WISCONSIN

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

PULPING AND PAPERMAKING EXPERIMENTS

ON QUAKING ASPEN FROM COLORADO

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Summary

Quaking aspen (*Populus tremuloides*) from Colorado was pulped at the Forest Products Laboratory by the groundwood, sulfite, neutral sulfite semichemical, and sulfate processes. Magazine coating-base papers were made with the groundwood and sulfate pulps in the furnish. The results show that aspen grown in this locality is equivalent to that grown in the Lake States for pulp and paper manufacture.

Introduction

Aspen and cottonwood are plentiful in the Southern Rocky Mountain area but have not been used as sources of pulpwood, even though these same species are widely used for this purpose in the Lake States. This abundance of aspen and cottonwood in the Southern Rockies is shown by the net volume of about 3.12 million board feet of live saw timber on commercial forest lands alone,[2] or nearly 80 percent of the volume in the Lake States. In Colorado and New Mexico the total volume of these woods is about 2.58 million board feet. The wood of these species grown in the Rocky Mountain area is probably as suitable for papermaking as that grown in the Lake States, but there is a possibility that some physiological differences attributable to locality of growth could affect their usefulness. This report discusses pulping and papermaking experiments on aspen wood obtained from Colorado and compares the results with those previously obtained from Lake States aspen.

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

[2]Forest Service. Timber Resources for America's Future. U. S. Dept. Agr. Forest Resource Report No. 14, January 1958.

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Description of the Wood

Approximately one cord of aspen, cut in the vicinity of Kremmling, Colo., was supplied to the Forest Products Laboratory by the U. S. Forest Service Regional Office at Denver. The shipment (No. 3336) consisted of 89 peeled logs, 4 feet in length. Disks cut from 20 randomly selected logs had the following average physical characteristics:

Density (moisture-free weight and green volume)	20.8 lbs. per cu. ft.
Diameter	6.8 in.
Rings per log	46
Rings per inch of radius	13.6

Since the wood was received without bark, positive identification was not possible but it most probably was quaking aspen (*Populus tremuloides*). The density of the wood in this sample was within the range of aspen grown in the Lake States.

Groundwood Pulping

The groundwood pulping was done at the Forest Products Laboratory with the experimental 3-pocket grinder. The grindstone is 54 inches in diameter and 8 inches wide. Two stones were used in the experiments, one of 90-grit aluminum oxide abrasive and the other a natural sandstone. The groundwood pulps were screened on a flat-plate screen having slots 0.008 inch in width. The pulp test sheets of about 115 pounds base weight (ream of 500 sheets, 25 by 40 inches) were tested by TAPPI standard methods. The screen analyses were made on an Appleton Selective screen. Data on the grinding of the wood and tests of the pulps are given in table 1. For comparison, data on two typical groundwood pulps made from Lake States aspen are included in the table.

By varying the pressure of the wood on the grindstone and the condition of the grinding surface, pulps ranging rather widely in strength properties were obtained. Pulps produced in grinder runs Nos. 974 and 975 using a grindstone with a medium dull grinding surface were not much different in energy consumption per ton of wood ground and in pulp properties, even though made at different grinding pressures. They were also comparable to a pulp made from Lake States aspen at an intermediate pressure (grinder run No. 931). The similarity of the Colorado and Lake States aspens for groundwood pulping is shown further by comparing grinder run No. 980 (Colorado) with No. 943 (Lake States), both made with nearly the same grinding pressure and stone surface condition. The high freeness of the Colorado aspen pulp indicates it might be advisable to grind the wood on duller surfaces than was used in this experiment.

The net effect of increasing pressure as the stone becomes duller is shown in grinder runs Nos. 982, 983, and 986. The energy consumption was reduced markedly with each step increase in pressure. The screen analysis indicates an increase in the percentage of longer fibers and the pulp strength remained high and relatively constant. As was reported for Lake States aspen[3] the most favorable grinding conditions appear to be obtained by the use of high pressure and a dull grinding surface.

The pulps from grinder runs Nos. 982 and 996 were used in making coating-base paper.

These experiments show aspen from Colorado as represented by this sample will produce about the same quality of groundwood pulp as aspen from the Lake States.

Sulfite Pulping

A duplicate pair of small-scale (0.8-cubic-foot-capacity digester) calcium-base acid-sulfite cooks were made on the aspen from Colorado using a liquor containing 1.14 percent combined sulfur dioxide and 5.47 percent total sulfur dioxide. The cooking time was 9.5 hours, of which 3.5 hours were at the maximum temperature of 125° C. The average of the yields of screened pulp obtained was 55.5 percent based on moisture-free material. The average of the permanganate numbers of the pulps was 12.3. The cooking data and average chemical analysis of the two pulps are given in table 2. The pulp strength data are given in table 3. Both tables contain data on a pulp with about the same permanganate number obtained from a sample of Lake States aspen.

After beating, and compared at the same freeness, the Colorado aspen pulp was higher than the Lake States pulp in all strength properties; in some properties the difference was appreciable. The brightness of the unbleached Colorado aspen pulp was also higher than that of the Lake States pulp though the reason may be attributed to the fact that the latter had been processed before making the brightness determination.

Semichemical Pulping

Small-scale neutral sulfite semichemical pulps were made in duplicate on the Colorado aspen. The average results of the two cooks are given in tables 4 and 5, along with data for Lake States aspen neutral sulfite semichemical pulp made under almost the same conditions. The yields and chemical analyses of the pulps made from the two samples of wood are

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[3] Hyttinen, Axel, Mackin, G. E., and Schafer, E. R. Experiments on the Grinding of Quaking Aspen and Use of the Pulp in Printing Paper. Forest Products Laboratory Report No. 1697, 1956.

nearly identical (table 4). The Colorado aspen pulp at 650 milliliters Canadian Standard freeness was practically equal to the Lake States aspen pulp in strength properties (table 5). At the lower freenesses of 450 and 250 milliliters, the Colorado aspen pulps were like the Lake States aspen pulps in bursting and tearing strengths, but much better in folding endurance and breaking length. The Lake States pulp was bulkier (had lower density of test sheet) than the Colorado pulp at all freeness levels. The brightness of the two pulps was about the same.

Sulfate Pulping

The average data for the yields, permanganate numbers, and bleach requirements of pulps produced from Colorado aspen are shown in table 6 to be practically identical to pulps produced under the same conditions from Lake States aspen. Both unbleached and bleached pulp test sheets of Colorado aspen were stronger and denser than those made from Lake States aspen pulp when pulps beaten to the same freeness were compared. The differences in folding endurances and breaking lengths were appreciable, as were observed also for the neutral sulfite semichemical pulps.

A larger scale cook of Colorado aspen (digestion No. 4113) was made to supply pulp for papermaking experiments. Though cooked to the same yield and permanganate number as the small-scale cooks, the unbleached pulp, beaten to the same degree of freeness, was a little stronger.

Papermaking

Several experimental paper machine runs were made to produce magazine coating-base paper from the Colorado aspen groundwood and bleached sulfate pulps. The furnishes and properties of the papers are given in table 8. Data for a commercial coating-base paper are also included.

A paper (machine run No. 4691) consisting entirely of Colorado aspen pulps--60 percent as groundwood pulp and 40 percent as sulfate pulp--was equal to the commercial magazine paper in tensile strength, but was weaker otherwise. Substitution of a commercial Douglas-fir sulfate pulp for half of the Colorado aspen sulfate pulp (machine run No. 4692) raised the tearing resistance to that of the commercial paper. When the stock was jordaned, the bursting strength of the paper (machine run No. 4693) was raised to that of the commercial paper, but the tearing resistance was lowered a little.

For machine run No. 3930, Colorado aspen groundwood pulp was mixed with an equal portion of a commercial softwood sulfite pulp. The paper was nearly equal in tearing, folding, and tensile strengths, but lower in bursting strength than a paper (machine run No. 4303) in which the

Colorado aspen groundwood was replaced with a commercial groundwood made from one-third Lake States aspen and two-thirds spruce. This paper (No. 3930), though higher in tearing resistance, was not as strong otherwise as the commercial coating-base paper.

Conclusions

Quaking aspen (*Populus tremuloides*) grown in Colorado and other localities in the Southwest is a satisfactory wood for the production of pulp and paper. The sulfite pulp was stronger than a comparable pulp made from Lake States aspen. Pulps made by the other processes were practically equivalent to those made from Lake States aspen.

Table 1.--Data on groundwood pulping of quaking aspen

Grinder run No.	Moisture content of wood	Stone surface condition	Grinding data[1]: Pressure of wood on stone	Grinding data[1]: Grinding rate of moisture-free wood per 24 hours[3]	Grinding data[1]: Power input[3]	Grinding data[1]: Energy consumed per ton of moisture-free wood	Properties of pulp suspension: Freeness Canadian Standard	Properties of pulp suspension: Screen analysis: Retained on 24-mesh	Properties of pulp suspension: Screen analysis: Passing 150-mesh	Properties of pulp suspension: Screen analysis: Fiber length index[4]	Properties of pulp test sheets[2]: Burst	Properties of pulp test sheets[2]: Tear	Properties of pulp test sheets[2]: Breaking length	Properties of pulp test sheets[2]: Density	Properties of pulp test sheets[2]: Brightness
	Percent		Lb. per sq. inch	Tons	Hp.	Hp. days	cc.	Percent	Percent	Mm.	Pt. per lb. per ream	Gm. per lb. per ream	Meters	Gm. per cc.	Percent
Aspen from Colorado															
974	68.6	Medium dull[5]	30	1.84	106	58	160	3.1	47.6	0.085	0.11	0.44	1,527	0.39	58.0
975	68.6	Medium dull[5]	20	1.06	64	61	160	2.0	48.8	.085	.14	.44	1,883	.38	61.0
980	68.6	Medium dull[6]	12	.38	31	82	260	8.8	34.0	.108	.16	.49	2,030	.37	.....
982	68.6	Dull[6]	15	.26	49	192	60	3.2	51.7	.083	.25	.59	3,090	.46	55.7
983	71.8	Very dull[6]	20	.40	71	180	85	5.1	40.5	.096	.22	.52	2,770	.42	.....
996	76.2	Very dull[6]	30	.66	81	123	80	10.1	38.5	.103	.25	.55	2,810	.45	56.2
Aspen from Lake States															
931	78.0	Dull[6]	25	1.15	66	57	175	4.6	44.6	.092	.14	.48	1,580	.36	.....
943	74.3	Dull[6]	12	.33	32	97	100	.....	.....	.....	.18	.43	2,210	.41	55.1

[1] In all experiments the same peripheral speed, 3,120 feet per minute, and grinder pit consistency, 3 to 4 percent, were used. Grinder pit temperature was 145° F. in all experiments except in run Nos. 931 and 943, in which it was 130° F.

[2] Basis weight of test sheets, 115 pounds per ream (500 sheets 25 by 40 inches).

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

[4] Calculated from amounts retained on 24-, 42-, 80-, and 150-mesh screens of the Tyler series and on that passing through the 150-mesh screen.

[5] Aluminum oxide abrasive (90 grit) pulpstone. The surface had been used for about 26 hours after last being dressed with an 8-cut, 1-1/2-inch lead, spiral burr.

[6] Sandstone with 10-cut, 1-1/2-inch lead, spiral pattern. At the start of run No. 980, the stone had been used 11 hours since the last dressing. Before run No. 982 the surface used in run No. 980 was further dulled by bricking lightly and then conditioned for 2 hours by grinding miscellaneous wood. At the start of run No. 983, the stone surface had been used 13.5 hours after the brick treatment and before run No. 996, the surface had received 17 hours of wear after the bricking. Runs Nos. 931 and 943 had been made previously on a dull surfaced sandstone.

Table 2.--Calcium-base acid-sulfite pulping of Colorado and Lake States quaking aspen to similar permanganate numbers

Pulping conditions and pulp tests	Colorado aspen (Digestions Nos. 1143y, 1144y)	Lake States aspen (Digestion No. 5187-I)
Pulping:		
Cooking liquor:		
Combined sulfur dioxide.....percent	1.14	0.97
Total sulfur dioxide.....percent	5.47	4.97
Volume[1].....gal. per 100 lb. wood[2]	61.0	64.3
Cooking schedule:		
Room temperature to 105° C.....hr.	2	.....
At 105° C.....hr.	1	.....
From 105° to 125° C.....hr.	3	.....
At 125° C.....hr.	3.5	.....
Room temperature to 90° C.....hr.	.....	0.5
At 90° C.....hr.	.....	0.5
From 90° to 148° C.....hr.	.....	5.25
At 148° C.....	.....	0.25
Pulp:		
Yield:[2]		
Screenings.....percent	0.4	.....
Screened pulp.....percent	55.5	.....
Chemical analysis:[3]		
Lignin.....percent	1.3	2.7
Holocellulose.....percent	93.1	94.8
Alpha-cellulose.....percent	79.3	83.6
Pentosans.....percent	9.0	6.5
Soluble in:		
Alcohol-benzene.....percent	3.1	.....
Ether.....percent	1.9	0.9
1 percent NaOH.....percent	16.2	10.7
Hot water.....percent	2.0	2.8
Permanganate number.....	12.3	11.9

[1] Includes moisture in the chips

[2] Based on moisture-free wood.

[3] Based on moisture-free pulp.

Table 3.--Physical tests on acid sulfite pulps of similar permanganate number made from Colorado and Lake States aspen[1]

Pulps from	Freeness (Canadian Standard)	Pulp test values					
		Bursting strength	Tearing resistance	Folding endurance	Breaking length	Density	Brightness (unbleached)
	Ml.	Pts. per lb. per ream[2]	Gm. per lb. per ream[2]	Double folds	Meters	Gm. per cc.	Percent
Colorado aspen (Digestion Nos. 1143y-1144y)							
Unbeaten	620	0.27	0.75	4	4,330	0.70	56
Beaten[3]	350	.71	.65	110	8,000	.94	.....
Beaten[3]	250	.76	.60	180	8,400	.99	.....
Lake States aspen (Digestion No. 5187-I)							
Processed[4]	380	.47	.56	11	4,750	.69	42
Beaten[3]	350	.47	.51	11	4,800	.72	.....
Beaten[3]	250	.54	.43	49	5,450	.78	.....

[1]Permanganate numbers, 12.3 for Colorado pulps and 11.9 for Lake States pulps.

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

[3]Interpolated from standard beater test curves.

[4]Pulp was processed in a disk mill prior to the standard beater test.

Table 4.--Neutral sulfite semichemical pulping of Colorado and Lake States aspen to about the same yield

Pulping conditions and pulp analysis	Colorado aspen (Digestions Nos. 1145y, 1146y	Lake States aspen (Digestions Nos. 970y, 997y, 1058y)
Pulping[1]		
Liquor charged:		
Concentration, Na_2SO_3.....gm. per l.	44.6	46.1
Concentration, $NaHCO_3$.....gm. per l.	15.9	16.0
Volume.....gal. per 100 lb. of wood[2]	40.0	40.0
Chemical applied: Na_2SO_3.....percent[2]	15.0	15.1
$NaHCO_3$.....percent[2]	5.3	5.6
Spent liquor, concentration, Na_2SO_3..gm. per l.	10.7	13.4
Time to 170° C.....hr.	1.5	3
Time at 170° C.....hr.	1.5	1.4
Yield of pulp.....percent[2]	76.4	76.2
Pulp Analysis[3]		
Lignin.....percent	9.9	.....
Holocellulose.....percent	82.9	82.0
Alpha-cellulose.....percent	63.8	63.0
Pentosans.....percent	19.0	17.0

[1]Chips steamed lightly for 1/2 hour before adding liquor.

[2]Based on moisture-free wood.

[3]Based on moisture-free pulp.

Table 5.--Physical tests on neutral sulfite semichemical pulps of about the same 76 percent yield made from Colorado and Lake States aspen[1]

Pulps from	Freeness (Canadian Standard)	Pulp test values					
		Bursting strength	Tearing resistance	Folding endurance	Breaking length	Density	Brightness (unbleached)
	Ml.	Pts. per lb. per ream[2]	Gm. per lb. per ream[2]	Double folds	Meters	Gm. per cc.	Percent
Colorado aspen (Digestion Nos. 1145y, 1146y)	650	0.45	0.95	10	4,900	0.65	53
	450	.76	.78	260	8,150	.80	.....
	250	.98	.54	660	9,800	.91	.....
Lake States aspen (Digestion Nos. 970y, 997y, 1058y)	650	.43	.99	12	4,840	.55	57
	450	.77	.71	98	6,850	.68	.....
	250	.90	.62	260	8,420	.76	.....

[1]Interpolated from standard beater test curves.

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

Table 6.--Sulfate pulping of Colorado and Lake States quaking aspen to similar yield and permanganate number

Pulping conditions and pulp tests	Colorado aspen		Lake States aspen
	Digestions 2825X, 2826X	Digestion 4113	Digestions 2945, 2946, 2947, 2948
Pulping			
Wood charged[1] ..... lb.	6	100	100
Chemicals charged:[1]			
Total chemicals ($NaOH + Na_2S$) ..... percent	17.5	17.5	17.5
Active alkali as Na_2O ..... percent	13.7	13.7	13.7
Sulfidity ..... percent	30	30	30
Liquor-wood ratio	3.5:1	3.5:1	3.5:1
Chemicals consumed[2] ..... percent	93	92	89
Time to 170° C ..... hr.	1.5	1.5	1.5
Time at 170° C ..... hr.	1.5	1.5	1.5
Pulp			
Yield:[1]			
Screenings ..... percent	0.3	0.9	0.5
Screened pulp ..... percent	55.9	54.4	54.9
Permanganate number	11.5	11.1	10.6
Bleach requirement, total chlorine[3] ..... percent	.....	[4]3.6	[5]4.2

[1]Based on moisture-free wood.

[2]Based on total chemicals.

[3]Total chlorine based on unbleached pulp.

[4]For a brightness of 80 percent. Three-stage bleach (chlorination, oxidative extraction, hypochlorite).

[5]For a brightness of 83 percent. Three-stage bleach (chlorination, caustic soda extraction, hypochlorite).

Table 7.--Physical tests on sulfate pulps of similar[1] yield and permanganate number made from Colorado and Lake States quaking aspen[2]

Digestion No.	Condition of pulp	Freeness (Canadian Standard)	Bursting strength	Tearing resistance	Folding endurance (M.I.T.)	Breaking length	Density	Brightness (G.E. equivalent)
		Ml.	Pts. per lb. per ream[3]	Gm. per lb. per ream[3]	Double folds	Meters	Gm. per cc.	Percent
			WOOD FROM COLORADO					
2825X, 2826X	Unbleached, unbeaten	610	0.27	1.70	2	5,000	0.66	32
	Unbleached, beaten	450	.86	1.02	190	8,500	.85	.....
	Unbleached, beaten	250	1.18	.73	1,200	10,000	1.00	.....
4113	Unbleached, unbeaten	480	1.00	1.04	285	8,140	.79	26
	Unbleached, beaten	450	1.06	.98	350	8,370	.81	.....
	Unbleached, beaten	250	1.30	.78	1,500	10,300	.95	.....
	Bleached, unbeaten	530	.53	1.07	15	4,820	.70	80
	Bleached, beaten	450	.74	1.06	100	6,300	.76	.....
	Bleached, beaten	250	1.00	.84	640	8,400	.90	.....
			WOOD FROM LAKE STATES					
2945, 2946, 2947, 2948	Unbleached, unbeaten	715	.31	.86	5	2,800	.52	.....
	Unbleached, beaten	450	.75	1.05	70	6,300	.70	.....
	Unbleached, beaten	250	.99	.88	340	7,700	.80	.....
	Bleached, unbeaten	630	.38	.98	7	2,500	.62	83
	Bleached, beaten	450	.61	.94	35	4,750	.70	.....
	Bleached, beaten	250	.77	.82	90	5,900	.79	.....

[1]Yields about 55 percent and permanganate numbers about 11.

[2]Test data interpolated from standard beater test curves.

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

Table 8.--Test results on magazine coating-base papers containing Colorado aspen groundwood and sulfate pulps

Machine run No.[1]	Headbox freeness (Canadian Standard)	Ream weight[2]	Thickness	Density	Bursting strength	Tearing resistance	Folding endurance (M.I.T.)	Tensile strength	Castor oil penetration	Air resistance (Gurley)	Opacity	Brightness (G.E. equivilant)	Ash
	Ml.		Mils.	Gm. per cc.	Pts. per lb. per ream[2]	Gm. per lb. per ream[2]	Double folds	Lb. per in. of width	Sec.	Sec. per 100 cc.	Percent	Percent	Percent
4691	165	34.4	2.6	0.73	0.19	0.60	2	7.26	50	65	85.4	64.1	5.5
4692	135	35.2	2.7	.72	.19	.82	3	6.40	52	57	86.8	63.0	5.6
4693	100	35.2	2.5	.78	.23	.69	6	7.74	81	243	86.2	62.6	5.2
3930	190	35.8	3.2	.62	.12	1.18	3	6.63	35	32	87.5	65.7	4.8
4303	.....	34.5	3.4	.56	.24	1.18	3	6.12	24	13	86.7	63.8	4.8
Commercial coating-base paper[3]	.....	33.0	.....	.68	.23	.82	4	7.3	.....	28	88.8	67.9	6.9

[1] No. 4691 consists of 60 percent groundwood (grinder run 996) and 40 percent bleached sulfate (digester No. 4113), 6 percent clay, 0.5 percent rosin size, and has a pH of 4.5.
No. 4692 consists of 60 percent groundwood (grinder run 996), 20 percent bleached sulfate (digester No. 4113), and 20 percent commercial bleached sulfate of Douglas-fir (shipment No. 4205), 6 percent clay, 0.5 percent rosin size, and has a pH of 4.9.
No. 4693 consists of 60 percent groundwood (grinder run 996), 20 percent bleached sulfate (digester No. 4113), and 20 percent commercial bleached sulfate of Douglas-fir (shipment No. 4205), 6 percent clay, 0.5 percent rosin size, and has a pH of 4.9. This stock was jordaned.
No. 3930 consists of 50 percent groundwood (grinder run 982) and 50 percent commercial bleached sulfite from western hemlock (shipment No. 3333), 5 percent clay, and has a pH of 7.
No. 4303 consists of 50 percent of a commercial groundwood pulp made from a mixture (1/3 Lake States aspen and 2/3 spruce--shipment No. 4018) and 50 percent commercial bleached sulfite from western hemlock (shipment No. 3333), 5 percent clay, and has a pH of 5.0.

[2] 500-sheet ream, 25 by 40 inches.

[3] Composed of 60 percent bleached groundwood pulp made of a mixture (1/2 spruce and 1/2 Lake States aspen), 40 percent of a mixture of bleached softwood chemical and hardwood semichemical pulps, and clay filler.

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- 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
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- List of publications on Wood Finishing
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- Partial list of publications for Furniture Manufacturers, Woodworkers and Teachers of Woodshop Practice

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