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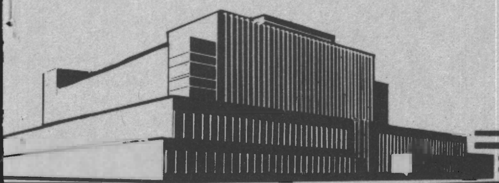

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UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
In Cooperation with the University of Wisconsin

PULPING AND PAPERMAKING EXPERIMENTS ON REDWOOD

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Summary

Old- and second-growth redwood (Sequoia sempervirens) were digested by the sulfate pulping process by normal procedures, but the yields of pulp (35.6 and 40.7 percent by weight, respectively) were lower than that obtained from Douglas-fir cooked to the same permanganate number. The yield of redwood pulp was also low on a volume basis (pounds of pulp per cubic foot of wood) because of its low density. The sulfate pulps were bleached in a six-stage process (using oxidative extraction in the second stage) with a total chlorine consumption of about 11 percent of the unbleached pulp. The initial brightness of the bleached pulp was about 84 percent. The redwood pulps had excellent strength. The pulp made from the second-growth wood was stronger than that made from the old-growth material in all properties except in tearing resistance.

The unbleached redwood pulps were used in making bag paper and linerboard. The bleached pulps were used in making milk carton stock, and bond, offset book, greaseproof, and filter papers.

The redwood pulps were used alone and also mixed with experimentally made Douglas-fir pulp. The paper generally had good properties for the intended product. Except for improving the tearing resistance, the addition of Douglas-fir pulp did not contribute appreciably to the quality of the paper.

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

Wood

Samples of old- and second-growth redwood (*Sequoia sempervirens*) from northern California were used in the experiments. Sections were cut from representative 4-foot slabs for density determinations. The debarked wood was converted to chips of nominal 5/8-inch length and screened to remove material passing a 1/4- by 1/4-inch sieve and that retained on a sieve 1-1/4 by 1-1/4 inches. The chemical analysis was made on samples of the chips used for pulping.

The wood density and chemical analysis are given in table 1. Redwood is a low-density wood and has a high lignin content compared to some other softwoods used for pulping, for example, Douglas-fir. These characteristics indicate that the yield of pulp obtained will be correspondingly lower on a volume basis, as well as on a weight basis.

Sulfate Pulping

Both the old- and second-growth materials were cooked with a total chemical of 24.84 percent, sulfidity of 25 percent, and an active alkali of 19.38 percent. The liquor-wood ratio was 6.5 to 1. The maximum temperature was 160° C., time to maximum temperature, 180 minutes, and total time, 390 minutes. The results of the pulping tests are given in table 2.

The old-growth redwood gave a low yield of 35.6 percent. The yield of 40.7 percent obtained from the second-growth wood was about 5.6 percent lower than that obtained from a sample of Douglas-fir from the same area cooked to about the same permanganate number. The bursting strength, folding endurance, and breaking length of the unbleached redwood pulps were better than those of the Douglas-fir pulp. The redwood pulps were appreciably lower in tearing resistance than the Douglas-fir pulp. The strength of the unbleached old-growth redwood pulp was a little better in tearing resistance, but otherwise was not quite so good as that of the second-growth pulp.

Bleaching

The redwood pulps having permanganate numbers of about 24 (table 2) were bleached in a six-stage process using oxidative extraction in the second stage and hydrogen peroxide in the sixth. The total chlorine equivalent applied for bleaching was 12 percent, and the amount consumed was 11 percent of the moisture-free weight of pulp. The initial brightness of the bleached pulps was about 84 percent. The brightness recession averaged 5.4 percentage points after heating the air-dried sheets for 1 hour at 105° C.

The yield of bleached pulps was relatively low at about 92 percent of the unbleached pulps. The yields of bleached pulp based on moisture-free wood would therefore be about 33 percent for the old-growth wood and 37 percent for the second-growth material. The strength retention on bleaching was about 90 percent, on the average, for the pulp made from the old-growth wood and essentially 100 percent for the second-growth redwood pulp.

The bleached redwood pulps prepared from wet unbleached pulps were better in strength than three commercial, machine-dried, bleached sulfate softwood pulps (except tearing resistance in one instance) as shown in the following tabulation. The data were interpolated from beater test data at 250 milliliters, Canadian Standard freeness.

Sulfate pulp	Bursting strength	Tearing resistance	Folding endurance
	(Pts. per lb. per rm.)	(Gm. per lb. per rm.)	(Double folds)
Redwood:			
Old-growth	1.32	1.84	1,930
Second-growth	1.58	1.60	2,740
Commercial:			
A, mainly Douglas-fir; some western hemlock	1.15	1.33	1,035
B, about 80 percent Douglas-fir and 20 percent western hemlock	1.27	1.97	1,840
C, southern pine.	1.08	1.55	850

Papermaking

The unbleached redwood pulps were used in bag papermaking and linerboardmaking experiments. The bleached pulps were used in making milk carton stock, and bond, offset book, greaseproof, and filter papers. Some of the papers and boards were made entirely from the redwood pulps. In the others, the pulps were mixed with experimental Douglas-fir sulfate pulp and/or a commercial hardwood sulfate pulp. The properties of the various papers and boards are given in tables 3 and 4 with, in some cases, typical data for the commercial products for comparison.

Bag Paper

Bag paper weighing about 50 pounds (on the basis of a ream 24 by 36 inches, 500 sheets) was made entirely from the redwood pulps and from mixtures of 50 percent redwood pulp and 50 percent experimental Douglas-fir pulp. These were compared with bag paper made entirely from the Douglas-fir pulp and a commercial bag paper made from southern pine kraft (table 3).

The papers made from 100 percent redwood pulp of either growth type (machine runs Nos. 4634, 4635, 4636, and 4637) had surprisingly good strength properties compared to the commercial sample. Their air-resistance values were, however, relatively high for this kind of paper. The papers made from the second-growth redwood pulp were stronger in bursting, tensile, and folding properties but weaker in tearing resistance than the papers made from the old-growth redwood pulp. The redwood pulp papers were stronger than papers made entirely from the Douglas-fir pulp, except in tearing strength. The paper made from the old-growth redwood pulp was equal to the Douglas-fir paper in formation, and that made from the second-growth redwood pulp was noticeably better in this property.

Mixing 50 percent of the Douglas-fir pulp with 50 percent of the redwood pulps (runs Nos. 4638, 4639, and 4663) raised the tearing strength and lowered the air-resistance value, as compared with papers made entirely from the redwood pulps.

Linerboard

Forty-two-pound linerboards (basis 1,000 square feet) were made from a mixture of equal parts of the old-growth redwood sulfate pulp and experimental Douglas-fir sulfate pulp. The boards were a little lower in all strength properties than the average of three commercial southern pine kraft linerboards (table 3). Jordaning the stock made little change in the properties of the board. The boards were slightly darker in color than many commercial linerboards, but some tests (not reported here) have indicated the color can be improved a little by modifying the cooking conditions.

Milk Carton Stock

Milk carton stock weighing about 230 pounds per 3,000 square feet was made from the bleached redwood sulfate pulps. Like the bag papers, these boards had surprisingly high strength properties (table 3). Higher strength values were obtained with the second-growth pulp than with the old-growth pulp. However, the various properties of both boards were equal to, or higher than, those of commercial milk carton board save in air resistance, where the commercial board had a much lower value.

Board made from a mixture of old-growth redwood pulp with an equal amount of Douglas-fir pulp (run No. 4647) was not appreciably different from the board made from the redwood pulp alone (run No. 4646), except in air-resistance value. Boards made from mixtures of 15 percent of old-growth redwood pulp and 85 percent Douglas-fir sulfate pulp were lower in nearly all properties than the board made from the 50-50 mixture of these pulps or the commercial board.

Bond Paper

The old-growth redwood bleached sulfate pulp was used in making 20-pound bond paper (ream 17 by 22 inches, 500 sheets). A paper (run No. 4657, table 4) was made with 32.5 percent of the redwood pulp, 32.5 percent of an experimental Douglas-fir bleached sulfate pulp, and 35 percent of a commercial hardwood bleached sulfate pulp. Though lower in bursting strength and tensile strength than a commercial bond paper used for comparison, it had higher tearing resistance and folding endurance. This paper was surface coated at the size press with a high-viscosity substituted starch (run No. 4658). The coated paper was improved in bursting, tensile, and folding strength in comparison to the uncoated paper. Its bursting strength was within the range of that of a No. 1 bond paper.

Two bond papers were made in which 65 percent of the furnish was old-growth redwood sulfate pulp and 35 percent was commercial hardwood sulfate pulp. The furnish for machine run No. 4648 was unjordaned, and that for machine run No. 4649 was jordaned. These papers were equivalent to, or better than, the commercial bond paper in most strength properties, but they lacked the good formation of high-quality bond.

Offset Paper

An offset book paper (machine run No. 4659, table 4) was made from 50 percent of the old-growth redwood bleached sulfate pulp and 50 percent of the commercial hardwood sulfate pulp. It was equivalent to a commercial offset book paper in most properties. Its most noticeable defect was poorer formation than the commercial product.

Greaseproof Paper

The second-growth redwood bleached sulfate pulp was beaten to 130 milliliters, Schopper-Riegler freeness, and made into 30-pound greaseproof paper. The paper had a high turpentine penetration value, indicating good grease resistance, and gave a good "blister" when subjected to a heat blister test.

Filter Paper

The redwood pulp fiber appeared to be suitable material for making porous paper such as filter papers. One run was made using the old-growth bleached pulp. For this trial a special headbox for forming paper from a highly dilute suspension was used. A porous web was made from unbeaten pulp. The sheet had a density of 0.35 gram per cubic centimeter and had exceptionally good formation and high dry and wet web strengths, considering the fiber length and unbeaten condition of the stock. The appearance of the sheet indicated the possibilities of the redwood fiber in filter and other porous paper products.

Table 1.--Chemical composition and density of redwood

Characteristic	Old growth (Shipment 4154)	Second growth (Shipment 4155)
Density (moisture-free weight and green volume) .... lb. per cu. ft.	22.3	21.5
Lignin .... percent	33.3	33.1
Holo-cellulose .... percent	55.1	60.5
Alpha-cellulose .... percent	42.6	45.7
Pentosans .... percent	7.2	7.2
Solubility in:		
Alcohol benzene .... percent	9.9	0.4
Ether .... percent	0.8	0.1
1 percent sodium hydroxide .... percent	18.8	13.9
Hot water .... percent	8.7	5.1
Ash .... percent	0.1	0.1

Table 2.--Results of sulfate pulping tests

Item	On redwood		On Douglas-fir
Type of growth	Old growth	Second growth	Old growth
Digestion No.	[1]1-4165	[1]1-4167	4153
Chemicals consumed ... percent	48.1	60.6	...
Yield (moisture-free wood basis):			
Screened pulp ... percent	35.6	40.7	43.1
Screenings ... percent	0.0	0.1	0.4
Permanganate number	23.2	24.5	24.1
Strength of unbleached pulp[2]			
Bursting strength ... pts. per lb. per rm.	1.47	1.68	1.26
Tearing resistance ... g. per lb. per rm.	1.83	1.52	2.60
Folding endurance ... double folds	2,060	2,160	1,000
Breaking length ... m.	10,300	12,400	8,600

[1]Cooking conditions were:

Sodium hydroxide	28.85 grams per liter
Sodium sulfide	9.37 grams per liter
Total chemical	24.84 percent of moisture-free wood
Active alkali	19.38 percent of moisture-free wood
Liquor-wood ratio	6.5:1 by weight
Sulfidity	25 percent
Maximum temperature	160° C.
Time to maximum temperature	180 minutes
Total time	390 minutes

[2]Beater test data values interpolated at a 450-milliliter Canadian Standard freeness.

Table 3.--Properties of bag paper and boards containing redwood sulfate pulp

Machine run No.	Redwood sulfate pulp[1]: Type of growth[2]	Redwood sulfate pulp[1]: Amount	Other pulp[1]: Kind	Other pulp[1]: Amount	Jordaned	Headbox freeness (Canadian Standard)	Ream weight (25 by 40 in., 500 sheets)	Thickness	Density	Bursting strength	Bursting strength	Average tearing resistance	Average tearing resistance	Average tensile strength	Average folding endurance (M.I.T.)	Air resistance (Gurley)	Ring crush: Machine direction	Ring crush: Cross machine direction
		Percent		Percent		Ml.	Lb.	Mils	G. per cc.	Pts.	Pts. per lb. per rm.	G.	G. per lb. per rm.	P.i.w.	Double folds	Sec. per 100 cc.	Lb.	Lb.
							BAG PAPERS[3]											
4636	Old	100	...	...	No	475	59.8	4.4	0.75	40.9	0.68	168.6	2.78	28.4	648	128	...	...
4637	...do...	100	...	...	Yes	405	59.6	4.2	.78	45.2	.76	137.4	2.31	29.9	880	235	...	...
4634	Second	100	...	...	No	385	59.6	3.9	.85	53.7	.92	136.0	2.28	35.6	1,291	277	...	...
4635	...do...	100	...	...	Yes	325	60.1	3.8	.87	55.5	.94	120.4	2.02	38.8	1,273	482	...	...
4638	Old	50	Douglas-fir sulfate[4]	50	No	430	62.9	4.7	.74	40.0	.64	176.5	2.78	26.8	629	73	...	...
4639	...do...	50	...do...	50	Yes	360	63.0	4.6	.76	43.6	.68	170.8	2.69	28.9	667	146	...	...
4663	Second	50	...do...	50	No	495	60.2	4.6	.72	45.8	.75	181.2	2.95	28.5	618	47	...	...
4557	...	...	...do...	100	No	405	60.1	4.4	.76	35.3	.58	153.0	2.55	23.5	327	35	...	...
4558	...	...	...do...	100	Yes	375	64.2	4.6	.77	37.8	.58	177.2	2.69	25.8	535	64	...	...
Commercial southern pine kraft bag paper							58	...	...	39	.67	124	2.14	26.4	...	30	...	...
							LINERBOARD											
4664	Old	50	Douglas-fir sulfate[5]	50	No	550	145.0	10.4	.77	104.3	.71	...	2.24	64.0	...	...	111.2	82.8
4665	...do...	50	...do...	50	Yes	535	151.4	11.0	.76	105.3	.68	...	2.34	61.6	...	...	113.3	83.8
Average 3 commercial southern pine kraft linerboards							146.9	12.5	.65	116.1	.79	...	2.47	66.2	...	...	116.9	86.3
							MILK CARTON STOCK[6]											
4646	Old	100	...	...	No	450	280.0	17.5	.89	121.1	.43	...	1.66	78.7	...	226	...	...
4645	Second	100	...	...	No	530	282.0	18.4	.85	181.2	.64	...	2.34	95.8	...	170	...	...
4653	Old	15	Douglas-fir sulfate[4]	85	No	515	274.1	18.9	.80	95.8	.35	...	1.13	66.4	...	56	...	...
4647	...do...	50	...do[7]	50	No	505	271.0	18.6	.81	118.2	.43	...	1.58	78.1	...	90	...	...
Commercial board							261.0	17.6	.82	116.7	.45	...	2.46	...	...	58	...	...

[1]Unbleached unless otherwise noted.

[2]Old-growth wood, Digestion No. 1-4165; second-growth wood, Digestion No. 1-4167.

[3]Papers sized with 1.5 percent rosin.

[4]Digestion No. 1-4157.

[5]Mixture of Digestions 1-4153 and 1-4154.

[6]Pulps bleached and papers sized with 2.0 percent rosin.

[7]Digestion No. 1-4154.

Table 4.--Properties of white papers containing redwood sulfate pulp

Machine run No.	Redwood sulfate pulp[1]: Type of growth	Redwood sulfate pulp[1]: Amount	Other pulp: Kind	Other pulp: Amount	Jordaned	Headbox freeness (Canadian Standard)	Ream weight (25 by 40 in., 500 sheets)	Thickness	Density	Bursting strength	Average tearing resistance	Average tensile strength	Average folding endurance (M.I.T.)	Air resistance (Gurley)	Brightness (G.E. equivalent)	Ash content	Castor oil penetration	Opacity
		Percent		Percent		Ml.	Lb.	Mils	G. per cc.	Pts. per lb. per rm.	G. per lb. per rm.	P.i.w.	Double folds	Sec. per 100 cc.	Percent	Percent	Sec.	Percent
BOND PAPER[2]																		
4657	Old	32.5	Douglas-fir sulfate[3]	32.5	No	300	55.1	3.4	0.90	0.33	1.52	16.2	82	85	83.2	4.2	103	80.3
			Commercial broad-leaved sulfate	35.0														
[4]4658	....do....	32.5	Douglas-fir sulfate[3]	32.5	No	300	60.1	3.5	.95	.38	1.46	22.2	175	194	82.5	3.9	246	80.7
			Commercial broad-leaved sulfate	35.0														
4648	....do....	65.0	.....do.....	35.0	No	235	51.9	3.0	.96	.45	1.43	16.4	80	239	83.0	3.6	166	78.2
4649	....do....	65.0	.....do.....	35.0	Yes	180	53.6	3.1	.96	.45	1.26	18.9	105	479	82.8	4.7	443	80.0
Commercial bond paper							52.5	3.8	.76	.44	1.19	22.0	48	42	76.6	8.3	60	86.7
OFFSET BOOK PAPER[5]																		
4659	Old	50.0	Commercial broad-leaved sulfate	50.0	Yes	275	55.5	3.9	.79	.43	1.41	18.7	57	247	85.2	14.7	523	89.5
Commercial offset book paper							52.5	3.4	.85	.50	1.04	23.9	81	109	75.4	18.0	131	90.5
GREASEPROOF PAPER																		
[6]4660	Second	100.0	....	....	No	....	31.5	1.8	.97	.70	.65	16.6	1,590	....	69.0	....	....	......
FILTER PAPER																		
4666	Old	100.0	....	....	No	....	30.5	4.8	.35									

[1] Old-growth wood, Digestion No. 1-4165; second-growth wood, Digestion No. 1-4167.

[2] Pulps bleached and papers sized with 1.5 percent rosin and filled with 5 percent clay.

[3] Digestion No. I-4154.

[4] Coated at size press with solution of cooked starch.

[5] Pulps bleached and papers sized with 1 percent rosin and filled with 15 percent clay and 5 percent titanium dioxide.

[6] Paper had a turpentine penetration value of over 1,800 seconds and responded well to a heat-blister test.