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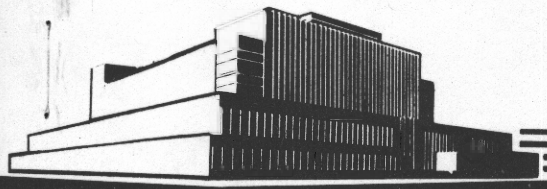

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FOREST SERVICE
In Cooperation with the University of Wisconsin

GROUNDWOOD AND SULFATE PULPING AND NEWSPRINT PAPERMAKING EXPERIMENTS ON ENGELMANN SPRUCE

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Summary

Experiments with Engelmann spruce wood from living trees and from beetle-killed trees that had been dead for at least 25 years demonstrated that a newsprint paper well above average in strength and brightness can be made from groundwood and semibleached sulfate pulps produced from this species.

Introduction

Interest in the development of a pulping industry in the Rocky Mountain region, with Engelmann spruce as the principal pulpwood, as well as the interest in the use of this species by Lake States pulp mills, has prompted the Forest Products Laboratory to verify and extend former work on the pulping of Engelmann spruce. This report presents the results of groundwood and sulfate pulping and newsprint papermaking experiments on live-cut and beetle-killed wood.

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

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Description of the Wood

The samples of Engelmann spruce used in these experiments were obtained from a shipment of wood from living trees on the Flathead National Forest in Montana and from a shipment of beetle-killed wood that had been standing dead for at least 25 years on the Aquarius Plateau in Utah. A sample of white spruce from Michigan was used for comparison with the Engelmann spruce groundwood pulps.

Certain physical characteristics of these samples of wood are given in table 1 with, for comparison, some data on Engelmann spruce from other localities previously tested for sulfate pulping.

The beetle-killed wood from Utah contained only 11 percent of moisture (based on weight of wood and moisture). Only a little bark adhered to the logs when they were received. Some blue stain was present in almost every log, about 16 percent by volume of the entire shipment being infected. Although all the logs contained some incipient decay (ranging from 1 to 15 percent, by volume) that had discolored but not softened the wood, the decayed wood amounted to only 4. 8 percent by volume for the whole shipment. Only one log contained a spot of advanced decay that had softened about 1 percent of the log by volume.

The density of the wood from Montana, based on its moisture-free weight and volume when green, was a little higher than that of the white spruce from Michigan. However, the density of the Michigan spruce was in the lower range of that common for white spruce. The Utah and Colorado samples of Engelmann spruce were lower in density than the Montana and Oregon samples. The lower density of Engelmann spruce is offset by its thin bark, or absence of bark on the dead wood, and its large size, so that the volume of wood per cord is relatively high. Consequently, the weight of wood and yield of pulp on a cord basis are comparable to those of other spruces.

A chemical analysis of the Engelmann spruce is presented in table 2. The differences between the samples are within the normal variation of these constituents in spruce wood.

Groundwood Pulping Experiments

The experimental grinder used had three pockets 16 inches wide and took blocks of wood 6 inches long. The pulpstones were 54 inches in diameter and 8 inches in width. Several types of stones were used in these experiments. The stones are described in table 3 along with the other grinding conditions. The pulps were screened through a flat-plate screen with slots 0.008 inch wide. Pulp test sheets of about 115 pounds per standard ream (25 by 40-500) were made from the screened pulp and were tested by TAPPI standard tests.

Green Wood

The green Engelmann spruce and the white spruce were ground under comparable conditions. Samples of each were ground on a dull stone (grinder runs 393 and 394, table 3) and on a sharp stone (grinder runs 395 and 396). The runs on the dull stone surface utilized somewhat more than the normal amount of energy, but gave exceptionally strong pulps with slightly lower than normal freeness and average fiber length. With the sharp stone, freer pulps of standard strength were produced at rather low energy consumption. Under the same conditions, the two species gave pulps of about the same strength. It is concluded, therefore, that Engelmann spruce and white spruce of about the same density may be ground similarly to produce similar pulps.

Beetle-Killed Wood

The dry wood seemed to be very sensitive to pressure changes below a pressure of 20 pounds per square inch. Increasing the grinding pressure from 15 to 20 pounds per square inch (runs 869 and 871) caused a large increase in freeness and greatly decreased the strength and energy consumption. Increasing the pressure further to 35 pounds (run 870) raised the freeness only slightly, however, and the decrease in strength and energy was proportionately less than that between 15 and 20 pounds. These test runs indicated that, for the surface on the aluminum oxide stone, a grinding pressure of between 15 and 20 pounds per square inch might produce pulp of satisfactory strength in the desired freeness range at reasonable energy consumption. Therefore, run 872 was made at 18 pounds of pressure to produce pulp for a paper machine run.

Run 873 was made with the same grinding pressure as run 872, but the 6-inch blocks used had been soaked in water for 5 days. The effect attained by soaking the wood was to produce a pulp with higher strength and freeness and containing longer fibers than pulp obtained from the dry wood. This pulp was about equal in strength to those produced from dry wood (runs 871 and 874) with somewhat higher energy consumption and much lower freeness.

The pulp made from the dry wood in grinder run 872 was a little higher in freeness than that usually used to make newsprint paper. Therefore, tests were made with a sandstone installed in the grinder in an effort to produce a more satisfactory pulp with a freeness between 90 and 100 cubic centimeters Canadian Standard. The pulp made in grinder run 874 was too low in freeness, however, and too high in energy consumption. Tests indicated that a mixture of 23 percent of this pulp and 77 percent of pulp from run 874 would have a freeness of about 90 cubic centimeters, which is in the desired range. Other properties of this mixture are given in table 3. It had about the same bursting and tensile strength as pulp from run 874, but it was a little higher in tearing strength.

Three groundwood pulps made from beetle-killed wood were used for papermaking trials. The pulps ranged in freeness from 50 to 130 cubic centimeters and all had bursting and tensile strength values equal to or higher than the average of a number of commercial newsprint groundwood pulps tested at the Laboratory. The tearing strength of the pulp obtained from dry wood was lower, however. The energy consumption in run 872 was about normal for newsprint grade, but for the other pulps it was a little high. All of the pulps were of highly acceptable quality for papermaking.

The woods from live and beetle-killed trees are of equal value for groundwood pulping if the differences in the moisture content of the wood, the kind of grindstone, and the other experimental conditions are considered.

Sulfate Pulping Experiments

The beetle-killed Engelmann spruce was used to make the sulfate pulp used in the newsprint paper experiments.

Cooking Conditions and Procedure

The digestions were made in a 14-cubic-foot tumbling steel digester heated indirectly with steam. The active alkali charged per 100 pounds of moisture-free wood consisted of 15.86 pounds of sodium hydroxide and 6.64 pounds of sodium sulfide, which gave a total of 17.57 pounds in terms of sodium oxide. The initial concentration of the active alkali in the cooking liquor in the digester, including the moisture in the chips and calculated as sodium oxide, was 43.93 grams per liter. The sulfidity based on the active alkali of the cooking liquor was 30 percent. The total volume of cooking liquor, including the moisture in the chips and the water charged, was 48 gallons per 100 pounds of moisture-free wood, or an equivalent liquor-to-wood ratio by weight of 4 to 1.

A maximum cooking temperature of 170° C. (equivalent to a gage pressure of 100 pounds per square inch) was used. The time from 30° to 170° C. was 1.5 hours and the time at 170° C. was 1.5 hours. At the end of the cooking schedule, the pulp was blown from the digester under a pressure of 100 pounds per square inch, washed with water, screened through 8-cut plates (0.008 inch in width), and run over a wet machine.

The density of the black (spent) liquor at 15° C. was 11.6° Baume, and 75.7 percent of the chemicals originally charged were consumed during cooking. The yield of screened unbleached sulfate pulp on a moisture-free basis was 44.8 percent, and that of screen rejects was 0.5 percent based on the wood. The permanganate number of the pulp was 19.

From the results of the TAPPI Standard beater test given in table 4, the strength of the unbleached sulfate pulp was more than adequate for a newsprint furnish. The pulp was higher in bursting strength and lower in tearing strength than most commercial softwood unbleached kraft pulps.

The cooking conditions used previously for digestions of green Engelmann spruce from Oregon and of beetle-killed Engelmann spruce from Colorado were not exactly the same as those outlined for the Utah wood, but they were close enough to allow the following general comparison: (1) The screened pulp yield and the chemical consumption obtained by cooking the beetle-killed Utah wood were close to those obtained for the beetle-killed wood from Colorado, but lower than those obtained for the green spruce from Oregon. (2) The amount of screen rejects was about the same for both the Utah and the green wood. (3) Because of the tendency of dry chips to pack less densely than green chips, the dry condition of the beetle-killed Utah spruce would probably cause a lower charge of wood per unit of digester space.

Bleaching of the Sulfate Pulp

The sulfate pulp for the paper machine runs was bleached (bleach 2148) to a brightness of 76 percent (G. E.) in three stages with 6. 5 percent of chlorine in the chlorination stage, 2 percent of caustic soda for extraction, and 1. 6 percent of chlorine as calcium hypochlorite in the third stage. The yield, based on unbleached pulp, was 92. 6 percent.

In table 4 it is shown that the unbeaten pulp was improved in tearing strength but lowered some in freeness, bursting strength, tensile strength (breaking length), and folding endurance by bleaching. However, the folding endurance of the bleached pulp was considerably higher than that of the unbleached pulp after the pulps were beaten. These results indicate a loss in hemicelluloses rather than an oxidation of the cellulose. The loss in hemicelluloses and, consequently, the loss in bursting and tensile strength might be minimized by omitting the caustic soda extraction stage of the bleaching process.

Newsprint Papermaking Experiments

Green Wood

On the basis of the pulp tests, both of the groundwood pulps made from the green Engelmann spruce were satisfactory for production of newsprint. The pulp produced on the duller stone surface (grinder run 394) could also be used in book and magazine paper containing groundwood. This groundwood pulp and the white spruce pulp made under similar conditions (grinder run 393) were each run 100 percent into newsprint-type papers -- that is, without chemical pulp. The data in table 5 (paper machine runs 1790 and 1791) show that their strength compares quite well with that of commercial newsprint papers. Although the tearing strength of the Engelmann spruce papers is lower, the bursting and tensile strength values are higher than those of the average newsprint paper.

These runs are of interest from an experimental point of view. It is not likely that a furnish consisting only of groundwood pulp could be run at the higher speeds required for economical operation of a commercial newsprint machine. The addition of chemical pulp would also be desirable for the improvement it would give to the tearing strength.

Beetle-Killed Wood

The newsprint papers made from the beetle-killed wood were composed of 80 and 85 percent groundwood pulp and the remainder of semibleached sulfate pulp. One-half of one percent of rosin size and an amount of alum sufficient to maintain a whitewater pH of about 5 were used. No dye was added. The 3 groundwood pulps were used for separate machine-run furnishes. In a fourth machine run, the furnish contained a mixture of groundwood pulps, Nos. 872 and 874.

The furnishes and properties of the papers are given in table 6. Paper from machine run 3327, which contained 80 percent of groundwood pulp 872, had good strength properties. It is probable that the amount of this groundwood pulp could have been increased with satisfactory results as far as strength is concerned. This is indicated by the results obtained in machine run 3329, containing 85 percent of the groundwood mixture, most of which consisted of groundwood pulp 872. The groundwood pulp used in machine run 3330 had been made from the water-soaked wood and was a little stronger than the others. Its better strength slightly improved the strength of the newsprint paper.

The strength and brightness of all the papers were equal to or higher than the average of commercial newsprint. The natural color of the papers was slightly yellow. If the yellowish tint is objectionable, it could be easily masked by the addition of a little blue dye. The opacity of all the papers was fairly good, but they did not absorb castor oil as well as the commercial papers.

Table 1.--Physical characteristics of Engelmann spruce and white spruce pulpwoods

Wood	Shipment No.	Diameter	Age	Rate of growth	Density[1]
		In.	Years	Rings per in.	
ENGELMANN SPRUCE					
Beetle-killed wood from Utah	3030	12.7	223	33.7	19.0
Green wood from Montana	1509	11.4	88	15.5	22.4
Green and dead wood from Colorado[2]	2466	10.8	68	12.5	19.2
Green wood from Oregon	2659	9.3	145	31.5	22.5
WHITE SPRUCE					
Green wood from Michigan	1571	9.8	53	10.9	21.6

[1] Weight when ovendry and volume when green.

[2] This shipment consisted of wood from 5 living and 25 beetle-killed trees.

Table 2.--Chemical composition of Engelmann spruce[1]

Wood	Shipment No.	Lignin	Holo-cellulose	Alpha cellulose	Total pentosans	Solubility			
						Alcohol-benzene	Ether	Caustic soda (1 percent)	Hot water
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Green wood from Montana	1509	27.9	.....	42.4	12.1	1.3	0.5	8.0	1.7
Green wood from Oregon	2659	26.3	67.9	44.3	9.2	2.8	1.4	12.2	3.7
Beetle-killed wood from Colorado	3049	28.2	67.3	45.2	7.4	1.7	1.1	11.6	1.8
Beetle-killed wood from Utah	3030	27.4	70.7	45.4	8.4	3.5	1.4	10.4	1.3

[1] Percentages based on weight of moisture-free wood.

Table 3.--Groundwood pulping of Engelmann spruce

Grinder run No.	Wood: Dryness	Wood: Amount ground	Grinding data: Pressure of wood on stone[2]	Grinding data: Grinding moisture-free wood per 24 hours[3]	Grinding data: Power input[3]	Grinding data: Energy consumed per ton moisture-free wood	Properties of pulp suspension: Freeness: Schopper-Riegler	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[1]: Bursting strength (25x40-500)	Properties of pulp test sheets[1]: Tearing strength (25x40-500)	Properties of pulp test sheets[1]: Tensile strength	Properties of pulp test sheets[1]: Breaking length	Properties of pulp test sheets[1]: Density	Properties of pulp test sheets[1]: Brightness
	Percent	Lb.	P.s.i.	Tons	Hp.	Hp.-days	Cc.	Cc.	Percent	Percent		Pt. per lb. per rm.	Gm. per lb. per rm.	P.s.i.	M.	Gm. per cc.	Percent
BEETLE-KILLED ENGELMANN SPRUCE FROM UTAH[5]																	
871	89.4	55	15	0.53	49	92	245	45				0.35	0.54	2,250	3,610	0.44	
869	89.4	64	20	.85	53	63	370	115				.22	.45	1,214	2,180	.39	
870	89.4	62	35	3.35	124	37	400	120				.11	.35	836	1,580	.37	
872	88.8	158	18	.85	53	62	400	110	3.9	48.2	0.087	.26	.48	1,680	2,790	.42	56.2
873	63.2[6]	140	18	.69	54	79	420	130	13.0	38.8	.104	.36	.65	2,170	3,660	.42	55.8
874[7]	88.8	91	35	.86	94	110	225	50	5.3	49.1	.085	.34	.50	2,420	3,800	.45	57.4
(8)							300	90	4.3	48.7	.087	.26	.54	1,600	2,810	.40	55.8
LIVE-CUT ENGELMANN SPRUCE FROM MONTANA[9]																	
394	54.2		40	1.67	119	71	305		13.8	44.8	.093	.44	.85	2,790			56
396	54.2		23	1.80	75	42	550		9.8	37.8	.102	.20	.66	1,300			55
LIVE-CUT WHITE SPRUCE FROM MICHIGAN (FOR COMPARISON)[9]																	
393	78.0		40	1.48	111	75	250		10.0	52.2	.084	.49	.89	2,960			58
395	78.0		23	1.58	74	47	460		12.7	34.5	.108	.25	.71	1,420			58
AVERAGE OF 29 COMMERCIAL NEWSPRINT GROUNDWOOD PULPS						65	350		17			.19	.59	945	1,550		52

[1] Basis weight of test sheets was 115 pounds per ream of 500 sheets, 25 by 40 inches.

[2] Actual thrust of pressure foot (determined by calibration of the cylinder pressure) divided by the area (96 square inches) represented by the product of the pocket width and wood length.

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

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

[5] A grinder pit temperature of 150° F., a pit consistency of 3 to 4 percent, and peripheral speed of 3,470 feet per minute were used in all experiments except in run 874 where the peripheral speed was 3,120. An aluminum oxide abrasive pulpstone (A60A1) of 60-grit size was used except in run 874 where a sandstone was used. Both stones had been dressed with 10-cut, 1-1/2-inch lead spiral and 14-point diamond burrs. The aluminum oxide abrasive stone had been used 60 hours since it was burred and the sandstone had been used 3 hours.

[6] The wood was the same as used in runs 869-872 and 874, except that it had been soaked in water.

[7] This run was made on a sandstone as noted in footnote 5.

[8] Mixture of 77 percent pulp from run 872 and 23 percent from run 874.

[9] A silicon carbide stone (3760/5N7) was used. The stone surface was dull for runs 393 and 394 and quite sharp for runs 395 and 396. The pit temperature and peripheral speed were 160° F., and 3,120 feet per minute, respectively.

Table 4.--Summary of results of beater test on Engelmann spruce sulfate pulp

Beating time	Freeness C.S.	Bursting strength	Tearing strength	Breaking length	Folding endurance (M.I.T.)	Density
Min.	Cc.	Pts. per lb. per rm.	Gm. per lb. per rm.	M.	Double folds	Gm. per cc.
UNBLEACHED PULP						
0	650	1.27	1.35	8,700	720	0.72
30	450	1.65	1.01	11,000	930	.89
53	250	1.70	.93	12,300	1,480	.95
PULP BLEACHED TO 76 PERCENT BRIGHTNESS[1]						
0	575	.99	1.93	6,240	521	.71
16	450	1.41	1.06	9,300	1,250	.86
42	250	1.56	.92	9,600	1,800	.98

[1] Bleach 2148

Table 5.--Newsprint paper composed entirely of Engelmann spruce or white spruce groundwood pulps

Machine run No.	Groundwood pulp: Species	Groundwood pulp: Grinder run No.	Groundwood pulp: Jordaning	Weight per ream[1]	Thickness	Bursting strength	Tearing strength	Tensile strength	Brightness (G. E. equivalent)	Castor oil penetration	Opacity	Ash
				Pounds	Mils	Pts. per lb. per rm.[2]	Gm. per lb. per rm.[2]	P.s.i.	Percent	Seconds	Percent	Percent
1790A	Engelmann spruce	394	None	37.5	3.08	0.21	0.41	3,290	56	78	93	1.5
1790B	.....do.....	394	Jordaned	38.2	3.32	.34	.31	3,800	56	109	93	1.0
1791	White spruce	393	None	37.0	3.36	.29	.38	3,580	57	153	91	1.5
Average of commercial newsprint papers				38.0	3.30	.25	.54	2,537	58	50	92	1.0

[1] Standard ream 25 by 40-500. To convert to the newsprint trade ream of 24 by 36-500, multiply by 0.864.

[2] To convert to newsprint trade ream basis, multiply by 1.157.

Table 6.--Newsprint papers made from Engelmann spruce groundwood and semibleached sulfate pulps

Machine run No.	3327	3330	3328	3329	Commercial newsprint[1]
Furnish:[2]					
Semibleached kraft, percent	20	15	20	15	.....
Groundwood, percent	80	85	80	85	.....
Grinder run No.	872	873	874	(3)	.....
Freeness of headbox stock					
Canadian Standard, cc.	130	125	65	100	.....
Tests on paper					
Ream weight (25 x 40-500), lb.	40.0	39.4	39.5	39.8	38
Thickness, mils	4.1	4.0	3.3	3.8	3.3
Density, gm. per cc.	.54	.55	.66	.58	.64
Bursting strength[4], pts. per lb. per rm.	.38	.38	.42	.42	.25
Tearing strength[4], gm. per lb. per rm.	.72	.76	.61	.64	.54
Tensile strength, lb. per sq. in.	2,685	2,847	4,635	3,780	2,537
Castor oil penetration, sec.	88	91	267	126	50
Size No.	.40	.49	.92	.58	.....
Gloss, percent	29.6	33.9	32.6	32.9	41
Porosity, sec.	55	61	303	98	49
Opacity, percent	91.2	88.8	90.4	89.6	92
Brightness (G.E. equivalent), percent	59.4	59.2	59.1	59.2	58

[1] Average of commercial newsprint papers.

[2] Other ingredients 1/2 percent of rosin size and 1 percent of alum.

[3] A mixture of pulps from grinder runs 872 and 874. See table 3, footnote 8.

[4] To convert to the newsprint trade ream basis (24 by 36-500) multiply by 1.157.