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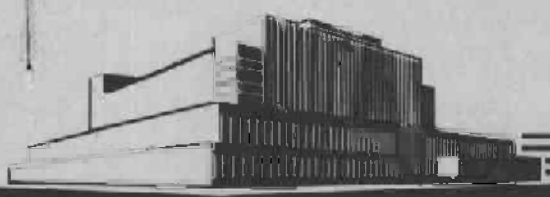
February 1959

No. 2142



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

COLD SODA PULPING OF SOUTHERN OAKS, SWEETGUM AND COTTONWOOD[1]

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Summary

Batch and continuous cold soda pulping methods developed at the U. S. Forest Products Laboratory were used to pulp several southern hardwoods. Pulping characteristics were determined, and the properties of pulps made from these woods were compared.

A mixture of two red oak species, water oak (Quercus nigra L.) and willow oak (Quercus phellos L.), was pulped under various conditions of pressure, time, temperature, and chemical concentration to produce pulps having yields in a range of from 82 to 96 percent. Pulp strength was increased by increasing the time, temperature, or pressure of the caustic soda treatment. Increasing the caustic soda solution concentration above 35 grams per liter lowered the yield and brightness of pulp made at room temperature but had little effect on its strength, which was slightly above that of softwood groundwood. The brightness of pulp bleached in a single stage with 10 percent available chlorine in the form of calcium hypochlorite decreased about 5 percentage points as the caustic soda steeping temperature was increased in a range of from 25° to 89° C.

Pulp suitable for use in printing paper as a substitute for southern pine groundwood was made by treating a mixture of several hardwoods, including red and

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[1] Presented at the 12th Alkaline Pulping Conference, sponsored by the Alkaline Pulping Committee of the Technical Association of the Pulp and Paper Industry, Hot Springs, Ark., September 24-26, 1958.

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

white oaks, gums, and poplar, with caustic soda solutions at room temperature in a digester for either (1) 2 hours at atmospheric pressure or (2) 30 minutes at 150 pounds per square inch. Sweetgum (Liquidambar styraciflua) cold soda pulp was slightly stronger than southern pine groundwood but darker in color. Cold soda pulp made from cottonwood (Populus deltoides) was somewhat stronger and lighter in color than sweetgum cold soda pulp.

Corrugating boards produced from cold soda pulps made in the continuous system from mixtures of (1) water oak and willow oak and (2) red oak and white oak had Concora values of 54.1 and 51.3 pounds, respectively. A somewhat stronger board made from cottonwood cold soda pulp had a Concora value of 77.4 pounds.

Introduction

The importance of hardwoods to the paper industry in the southern States is illustrated by statistics found in the Timber Resources Review of 1958. According to data obtained in 1952, the net volume of hardwoods growing in the South exceeded that of the softwoods by 30 percent. The report also showed that hardwood timber in this section was growing 62 percent faster than it was being cut.[3]

One possible use for more hardwood in the South is in the production of high-yield semichemical pulps that are suitable for use as low-cost partial substitutes for southern pine groundwood and sulfate pulps, and for other products. The commercial success of the cold caustic soda semichemical process in pulping hardwoods during the last 2 years has proven that this method, first developed at the U. S. Forest Products Laboratory in 1949, is a satisfactory means of utilizing a raw material of which there is an abundance, at the same time providing high-yield pulps with improved properties. The fundamental steps in this process include: Treating chips with a sodium hydroxide solution, draining off excess liquor, and fiberizing the softened chips in a disk mill. Cold soda pulps being made by several mills in the United States, as well as mills in Tasmania and Italy, are used in the manufacture of corrugating board, printing papers, and tissue. There are also indications that cold soda pulps can be used satisfactorily in other products, such as toweling and various types of paperboard.

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[3] U. S. Forest Service. Timber Resources for America's Future. Table 9 of Appendix. Forest Resource Report No. 14. Forest Service, U. S. Department of Agriculture.

Although the cold soda process is already being used commercially in the southern States to produce groundwood-type pulps from the oaks and gums, it was important to obtain more information on the pulping characteristics of these and other southern hardwoods, which should lead to improved pulp quality and wider use. Experiments have shown that the oaks and gums respond more slowly to treatments with caustic soda at room temperature and pressure, conditions commonly used in this process, than do hardwoods of lower density and lignin content, such as aspen and birch. Cold soda pulps produced under mild conditions from the more dense hardwoods are generally weaker and darker in color than those made from the more easily pulped hardwoods.

Methods of accelerating the penetration of caustic soda liquor into chips (pre-evacuation, hydrostatic pressure, and mechanical compression) have shown promise in shortening the time and improving the uniformity of treatment in pulping aspen by this process.[4] One of the purposes of the experiments reported here was to determine the possibilities of using these forced-penetration methods for improving the quality of cold soda pulps made from various mixtures of southern oaks and gums. Much of the work was done on a mixture of water oak and willow oak, two species of the red oak group found in the West Gulf Region.

Some of these experiments were designed to determine the possibility of increasing the strength of oak cold soda pulp by increasing the treating temperature above the usual 25° C. Darker pulps were expected as a result of the higher temperature, but it was not known whether or not they would be more difficult to bleach. Another important point considered was that, if stronger and perhaps stiffer pulps could be made from oak by using higher treating temperatures, they very likely would be more suitable than the ordinary pulp for making corrugating medium where the color is not a serious matter.

This study included:

(a) Preliminary batchwise pulping experiments on the mixture of water oak and willow oak using pre-evacuation and hydrostatic pressure impregnation conditions at various temperatures, caustic soda concentrations, and treating times for comparison with standard cold soda steeping at atmospheric pressure.

(b) Continuous pulping trials in a roll-type mill[5] to determine the effects of caustic soda concentration on the pulping characteristics of sweetgum.

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[4] Brown, K. J. and Monsson, W. H. Cold Soda Pulping of Aspen by Improved Methods. Tappi, Vol. 39, No. 8, pp. 592-599.

[5] Brown, K. J. and Hilton, R. D. New-Fast-Continuous Cold Soda Hardwood Pulping Process. Paper Trade Journal, Vol. 10, No. 21, pp. 42-46.

(c) Pilot-plant scale trials in batch and continuous equipment to compare the cold soda pulping characteristics of sweetgum, cottonwood, and mixtures of southern oaks.

(d) Comparison of properties of corrugating boards made from cold soda pulps produced from cottonwood, the mixture of water and willow oak, and a mixture of red and white oaks.

(e) Small-scale bleaching tests, using calcium hypochlorite to determine effects of the temperature and caustic soda concentration during pulping on the brightness and opacity of the bleached pulps.

Experiments

Cold soda pulping trials were made on 3 mixtures of hardwoods and on 2 individual hardwoods. Peeled pulpwood was used in all of the experiments. Except as noted, chips produced in a laboratory chipper were about 1/2 inch long in the fiber direction. Oversized and undersized materials were removed from the chips by passing them over vibrating screens and accepting the fraction that passed through a 1-1/8-inch screen and was retained on a 1/4-inch screen.

Water oak and willow oak pulpwood logs obtained from southwestern Louisiana averaged about 7 inches in diameter and were similar in density, about 37 pounds per cubic foot on the basis of weight when ovendry and volume when green. The average age of the logs was 26 years. The water and willow oak grew at the average rates of 0.30 and 0.24 inch in diameter per year, respectively. Chips prepared from these woods were mixed in the proportion of 4 volumes of water oak to 1 volume of willow oak and stored in moisture-proof containers, so that their moisture content, which was about 30 percent, remained almost constant throughout the trials.

Freshly cut cottonwood, red oak, and white oak pulpwood logs received from the lower Mississippi Valley region varied from 5 to 8 inches in diameter. A mixture of the oaks, prepared by mixing 1 volume of red oak chips with 2 volumes of white oak chips, had a moisture content of 31 percent. The cottonwood chips had a moisture content of 47 percent.

A mixture of chips prepared commercially from hardwoods in the Southeast Region contained approximately equal parts of (1) red oak, (2) white oak, (3) chestnut oak, and (4) a group of less dense hardwoods including several gums and poplar. The average moisture content of this mixture during the pulping trials was 25 percent. Sweetgum chips prepared from pulpwood obtained in the West Gulf Region had an average moisture content of 50 percent.

Pulping

Preliminary trials. --Preliminary cold soda treating experiments on the mixture containing 80 percent of water oak and 20 percent of willow oak were made in stainless steel tumbling autoclaves of 0.8-cubic-foot capacity, which held 9 pounds of chips on the moisture-free basis. The conditions and results of these pulping trials are given in table 1. A reference treatment was made under atmospheric conditions, using a liquor-to-wood ratio of about 4 to 1. Hydrostatic pressure treatments were made by placing 15 pounds of pneumatic pressure per square inch in a reservoir of caustic soda liquor that was connected to the autoclave containing the chips. The liquor-to-wood ratio during the hydrostatic pressure treatments was 5 to 1 (excluding the excess liquor left in the reservoir). In one trial, a vacuum of 26.5 inches of mercury was drawn on the chips before the liquor was introduced under a hydrostatic pressure.

After the caustic soda treatment, the chips were drained free of liquor and weighed to determine the amount of liquor absorbed. They were then immediately fiberized to a coarse pulp in an 8-inch-diameter, single-rotating disk mill. The clearance between the plates in the mill was set at approximately 0.005 inch before each fiberizing run, so that the motor was drawing 6 amperes of current with a constant flow of water between the plates (3.0 gallons per minute) to produce a consistency between the plates of about 2 percent. The electrical energy consumed was used as an indication of the amount of chip softening afforded by the caustic soda treatment.

As shown in table 1, increasing the pressure during a 2-hour steep at room temperature from 0 to 150 pounds per square inch increased by 15 percent the amount of liquor absorbed by the chips, increased the amount of caustic soda used about 15 percent, and decreased by the fiberizing energy requirements 35 percent. Removing the air from the chips prior to the caustic soda steep at 150 pounds per square inch caused further increases in liquor absorption and chemical consumption of 13 and 10 percent, respectively, and an additional decrease in fiberizing energy of 5 percent. The use of hydrostatic pressure and vacuum did not seem to have any significant effect on pulp yield.

Increasing the time of a room-temperature, hydrostatic pressure treatment made with a 35-gram-per-liter caustic soda solution in a range of from 0.5 to 4 hours (1) increased the amount of chemical used in a range of from 3.9 to 10.3 percent, (moisture-free wood basis), (2) decreased the pulp yield in a range of from 94.1 to 89.9 percent, and (3) decreased the fiberizing energy requirements about 35 percent. These results are illustrated by the curves in figures 1 and 2.

Most of the tests were made at room temperature (approximately 25° C.), but, during 1 series of treatments, temperatures of 41°, 60°, and 89° C. were

maintained by indirectly heating the autoclave with steam. As shown in table 1 and in figures 1 and 2, increasing the treating temperature in this range during a 2-hour treatment at 150 pounds per square inch (1) increased the amount of chemical used about 15 percent, (2) decreased the pulp yield in a range of from 92 to 81.6 percent, and (3) decreased the fiberizing energy about 45 percent.

Under constant treating conditions of 2 hours at room temperature and 150 pounds of pressure per square inch, increasing the concentration of the caustic soda solution in a range of from 7.4 to 77.8 grams per liter resulted in (1) increasing the amount of chemical used in a range of from 2.8 to 10.9 percent (moisture-free wood basis), (2) decreasing the pulp yield in a range of from 95.6 to 90.7 percent, and (3) decreasing the fiberizing energy requirements 53 percent, as shown in table 1 and figures 1 and 2.

Preliminary continuous cold soda pulping trials were made on sweetgum chips to determine the effects of chemical concentration on pulp yield and quality. The trials were made by feeding chips into a roll-type refining mill where they were repeatedly compressed between a revolving cylinder and a rotating roll and retained in the presence of the caustic soda solution for about 30 seconds before being discharged in the form of a partially fiberized pulp. About 100 pounds (moisture-free basis) of chips were treated in each of these trials.

The chips were fed into the roll mill at the rate of about 300 pounds per hour. The solids content of the pulp material discharged from the roll mill varied between 20 and 27 percent. The material discharged from the roll mill was held for 30 minutes, then pressed in a 3-section, 7-inch-diameter screw press to a dryness of about 51 percent. The pressed material was fiberized and refined in a double pass in a 36-inch-diameter, double-rotating disk mill. Other conditions and results of these tests are given in table 3.

Results of continuous trials made on sweetgum at room temperature indicated that increasing the caustic soda solution concentration in a range of from 20.3 to 51.5 grams per liter increased the amount of chemical used in a range of from 4.1 to 13.7 percent (moisture-free wood basis) and decreased the pulp yield about 2 percentage points, as shown in table 3. Another result of increasing the amount of caustic soda applied to the chips was to decrease the total amount of fiberizing energy consumed by the roll mill, screw press, and disk mill in a range of from 49.3 to 38.6 horsepower-days per ton of air-dry pulp.

Pilot-plant pulping. --Quantities of cold soda pulps needed for subsequent corrugating board trial runs were made by treating the mixture of water oak and willow oak chips with caustic soda solutions (1) batchwise in a 14-cubic-foot, steam-jacketed digester, and (2) continuously in the roll mill, using optimum

conditions established in preliminary trials and given in table 3. Chips treated both ways were screw pressed, fiberized in a single pass through the 36-inch disk mill, screened through 0.012-inch slotted flat screens, and dewatered on a wet machine. Sweetgum and cottonwood cold soda pulps were prepared in a similar manner by batch treatments in the 14-cubic-foot digester (table 3).

A series of pilot-plant scale batch cold soda treatments were made on the mixture containing approximately equal parts of (1) red oak, (2) white oak, (3) chestnut oak, and (4) a group of gums and poplar to determine the effect of applying hydrostatic pressure during a room-temperature steep in caustic soda. At a given caustic soda concentration of either 30 or 50 grams per liter, approximately the same results, with respect to chemical consumption, pulp yield, and energy consumption, were obtained from treatments made under 150 pounds per square inch of hydrostatic pressure for 30 minutes as were obtained from those made under atmospheric conditions in 2 hours (table 3).

Conditions and results of continuous pulping trials made on cottonwood and a red and white oak mixture in the preparation of pulps used in making corrugating boards are given in table 4. In comparison with the mixture of water oak and willow oak, the amounts of caustic soda used in making the pulps from these species were about in the same range.

Pulp Properties

Pulps prepared from the mixture of water oak and willow oak chips treated in the autoclave were submitted to strength development in a 1.5-pound test beater. Strength tests were made on the pulps in accordance with Tappi Standard Methods, except that 55-pound (ream of 500 sheets, 25 by 40 inches) sheets were used. A portion of each pulp was also refined to a freeness of approximately 300 milliliters (Canadian Standard) by recycling it through the 8-inch disk mill. The pulps refined in this manner were tested for brightness and used in subsequent bleaching trials. The results of these physical tests are given in table 2.

In comparison with a 2-hour steep made on the mixture of water oak and willow oak at atmospheric conditions and a caustic soda concentration of 35 grams per liter, applying (1) a hydrostatic pressure of 150 pounds per square inch and (2) a vacuum before the hydrostatic pressure treatment increased the bursting strength of the pulp at a freeness of 200 milliliters (Canadian Standard) about (1) 25 percent and (2) 40 percent, respectively, without having any significant effect on its tearing resistance and brightness. When the time at room temperature of a hydrostatic pressure treatment made with a 35-gram-per-liter

solution was increased in a range of from 0.5 to 4 hours, the bursting strength was doubled and the tearing resistance of the pulp increased 35 percent, as shown in table 2 and figure 2, without affecting its brightness. At a constant caustic soda concentration of 35 grams per liter, increasing the temperature in a range of from 25° to 89° C. during a 2-hour hydrostatic pressure treatment increased the bursting strength of the pulp 50 percent but decreased its brightness in a range of from 42.3 to 33.8 percent (table 2 and figures 2 and 3). The effect of treating temperature on the properties of the bleached pulp is discussed later.

The effects of increasing the caustic soda solution concentration in a range of from 7.4 to 77.8 grams per liter at constant treating conditions of 2 hours at room temperature and 150 pounds per square inch were (1) to increase the pulp's burst and tear factors approximately 11 and 3.5 times, respectively, and (2) to lower its brightness about 3 percentage points (table 2). As shown by the curves in figure 2, the increases in pulp strength between chemical concentrations of 35 to 78 grams per liter were only slight. A mechanical pulp (No. 3382) made under the same conditions but with water only was no lighter in color than pulps made with caustic soda and its low strength properties were about the same as those of the cold soda pulp made with a 7.4-gram-per-liter caustic soda solution. An attempt to improve the results obtained with a low-concentration caustic soda treatment by increasing the temperature to 60° C. (No. 3372) resulted in somewhat higher pulp strength without loss in brightness. The effect of concentration in pulping this oak mixture is also discussed in the section of this report on bleaching.

The results of studying other variables in the pulping of the water oak-willow oak mixture were: (1) Washing the chips after the caustic soda treatment and before fiberizing (No. 3384, tables 1 and 2) increased the brightness of the unbleached pulp 1.3 percentage points but decreased both the tearing resistance and tensile strength of the pulp; and (2) steaming the chips for 0.5 hour at atmospheric pressure prior to a 1-hour caustic soda treatment at 65° C. produced a pulp as strong and at the same yield but 2.2 percentage points lower in brightness than that produced by a 2-hour treatment at 60° C. without presteaming.

Results of continuous trials made on sweetgum in the roll mill at room temperature showed that increasing the caustic soda concentration in a range of from 20.3 to 51.5 grams per liter approximately doubled the strength properties of the pulps without significantly affecting its brightness (table 3). The strength properties and brightnesses of the sweetgum pulps made by both the continuous and batch methods were about the same as those of pulps made in the pilot-scale equipment from both the water and willow oak mixture and the southern hardwood mixture containing mostly oaks, gums, and poplar using similar chemical concentrations of between 50 and 60 grams per liter (table

3). Cold soda pulp made from cottonwood was somewhat stronger, as shown in table 3, and had a comparatively high unbleached brightness of 51.9 percent.

Boardmaking

Cold soda pulps made continuously from (1) the mixture of 80 percent of water oak and 20 percent of willow oak, (2) cottonwood, and (3) the mixture of 1 part of red oak and 2 parts of white oak, were converted into 26-pound (per 1,000 square feet) corrugating boards on a 13-inch Fourdrinier paper machine. Strength tests on the corrugating boards were made according to standard methods (table 4). In addition, a Concora Medium Tester was used to determine the flat crush resistance of the boards in the corrugated condition.

As shown in table 4, the strength properties, including Concora, for the corrugating boards made from pulps produced from the two oak mixtures were very similar. Their Concora values (54.1 and 51.3 pounds) were somewhat below the commercial range of 70 to 80 pounds, but in ring compression resistances they compared very closely with commercial boards. The board made from the cottonwood cold soda pulp was somewhat stronger than the boards containing the oak mixture pulps, and it had a good Concora value of 77.4 pounds (table 4).

Bleaching

Small-scale calcium hypochlorite bleaching trials were made on selected cold soda pulps prepared from the water oak-willow oak mixture to determine the effects of variations in caustic soda concentration and temperature during pulping on the brightness and opacity of the bleached pulps. Dosages of chemicals and the bleaching conditions are given in table 5. Sodium silicate solution was added to the pulp to minimize strength loss. Caustic soda in amounts approximately proportional to the amounts of hypochlorite was added with the bleach liquor to provide the high alkalinity essential for effective bleaching with hypochlorites. The temperature and consistence, 37° C. and 10 percent, respectively, were in the range usually found in commercial hypochlorite bleaching. The bleached pulps were washed thoroughly before the test sheets were formed.

Bleaching results showed that the brightness of the oak bleached cold soda pulps was roughly proportional to the brightness of the unbleached pulps and that pulps made under favorable steeping conditions can be bleached to about 60 and 70 percent brightness with 6 and 10 percent, respectively, of available chlorine (moisture-free pulp basis). With these dosages, the gain in brightness per pound of hypochlorite applied was higher than with either higher or lower

amounts of hypochlorite. As shown in figure 3, increasing the temperature of the caustic soda pulping treatment in a range of from 25° to 89° C. decreased the brightness of pulp bleached with 10 percent of available chlorine (moisture-free pulp basis) about 5 percentage points. There was no consistent relationship between the concentration of the pulping liquor and final brightness.

Opacity values of test sheets made from the bleached pulps fell within a fairly narrow range and showed no consistent relationship to pulp yield, pulping liquor concentration, or bleached pulp brightness. As found previously,[6] it is likely that the opacity of these pulps was influenced chiefly by such factors as the amount of fine material and the degree of bonding between fibers. The strong influence of the amount of fine material on opacity is shown in table 6. Results of screen classification tests made in a Bauer-McNett Classifier on pulps bleached in pilot-scale equipment showed that, when the amount of fine material in the pulp was decreased from 38.2 percent to 35.6 percent, probably because of losses during washing, its opacity dropped from 86.2 to 82.5 percent. A conventional groundwood pulp included for comparison purposes contained 43.3 percent of fines and had an opacity of 92.7 percent (table 6). This suggests the possibility of increasing the opacity of cold soda pulp to the level of conventional groundwood by increasing its content of fines to 43 percent.

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[6] Brown, K. J. Special Considerations Affecting Improvements in the Cold Soda Pulping Process. Southern Pulp and Paper Manufacturer, Vol. 21, No. 3, pp. 66-76, March 1958.

Table 1.--Batch cold soda pulping experiments on a mixture consisting 80 percent of water oak and 20 percent of willow oak by volume

Treatment No.	Temperature	Time	Sodium hydroxide concentration[1]	Liquor absorbed by chips (original wet wood basis)	Sodium hydroxide used[2] (original moisture-free wood basis)	Fiberizing[3] Energy consumed (per ton of air-dry pulp)	Fiberizing[3] Pulp freeness (Canadian Standard)	Pulp yield
	°C.	Hr.	Gm. per l.	Percent	Percent	Hp.-days	Ml.	Percent
ATMOSPHERIC PRESSURE								
3362	29	2	33.7	51.7	7.7	40.1	620	91.6
HYDROSTATIC PRESSURE AT 150 P.S.I.								
3367	25	.5	34.4	59.1	3.90	34.6	595	94.1
3374	25	1	34.2	67.8	7.46	29.5	650	92.8
3363	25	2	35.1	58.6	8.98	26.1	605	92.0
3384	25	2[4]	35.6	64.0	8.18	25.7	720	88.9
3368	25	4	35.0	63.2	10.26	22.2	675	89.8
3363	25	2	35.1	58.6	8.98	26.1	605	92.0
3365	41	2	35.1	60.5	9.42	23.3	635	92.8
3371	60	2	34.6	60.6	9.93	20.7	705	88.9
3373	265[5]	1	34.1	.....	7.08	24.6	650	89.1
3383	89	2	35.5	51.2[6]	10.20	14.9	745	81.6
3382	24	2	0	52.0	0	32.7	655	96.1
3375	25	2	7.4	63.4	2.75	42.2	560	95.6
3366	25	2	14.7	57.7	5.42	37.5	580	93.7
3398	25	2	24.5	63.6	7.02	28.7	.....	91.5
3363	25	2	35.1	58.6	8.98	26.1	605	92.0
3369	26	2	77.8	59.0	10.90	19.6	635	90.7
3372	60	2	6.4	49.2	2.85	34.4	600	94.4
PREEVACUATION AND HYDROSTATIC PRESSURE AT 150 P.S.I.								
3364	27	2	34.9	64.1	9.87	24.8	625	92.8

[1] Calculated on the basis of all water in the system, including that in the chips.

[2] Includes all of the chemical consumed by reaction, plus that left unconsumed in the chips after treatments made in an 0.8-cubic-foot autoclave.

[3] Conducted in an 8-inch single-rotating disk mill under constant conditions (0.005-inch plate clearance and 2 percent consistency) using plate pattern No. 6946.

[4] Treated chips were washed for 1 hour before fiberizing.

[5] Chips were presteamed at atmospheric pressure for 0.5 hour.

[6] This value is low because of an unavoidable loss of weight by evaporation after treating.

Table 2.--Physical properties of batch cold soda pulps prepared from a mixture consisting 80 percent of water oak and 20 percent of willow oak by volume

Treatment No.	Pulping conditions: Temperature	Time	Sodium hydroxide concentration	Pulp properties (at Canadian Standard freeness of 200 ml.[1]): Beating time	Burst factor	Tear factor	Breaking length	Density	Unbleached brightness[2] (G. E. equivalent)
	°C.	Hr.	Gm. per l.	Min.			Meters	Gm. per cc.	Percent
ATMOSPHERIC PRESSURE									
3362	29	2	33.7	44	18.7	61.7	3,900	0.43	42.5
HYDROSTATIC PRESSURE AT 150 P.S.I.									
3367	26	0.5	34.4	53	13.2	48.5	2,910	.40	41.2
3374	25	1	34.2	39	16.5	52.4	3,000	.43	.....
3363	25	2	35.1	64	23.1	62.5	4,550	.50	42.3
3384	25	2[3]	35.6	55	22.6	53.2	3,800	.46	43.6
3368	25	4	35.0	54	26.4	65.6	4,840	.49	41.2
3363	25	2	35.1	64	23.1	62.5	4,550	.50	42.3
3365	41	2	35.1	60	24.2	61.0	4,780	.48	41.6
3371	60	2	34.6	69	25.9	64.9	4,820	.51	37.7
3373	65[4]	1	34.1	69	26.4	63.3	4,890	.49	35.4
3383	89	2	35.5	76	34.7	57.1	5,600	.58	33.8
3382	24	2	0	60	2.8	15.6	800	.33	41.8
3375	25	2	7.4	28	2.2	18.0	830	.32	41.6
3366	25	2	14.7	54	10.5	42.2	2,240	.38	44.1
3363	25	2	35.1	64	23.1	62.5	4,550	.50	42.3
3369	26	2	77.8	54	24.2	64.1	4,580	.50	39.4
3372	60	2	6.4	56	7.2	34.4	1,470	.34	42.1
PREEVACUATION AND HYDROSTATIC PRESSURE AT 150 P.S.I.									
3364	27	2	34.9	80	26.4	62.5	4,960	.51	42.4

[1] Developed by refining in a 1.5-pound test beater.

[2] After refining to a freeness (Canadian Standard) of approximately 300 milliliters in an 8-inch disk mill.

[3] Treated chips were washed for 1 hour before fiberizing.

[4] Chips were presteamed at atmospheric pressure for 0.5 hour.

Table 3.--Cold soda pulping of several southern hardwoods (pilot-plant scale)

Treatment No.	Method[1]	Treating conditions: Temperature	Time	Pressure	Sodium hydroxide concentration[2]	Sodium hydroxide used[2] (moisture-free wood basis)	Pulp yield	Total energy[4] consumed (per ton of air-dry pulp)	Pulp properties: Freeness (Canadian Standard)	Burst factor	Tear factor	Breaking length	Density	Brightness (G. E. equivalent)
		°C.	Hr.	P.s.i.	Gm. per l.	Percent	Percent	Hp.-days	Ml.			Meters	Gm. per cc.	Percent
						OAK MIXTURE[5]								
4222	Batch	80	2	150	50.0	13.1	86.9	28.6	495	12.7	53.2	1,850	0.42	38.0
KM157	Continuous	58	do.	do.	59.6	12.8	do.	29.0	410	13.2	54.7	1,980	.41	42.0
						HARDWOOD MIXTURE[6]								
4210	Batch	24	2	0	30.0	9.4	92.0	31.4	175	13.2	50.8	2,500	.47	40.8
4211	do.	23	2	0	50.0	12.8	91.9	26.7	235	13.2	50.8	2,320	.47	40.2
4212	do.	21	0.5	150	30.0	9.0	93.5	34.1	150	14.3	45.4	2,525	.46	39.5
4221	do.	26	.5	150	50.0	12.7	89.2	27.8	275	17.1	55.5	3,420	.52	38.5
						SWEETGUM								
4021	do.	26	2	0	54.0	12.9	90.1	22.7[7]	400	14.3	57.1	2,850	.50	40.8
KM172	Continuous	28	do.	do.	51.5	13.7	91.7	38.6	185	16.5	56.3	3,010	.46	41.1
KM181	do.	29	do.	do.	33.9	8.5	92.4	38.9	240	9.4	53.9	2,200	.48	42.6
KM173	do.	29	do.	do.	20.3	4.1	93.9	49.3	110	7.2	33.7	1,700	.40	42.0
						COTTONWOOD								
4118	Batch	30	2	0	57.2	9.4	91.3	do.	500	21.5	80.5	3,410	.56	51.9

[1] Batch treatments were made in a 14-cubic-foot digester. Continuous treatments were made in a roll mill having a 16-inch diameter, 4-foot-long cylinder, using a linear pressure on the inside roll of 120 pounds per inch and a cylinder speed of 260 revolutions per minute. Treated chips were stored approximately 0.5 hour before screw pressing.

[2] Analysis of treating liquor. Does not include the moisture in the chips.

[3] Includes all of the chemical consumed by reaction plus that left unconsumed in the treated chips.

[4] Includes all of the energy consumed during the various stages of fiberizing and refining (roll mill, screw press, and disk mill).

[5] Mixture contained 80 percent of water oak and 20 percent of willow oak, by volume.

[6] Mixture contained approximately equal parts of (1) white oak, (2) red oak, (3) chestnut oak, and (4) a group of less dense hardwoods including poplar and gum.

[7] Chips were not screw pressed before fiberizing in a disk mill.

Table 4.--Properties of corrugating boards made from cold soda pulps produced continuously from southern hardwoods

Treatment No.	Pulping conditions[1]: Temperature	Sodium hydroxide concentration	Sodium hydroxide used (moisture-free wood basis)	Total fiberizing energy consumed (per air-dry ton of pulp)	Board properties: Machine run No.	Headbox freeness (Canadian Standard)	Weight (per 1,000 sq. ft.)	Density	Bursting strength (Mullen)	Tearing resistance (average)	Tensile strength	Average ring compression[2]	Concora[3]
	°C.	Gm. per l.	Percent	Hp.-days		Ml.	Lb.	Gm. per cc.	Pts.	Gm.	Lb. per in. of width	Lb.	Lb.
WATER AND WILLOW OAK MIXTURE[4]													
KM157	58	59.6	12.8	29.0	4960	360	26.1	0.50	33.1	71	30.0	50.3	54.1
COTTONWOOD													
KM127	40	59.2	11.9	19.4	4581	400	26.0	.64	47.8	73	36.0	48.5	77.4
RED AND WHITE OAK MIXTURE[5]													
KM128	42	87.8	11.4	16.3	4585	415	26.0	.47	28.8	66	24.4	49.9	51.3

[1] Continuous trials in a roll mill having a 16-inch-diameter, 4-foot-long-cylinder, cylinder speed, 260 revolutions per minute; linear pressure on roll, 120 pounds per inch.

[2] Test specimen of 1/2 by 6 inches.

[3] Test specimen of 10 A-flutes, 1/2 inch wide.

[4] Mixture contained 4 parts of water oak and 1 part of willow oak, by volume.

[5] Mixture contained 1 part of red oak and 2 parts of white oak, by volume.

Table 5.--One-stage bleaching of mixed southern oak[1] cold caustic soda pulps with calcium hypochlorite

Pulp No.	Caustic soda steep: Concentration	Caustic soda steep: Temperature	Bleach No.	Bleaching treatment[2]: Chemicals applied[3]: Hypochlorite	Chemicals applied[3]: Caustic soda	Chemicals applied[3]: Sodium silicate	Duration	pH	Properties of pulp sheets: Brightness	Opacity[4]	Density
	Gm. per l.	°C.		Percent	Percent	Percent	Min.		Percent	Percent	Gm. per cc.
3382	20[5]	24	Unbleached						42.9		
3382	20	24	3878	6.0	3.0	4.0	25	11.2-10.8	60.5		
3382	20	24	3879	10.0	4.0	4.0	75	11.4-9.1	69.2	79.0	0.25
3375	7.4	25	Unbleached						41.6		
3375	7.4	25	3884	6.0	3.0	4.0	40	11.6-10.0	53.9		
3375	7.4	25	3885	10.0	4.0	4.0	65	11.9-9.8	67.7		
3366	14.7	25	Unbleached						44.1		
3366	14.7	25	3875	6.0	3.0	4.0	40	11.5-10.5	58.4		
3366	14.7	25	3849	10.0	4.0	4.0	45	12.5-8.7	71.9	81.7	.33
3366	14.7	25	3850	15.0	4.0	4.0	55	11.5-8.5	73.1	82.8	.33
3363	35.1	25	Unbleached						42.3		
3363	35.1	25	3872	3.0	2.0	4.0	15	11.4-11.2	47.5		
3363	35.1	25	3873	6.0	3.0	4.0	40	11.5-10.8	56.9		
3363	35.1	25	3851	10.0	4.0	4.0	45	12.2-10.4	66.4	81.3	.38
3363	35.1	25	3852	15.0	4.0	4.0	50	11.9-9.6	71.8	83.6	.35
3369	77.8	26	Unbleached						39.4		
3369	77.8	26	3874	6.0	3.0	4.0	45	11.7-10.9	56.9		
3369	77.8	26	3853	10.0	4.0	4.0	100	12.1-9.1	72.4	81.0	.45
3369	77.8	26	3854	15.0	4.0	4.0	115	12.2-9.4	73.1	80.8	.44
3371	34.6	60	Unbleached						37.7		
3371	34.6	60	3876	6.0	3.0	4.0	50	11.6-10.2	53.3		
3371	34.6	60	3877	10.0	4.0	4.0	100	11.7-10.0	62.6		
3383	35.5	89	Unbleached						33.8		
3383	35.5	89	3880	6.0	3.0	4.0	40	11.5-10.9	51.3		
3383	35.5	89	3881	10.0	4.0	4.0	100	11.7-10.0	61.6	77.0	.35

[1] Eighty percent of water oak and 20 percent of willow oak by volume.

[2] Temperature, 37° C. and consistence, 10 percent.

[3] Based on pulp weight, moisture-free. The percentage of hypochlorite is in terms of available chlorine.

[4] Corrected for a weight of 37 pounds per ream of 500 sheets, 25 by 40 inches.

[5] Water steep.

Table 6.--Screen classification and opacity of bleached cold soda pulps prepared from a mixture consisting 80 percent of water oak and 20 percent of willow oak by volume

Bleach No.[1]	Freeness (Canadian Standard)	Pulp fraction					Brightness (G. E. equivalent)	Opacity	Density
		Retained on 28-mesh screen	Between 28- and 48-mesh screen	Between 48- and 100-mesh screen	Between 100- and 200-mesh screen	Passing through 200-mesh screen			
	Ml.	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Gm. per cc.
BLEACHED COLD SODA[2]									
4268	130	4.2	17.9	26.0	16.3	35.6	65.5	82.5	0.45
4266	85	4.4	14.8	24.1	18.5	38.2	65.5	86.2	.42
COMMERCIAL BLEACHED GROUNDWOOD[3]									
.....	70	3.1	15.7	21.5	14.4	43.3	69.0	92.7	.49

[1] Bleached in a single-stage with 8.0 percent available chlorine in the form of calcium hypochlorite.

[2] Pulp prepared continuously in a roll mill using 8.1 percent of sodium hydroxide (moisture-free wood basis) and refined in 2 passes through a double-disk mill. Total energy consumed was 45.7 horsepower-days per ton of air-dry pulp.

[3] Prepared from a 50-50 mixture of spruce and aspen.

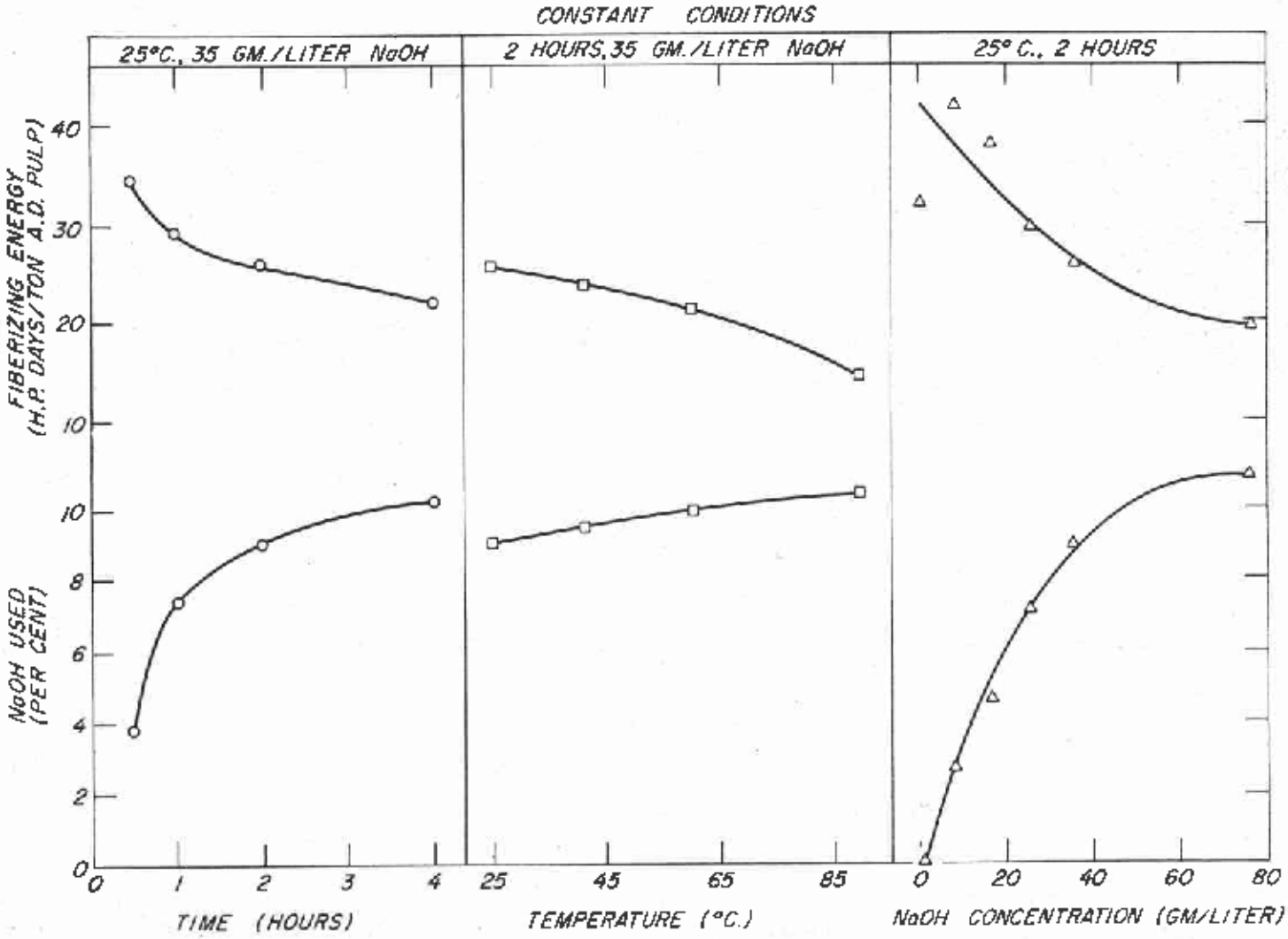

Figure 1. --Relations between the amount of caustic soda used (moisture-free wood basis), fiberizing energy consumption, and treating time, temperature, and chemical concentration in the caustic soda treating of a mixture consisting 80 percent of water oak and 20 percent of willow oak chips at a constant hydrostatic pressure of 150 pounds per square inch.

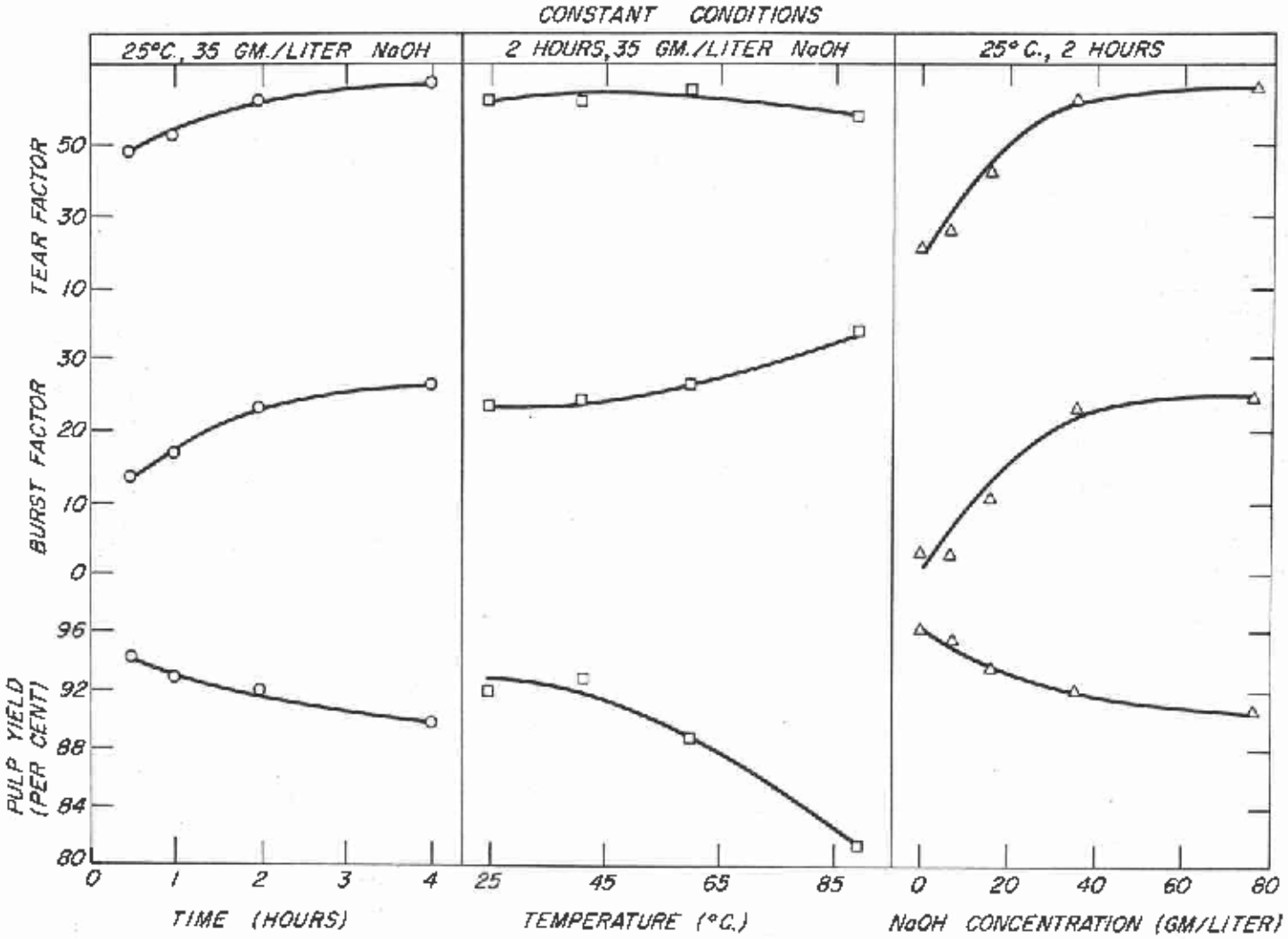

Figure 2. --Relations between pulp yield, burst and tear factors at 200 milliliters Canadian Standard freeness, and treating time, temperature, and chemical concentration in the caustic soda treating of a mixture consisting 80 percent of water oak and 20 percent of willow oak chips at a constant hydrostatic pressure of 150 pounds per square inch.

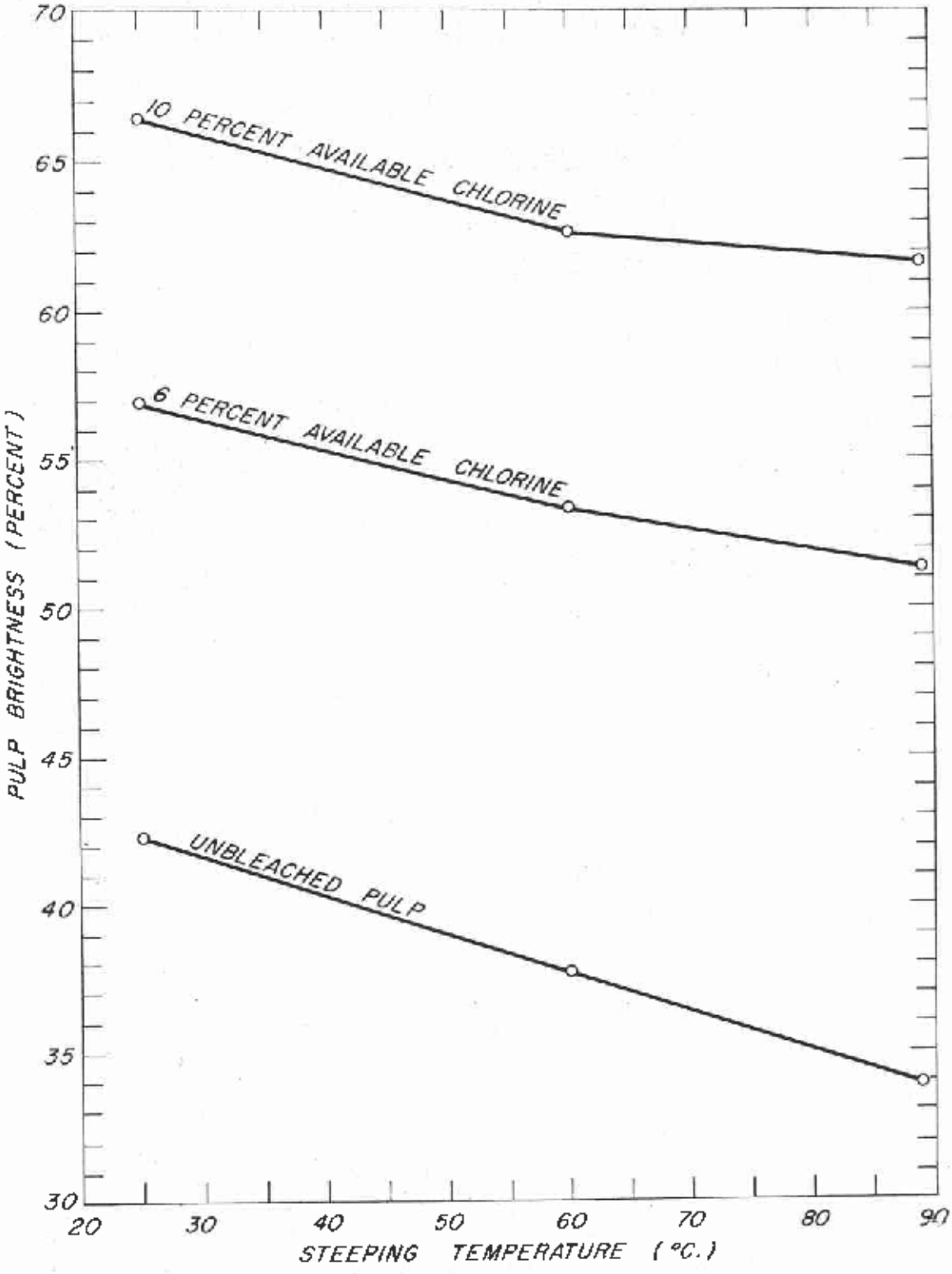

Figure 3.--Influence of caustic soda steeping temperature on the brightness of unbleached and hypochlorite-bleached cold soda pulps prepared from a mixture consisting 80 percent of water oak and 20 percent of willow oak.

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