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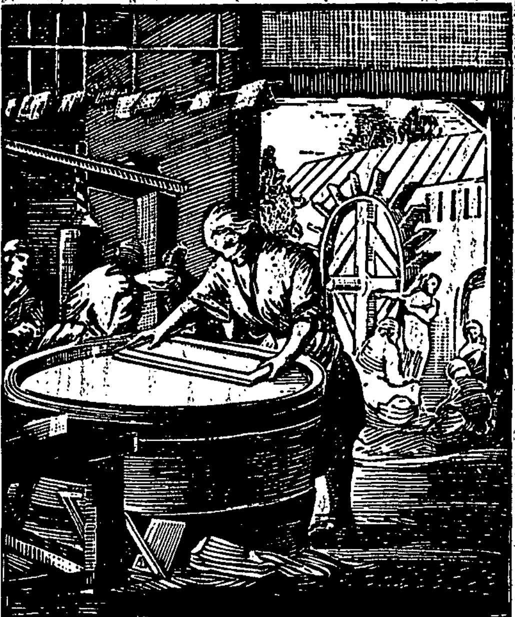

INSTITUTE OF
PAPER CHEMISTRY
Appleton, Wisconsin

IMPROVED BONDING STRENGTH OF GROUNDWOOD FURNISHES

Project 2948

Report Four
A Progress Report
to
MEMBERS OF GROUP PROJECT 2948

December 31, 1974

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Appleton Papers, Inc. — Locks Mill

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

IMPROVED BONDING STRENGTH OF GROUNDWOOD FURNISHES

SUMMARY

Part two of the extended program on Project 2948 was directed to: 1. The uniqueness and economic feasibility of the jet/alkali process for aspen, and 2. The effectiveness of the jet/alkali process for southern pine stone groundwood.

The economic assessment of the jet/alkali process was based on the operation of the Institute's jet cooker under conditions which produced optimum results from aspen stone groundwood. Under these conditions the cost of the process was estimated to be approximately $22-23/ton excluding costs of labor, equipment, etc. This processing cost added to the market cost of groundwood resulted in a figure of $232/ton which would not provide an economic advantage in a typical newsprint furnish normally comprised of 80% of groundwood and 20% of kraft unless the kraft component is reduced to something less than 4%. However, the economics become more favorable in furnishes normally containing less than 80% of groundwood and the advantage should be further enhanced when estimates are based on internal costs of groundwood rather than on market prices as utilized in this study.

Studies concerned with the uniqueness of the jet/alkali process compared the properties of pulps produced by this process with alkaline thermomechanical pulps. In this direction, a series of orientation experiments was conducted to establish suitable conditions for preparing a base-line thermomechanical pulp in water suspension from aspen chips. A laboratory Asplund Defibrator and a 12-inch disk refiner were utilized for this purpose. The maximum fiber consistency commensurate with smooth operation was 15% in the Defibrator and 5-6% in disk

refining. The experimental thermomechanical pulps tended to be low in tear strength and rather extensive refining was required to achieve an acceptable level in tensile properties. A set of processing conditions was selected and thermomechanical pulps were prepared in water suspension and in two concentrations of alkali. The alkali levels were equivalent, in one case, to the addition level utilized in processing a reference chemimechanical pulp in the jet/alkali process and, in the second case, to the same effective alkali concentration used in the jet/alkali process. The reference chemimechanical pulp was jet/alkali treated at 4% consistency utilizing 7.5% of alkali (based on fiber) or, in effect, at 0.3% of alkali in solution. For purposes of comparison a portion of the thermomechanical pulp in water suspension was subjected to the jet/alkali treatment under the aforementioned conditions (4% consistency, 7.5% of alkali). Handsheets were routinely prepared from 80/20 blends of treated chemimechanical or thermomechanical pulp/bleached softwood kraft and from 100% treated mechanical pulps. Reference controls were prepared from 100% kraft, 100% untreated groundwood and from 80/20 and 50/50 blends of untreated groundwood/kraft.

Tensile strength improvements of 30-37% were obtained by jet/alkali treating the reference chemimechanical pulp whereas similar treatment of the thermomechanical pulp produced increases of 61-65%. However, roughly equivalent or notably superior results were obtained by the alkaline thermomechanical treatments. At the same alkali concentration in solution (0.3%), the strength properties produced by thermomechanical treatment were roughly equivalent to those produced by the jet/alkali treatment of the base-line thermomechanical pulp. The alkaline thermomechanical pulp provided an advantage in brightness but at 3% lower yield. When comparisons were made at the same alkali addition level (7.5% based on fiber), the thermomechanical pulp produced papers which no longer resembled conventional groundwood papers but rather a translucent glassinelike web of high density and very low porosity. Under these conditions the yield was 81.9% and the breaking length reached a level of 8.3 km while folding endurance increased to 1460 double folds. These levels were well in excess of those provided by the 100% kraft controls. As would be expected, brightness, opacity, and scattering coefficient were greatly reduced.

The responsiveness of southern pine stone groundwood to the jet/alkali process was examined in a series of experiments utilizing more intense processing conditions than had been used in previous work with softwood groundwood. The southern pine groundwood was processed for six seconds at 5% consistency utilizing 6 and 12% of alkali (based on fiber) at temperatures of 250, 275, and 300°F. The dwell time was increased to 13 sec in one test at 300°F. Maximum strength was obtained at the most intense processing conditions but the level of tensile improvement obtained under these conditions, compared to untreated controls, was only 14.7% for the 80/20 blend of groundwood/kraft and 28.9% for the all groundwood paper. This increment of improvement was not sufficient to raise strength to the level afforded by the 50/50 controls and, therefore, the responsiveness of southern pine was less than that found previously for a northern softwood. Incorporation of sodium sulfite, sodium borohydride, or hydrogen peroxide failed to enhance the effectiveness of the jet/alkali process in contrast to earlier work with aspen stone groundwood.

In review, several methods have been developed under Project 2948 for improving the strength properties of aspen mechanical pulps; however, efforts to improve the properties of softwood groundwood have met with only moderate success. Accordingly, the recommendation is made that the program be extended to permit continued study of means to improve the quality of softwood mechanical pulps.

INTRODUCTION

This is Progress Report Four on Project 2948 concerned with means of improving the bonding strength of groundwood furnishes.

Optimum or near optimum conditions for treating aspen stone groundwood in the jet/alkali process were described in Progress Report Three. In review, processing 5% groundwood for six seconds at 230°F with approximately 6% of alkali (based on fiber) provided the best balance in strength and optical properties. The brightness loss associated with the jet/alkali process was prevented by incorporating 1.2-1.3% of hydrogen peroxide directly into the alkaline pulp suspension prior to jet cooking or by medium density bleaching with approximately 0.8% of peroxide after jet cooking. Some 100% groundwood papers proved as strong or stronger than 100% bleached kraft papers, depending upon the specific treatment. In line with the measured improvements in strength properties, scanning electron photomicrographs subsequently revealed greatly improved plasticity and conformability among fiber elements in the jet/alkali-treated pulp. Some increase in bonding may also have been due to the rupture of fibers which then unfolded to span a greater number of unreacted fiber elements than would normally be attained by a single plasticized fiber ribbon.

A letter survey concerned with the direction of work for the second half of the two-year program was submitted to the membership on May 8, 1974. In general, the responses to the survey were divided and, in consideration of this, a program for continued studies was subsequently formulated as outlined in our letter of July 19. In accordance with the outline, the experimental program is divided into two parts. Part one extends the work with aspen and is primarily directed at establishing the uniqueness of the jet/alkali process through comparisons with chemimechanical and thermomechanical pulps. It was reasoned that, of existing mechanical pulping processes, thermomechanical pulping with alkali would best approximate the jet/alkali process and thus afford a basis for assessing the uniqueness of the jet/alkali process.

The second part of the current experimental program examines the effectiveness of the jet/alkali process for southern pine stone groundwood. Initial work with a softwood groundwood of somewhat uncertain background (1) had indicated rather poor response at lower alkali concentrations and temperatures although the tensile strength attained at higher alkali levels exceeded that of the 50/50 untreated groundwood/kraft controls. Accordingly, the current program explores the effects of higher temperatures and alkali concentrations. Because of budget limitations, the program in both parts was necessarily restricted to a select number of experiments.

As a supplement to the experimental work, consideration is given in this report to the economics of the jet/alkali process for aspen based solely on the materials and energy costs involved in operating the Institute's jet cooker and on the market price of groundwood.

ECONOMIC ASPECTS OF THE JET/ALKALI PROCESS

The following cost estimates for the production of jet/alkali-treated groundwood are based on processing 5% pulp at 230°F with 6% alkali (based on fiber weight) through the Institute's steam jet cooker or, in effect, on those conditions producing optimum results from aspen stone groundwood. As such, the estimates are derived solely from the costs of steam, electric power, and alkali. Costs of manpower, capital investment, amortization of equipment, etc., are excluded as is the recovery of chemicals. The unit cost of mill steam and electric power was based on information provided by several local paper companies.

In arriving at the approximate cost figures, the following parameters were fixed:

Fiber consistency entering jet, %	5
Fiber consistency leaving jet, %	$\cong 4.7$
Temperature of pulp suspension entering jet, °F	68
Steam pressure entering jet (286°F), lb	54.7
Cooking temperature, °F	230
Flow rate through cooker, liters/min	$\cong 2$
Dwell time, sec	6
Driving motor, hp	1
Alkali addition (based on fiber), %	6

COST OF STEAM (C_s)

Based on engineering considerations, it is estimated (2) that the jet/alkali process will require approximately 3.2 lb of steam per pound of fiber or 6400 lb of steam per ton. At a mill rate of $1/1000 lb of steam, the cost of steam (C_s) will be $6.40/ton of fiber.

COST OF ELECTRIC POWER (C_p)

Assuming 75% efficiency for the electric motor, 1 hp will be roughly equivalent to 1 kw and, therefore, 1 hp hour will equal 1 kw hour. At the exit flow rate of 2 liters/min and 4.7% consistency, the fiber flow will be approximately 95 g/min or 0.0063 ton/hr. This will require 159 hp-hours per ton of fiber or 159 kw-hr/ton. At a mill rate of 1¢/kw-hr, the cost of power (C_p) will be $1.59/ton.

COST OF CHEMICAL (C_c)

The amount of sodium hydroxide at 6% based on fiber will be 120 lb/ton. At a rate of $0.12/lb, the cost of chemical (C_c) will be $14.40 per ton of pulp.

Hence, the total cost of the process (C_T) will be $C_s + C_p + C_c$ or $22.39/ton. When this cost is added to the market price of groundwood ($\cong$ $210/ton), the total cost for jet/alkali-treated pulp becomes approximately $232/ton. Assuming a current market price of $340/ton for bleached softwood kraft, a typical newsprint furnish comprised of 80% groundwood and 20% kraft would cost $236/ton. In order to reduce the cost when utilizing jet/alkali-treated groundwood, it would be necessary to increase the groundwood component to in excess of 96%. This, of course, may not be feasible due to inherently low tear strength. On this basis the advantage to the jet/alkali process would be, at best, marginal. However, an economic advantage should become evident in mixed furnishes containing a normal groundwood component less than 80%. For example, a 75/25 groundwood/kraft furnish would cost $242.50/ton based on market prices. In this case an economic advantage would be attained at all jet/alkali groundwood levels in excess of 90%. This would permit retention of some kraft needed for tear resistance.

The aforementioned examples have been based on market prices for groundwood and kraft but it can be assumed that the internal cost of groundwood to mills producing newsprint and other groundwood-content papers will be something less than the market price. Accordingly it should be possible to substitute jet/alkali groundwood for kraft and provide better economic advantages than given in the examples. Of course, part of the lower internal cost of groundwood will be offset by somewhat higher than indicated costs of the jet/alkali process due to labor, equipment, etc.

In its present state of development, the jet/alkali process offers the potential advantages of versatility and high yield to those companies producing hardwood stone groundwood and nonpressurized mechanical pulps. The potential substitution of jet/alkali pulp for chemical pulps in more expensive grades such as business forms, textbook papers, and computer printouts presents an attractive possibility.

EXPERIMENTAL

GENERAL PROCEDURES

Pulp Supplies and Treatments

Supplies of aspen chips, aspen chemirefiner pulp, and southern pine stone groundwood were procured from supporting companies for the experimental program. The chemirefiner pulp was supplied at approximately 8% solids and was subsequently dewatered to 20% consistency for storage. The southern pine groundwood was screened to remove approximately 0.5% of coarse material followed by dewatering to 28.4% solids. The aspen chips and both pulp supplies were stored at 40°F with preservative. For use in handsheets, the pulps were resuspended in tap water using a British disintegrator.

The bleached kraft pulp used in the earlier work (1,3) (Rayonier WBS-W) was again utilized in the present program. As in the previous work, the dry lap pulp was soaked overnight in tap water and then refined to approximately 690 ml Schopper-Riegler freeness in a 5-lb Valley beater. The Canadian freeness was 360 ml. The refined pulp was dewatered to 21% solids and then stored at 40°F with preservative. For use in handsheets, portions of the pulp were redispersed at 2.5% consistency in tap water by subjecting the diluted stock to 300 counts in a British disintegrator followed by dilution to 2.0% consistency.

Operation of Jet Cooker

The general procedure for operating the jet cooker was as follows:

Room temperature water was fed to the hopper (refer to Fig. 1; Report Three) and the steam pressure was adjusted to provide the desired temperature. When steady state conditions were attained and a low level of water remained in the hopper, four liters of either 4 or 5% pulp treated with the desired amount of reactants was added. It was found that the jet cooker could accommodate 4% of the chemirefiner pulp or 5% of stone groundwood. Approximately three liters of treated pulp were collected after discarding the first several hundred milliliters. The final flow through the jet was also discarded. The collected pulp was cooled to room temperature within approximately 10 minutes and a sample withdrawn for determination of residual alkali. The major portion of the collected pulp was then adjusted to pH 5 with dilute HCl. The pulp suspension was sampled at this point for consistency, freeness, and yield.

Preparation of Thermomechanical Pulps

Thermomechanical pulps were prepared on the basis of information provided in the literature which was almost exclusively directed at softwoods (4-6). For this purpose, 150-g batches (o.d. basis) of aspen chips were treated in an Asplund laboratory defibrator unit utilizing a two-minute pressurized step followed by a 30- or 60-second treatment in the defibrator at approximately 15% solids and finally by one or more passes through a Sprout-Waldron 12-inch disk refiner at 200°F and 4-5% consistency. The pressure in the pressurized and defibering steps fell in the range of 20-30 psi in all cases. Higher consistencies are normally utilized in both the defibering and refining steps in commercial thermomechanical processes; however, the laboratory equipment utilized in this work could not accommodate these conditions. In those cases involving more than one pass through the disk refiner, it was necessary to thicken the pulp between each pass. This was accomplished with a basket centrifuge, thereby unavoidably incurring the loss of solubles and some fines although the latter was minimized by recycling the filtrate through the fiber pad in the thickening process. The pulp samples were cooled to room temperature and then tested for freeness and consistency.

Handsheet Preparations

Handsheets were prepared from 100% groundwood, chemimechanical, and thermomechanical pulps as well as from blends of these pulps and bleached kraft. The equivalent of 40 g (total) of pulp was utilized for each set of handsheets comprised of eight sheets each. Prior to sheetmaking, the pulp was diluted to 0.5% consistency with tap water and the pH was adjusted to 5.0 with dilute sulfuric acid. Handsheets equivalent to 2.5 g (o.d. basis) were formed in an 8 x 8-inch Noble & Wood sheet mold in the manner described in Progress Report Two.

Testing and Analysis

Handsheets were preconditioned at 20% RH, 70°F and then stored at 50% RH and 73°F prior to testing according to TAPPI procedures. In most cases, testing included basis weight, thickness, density, breaking length, stretch, tensile energy absorption (TEA), extensional stiffness, tear factor (single sheet), folding endurance, air permeability, opacity, and scattering coefficient. Brightness was measured on unequilibrated paper within 24 hours of preparation. The testing program was limited to the more prominent strength tests in the case of orientation experiments with thermomechanical pulps.

Pulp suspensions from the jet/alkali process were tested for residual sodium hydroxide and yield according to procedures given in the appendix of Progress Report Three. Because of fiber and chemical losses incurred in the multistep processing required to produce the thermomechanical pulps, accurate determinations of yield and residual alkali could not be made on the same samples utilized in handsheet preparations. However, yield was determined by materials balance on separate samples of pulp processed under identical conditions in the Asplund Defibrator.

HARDWOOD STUDIES

Several series of orientation experiments were conducted to establish conditions for producing an acceptable thermomechanical pulp for the program. This work was directed at establishing the uniqueness of the jet/alkali process by comparing these pulps with those prepared by the thermomechanical process with and without alkali. Preliminary studies examined the effects of time and pressure in the defibrator and clearance in the refining operation. Handsheets formed from 100% thermomechanical pulps were tested primarily for strength properties and the results are recorded in Table I. For purposes of comparison, results obtained with the fresh sample of aspen chemimechanical pulp and those previously obtained with aspen stone groundwood (3) are included in the table.

Based on information provided in the literature (4-6), the thermomechanical pulp selected for reference should have a density no greater, and preferably lower, than that of stone groundwood. Further, the tensile and tear strength should be greater than that of the stone groundwood and chemirefiner pulps. Obviously, the ideal conditions were not fully attained and, in the absence of a more exhaustive study which would lie beyond the scope of the current program, the pulp utilized in Set 9 was selected as the best compromise.

Additional thermomechanical pulps were then prepared under the selected processing conditions incorporating sodium hydroxide at two levels of addition, i.e., 2 and 7.5% (based on fiber weight). The required amount of alkali was dissolved in 50 ml of water and then spread over the chips 1-2 minutes before

TABLE I

ASPEN THERMOMECHANICAL PULPS – ORIENTATION EXPERIMENTS

(Two-minute dwell time in preheater step)

Set No.	Pressure in Preheater Step, psi	Time in Defibrator, sec	Disk Refining, clearance, inch	Canadian Freeness, ml	Basis Weight, g/sq m	Thickness, μm	Density, g/cc	Breaking Length, km	TEA, g/cm/sq cm	Stretch, %	Tensile Stiffness, kg/cm	Tear Factor, (single sheet)
1	30	30	1 Pass at 0.001	340	63.5	204.2	0.311	1.53	6.05	0.93	160	18.0
2	30	60	1 Pass at 0.005 + 1 pass at 0.001	170	62.7	190.5	0.329	2.10	9.18	1.12	213	20.3
3	30	60	1 Pass at 0.005 + 1 pass at 0.003 + 1 pass at 0.001	110	62.8	177.3	0.354	2.58	12.47	1.20	245	20.9
4	30	60	1 Pass at 0.007 + 1 pass at 0.003 + 1 pass at 0.001	130	63.0	173.2	0.364	2.54	10.72	1.07	250	21.5
5	20	60	1 Pass at 0.005 + 1 pass at 0.003 + 1 pass at 0.001	165	62.9	143.8	0.438	2.91	13.39	1.14	255	18.1
6	30	30	1 Pass at 0.005 + 1 pass at 0.002	130	62.0	168.1	0.369	2.53	10.57	1.34	222	19.5
7	30	30	1 Pass at 0.005 + 1 pass at 0.003 + 1 pass at 0.001	90	62.3	145.3	0.429	3.29	15.45	1.19	273	20.1
8	30	30	1 Pass at 0.010 + 1 pass at 0.003	160	63.0	183.0	0.344	2.16	10.10	1.20	192	21.1
9	30	30	1 Pass at 0.010 + 1 pass at 0.003 + 1 pass at 0.001	140	63.4	155.0	0.409	2.87	14.30	1.30	241	22.2
10	Control (100% aspen stone groundwood)[a]			150	62.2	160.0	0.389	2.24	12.50	1.30	194	19.3
11	Control (100% aspen chemimechanical groundwood)			200	63.4	182.9	0.346	2.78	15.42	1.31	234	27.9

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[a] From Progress Report Three.

the two-minute pressurized step. With the necessary dilution in the defibrator to 15% consistency, the 2% alkali addition level provided an effective concentration of 0.3% alkali in solution or, in effect, the same as that subsequently utilized in processing the chemimechanical pulp in the jet/alkali process in which case the fiber consistency was 4% and the alkali addition level was 7.5%. Hence, the two alkali levels utilized in preparing the alkaline thermomechanical pulps were equivalent to the conditions utilized in the jet/alkali process with respect to concentration in one case and to addition level in the second case. A thermomechanical pulp prepared without alkali was subsequently jet/alkali treated to establish what benefits, if any, could be achieved beyond that afforded by the thermomechanical treatment. For purposes of reference, handsheets were prepared from 100% kraft, 100% untreated chemirefiner groundwood, and from 50/50 and 80/20 blends of untreated chemimechanical pulp and kraft. Physical test results for these papers are recorded in Table II. Suspension data for the thermomechanical and jet/alkali-treated pulps are listed in Table III.

SOFTWOOD STUDIES

Since initial work with softwood groundwood (1) suggested that more drastic processing conditions in the jet/alkali system would be required for this type of wood than for aspen, the first series of experiments examined the effects of high temperature and alkali concentration using the southern pine stone groundwood. The groundwood was processed six seconds at 5% consistency and 300°F using 6 and 12% NaOH (based on fiber) equivalent to 0.3 and 0.6% alkali in solution. The effect of increased dwell time (13 seconds) was examined at the higher alkali concentration. When poor response was obtained in these tests additional pulps were prepared at progressively lower temperatures, i.e., 275 and 250°F. Thus, in effect, pulps were prepared at temperatures above and

TABLE [illegible]

A COMPARISON OF JET/ALKALI AND THERMOMECHANICAL PULPS FROM ASPEN

Set No.	Fiber Composition	NaOH Added, % based on fiber	NaOH Concentration %	Basis Weight, μm	S.E.	Thickness, μm	S.E.	Density, g/cc	Breaking Length, km	S.E.	TEA, g/cm/sq cm	S.E.	Stretch, %	S.E.	Tensile Stiffness, kg/cm	S.E.	Tear Factor, (single sheet)	S.E.	MIT Folding Endurance, double folds	S.E.	Bendtsen Air Permeability, ml/min	S.E.	Brightness, %	S.E.	Opacity, %	S.E.	Scattering Coeff., sq cm/g	S.E.
[illegible]	Control, 100% kraft	None	--	62.7	0.28	107.2	0.95	0.585	5.23	0.058	55.24	3.753	3.57	0.125	353	11.9	120.9	7.03	407	39.1	266	6.5	56.8	0.13	72.1	0.75	313	9.6
13	Control, 50/50 chemimechanical/kraft	None	--	63.5	0.34	143.8	0.62	0.441	3.68	0.043	37.52	1.754	2.23	0.090	282	6.4	84.5	3.81	20	1.1	841	48.4	57.4	0.16	81.5	0.41	366	6.0
[illegible]	Control, 80/20 chemimechanical/kraft	None	--	62.3	0.12	162.6	0.07	0.383	2.97	0.045	19.33	1.020	1.54	0.065	240	4.6	53.9	1.09	4	[illegible]	1267	18.2	51.2	0.26	85.4	0.43	392	6.9
11	Control, 100% chemimechanical pulp	None	--	63.4	0.08	162.9	0.08	0.346	2.78	0.160	15.42	1.523	1.31	0.083	234	5.0	27.9	0.63	2	0.1	1503	66.8	48.4	0.15	87.5	0.66	415	11.8
[illegible]	80/20 Jet alkali-treated chemimechanical/kraft	7.5	0.3	63.0	0.28	130.6	0.62	0.483	3.88	0.109	30.47	3.786	1.75	0.157	321	2.8	58.4	1.17	11	0.8	297	9.1	46.1	0.42	95.1	0.48	352	7.6
[illegible]	100% Jet/alkali-treated chemimechanical pulp	7.5	0.3	[illegible]	0.24	136.1	0.62	0.464	3.81	0.125	23.64	2.147	1.45	0.087	325	3.3	37.3	0.63	4	0.2	275	17.8	43.0	0.29	96.9	0.35	357	5.0
[illegible]	80/20 Thermomechanical pulp/kraft	None	--	64.4	0.20	145.8	0.63	0.441	2.98	0.073	20.52	0.866	1.56	0.032	248	7.1	49.1	1.16	4	0.3	304	6.5	51.9	0.15	95.4	0.10	360	8.4
[illegible]	100% Thermomechanical pulp	None	--	63.4		155.0		0.409	2.87		14.30		1.30		241		24.2		1		296		48.8		96.7		577	
[illegible]	80/20 Jet/alkali-treated thermomechanical pulp/kraft	7.5	0.3	63.5	0.16	116.3	0.95	0.545	4.81	0.070	35.59	2.049	1.67	0.075	380	6.6	47.3	1.73	18	1.0	48	1.5	45.3	0.24	92.0	0.15	412	7.4
[illegible]	100% Jet/alkali-treated thermomechanical pulp	7.5	0.3	63.5	0.17	110.2	0.62	0.576	4.73	0.112	25.25	1.738	1.29	0.058	377	6.1	25.8	0.0	4	[illegible]	26	0.6	40.5	0.37	94.1	0.30	406	4.8
21	80/20 Alkaline thermomechanical pulp^a/kraft	2.0	0.3^b	62.6	0.14	129.0	0.51	0.436	4.57	0.090	39.49	1.067	1.98	0.018	327	8.4	49.8	0.78	16	0.9	49	1.6	48.2	0.12	91.6	0.19	440	4.4
[illegible]	100% Alkaline thermomechanical pulp^a	2.0	0.3^b	63.3	0.24	131.6	0.95	0.481	4.60	0.121	29.20	1.314	1.53	0.043	324	5.3	28.7	0.77	[illegible]	[illegible]	29	0.8	44.7	0.16	93.4	0.27	444	6.8
[illegible]	[illegible] Alkaline thermomechanical pulp^a/kraft	7.5	1.1^b	63.4	0.13	92.5	0.62	0.686	7.34	0.097	79.90	5.067	2.40	0.118	474	5.0	54.0	3.09	394	38.3	<12	0.0	30.7	0.17	72.6	0.60	178	3.2
[illegible]	100% Alkaline thermomechanical pulp^a	7.5	1.1^b	62.5	0.15	83.8	0.04	0.745	8.20	0.097	84.13	3.165	2.29	0.062	507	4.8	28.8	0.88	1462	184	<12	0.0	22.0	0.13	61.7	0.70	115	2.2

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[a] Alkali added to pulps before the thermomechanical treatment.

[b] Concentration in refiner where fiber consistency was approximately 15%.

TABLE III

SUSPENSION DATA — JET/ALKALI AND THERMOMECHANICAL PULPS FROM ASPEN

Pulp No.	Description	Fiber Consistency, %	NaOH Added, % based on fiber	NaOH Concentration in Soln., %	pH of Pulp Slurry		Total Solids in Pulp Slurry, %	Soluble Solids in Pulp Slurry, %	Yield, %	Free NaOH		Combined NaOH		Total NaOH	
					Before Cook	After Cook				Meq/ 100 ml	Mg/g	Meq/ 100 ml	Mg/g	Mg/g	% Accounted for
1	Thermomechanical pulp	≅15	None	--	--	--	--	--	95.1[a]	--	--	--	--	--	--
2	Alkaline thermomechanical pulp	≅15	2.0	0.3	--	--	--	--	88.2[a]	--	--	--	--	--	--
3	Alkaline thermomechanical pulp	≅15	7.5	1.1	--	--	--	--	81.9[a]	--	--	--	--	--	--
4	Jet/alkali-treated chemimechanical pulp	4.0	7.5	0.3	13.0	13.0	3.53	0.44	99.1[b]	3.78	36.9	2.12	20.7	57.6	82.5
5	Jet/alkali-treated thermomechanical pulp	4.0	7.5	0.3	13.1	12.9	3.75	0.50	91.5[c]	2.07	22.1	3.47	37.0	59.1	84.7

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[a] By materials balance.

[b] Uncorrected value.

[c] Corrected for a 95.1% yield from the thermomechanical pulping step.

below the transition temperature of lignin. Handsheets were prepared from 100% groundwood and 80/20 groundwood/kraft blends according to the general procedure described previously. Physical test results for these papers as well as the appropriate controls are given in Table IV. Selected strength and optical properties as functions of alkali level are presented in Fig. 1-10. Groundwood suspension data are presented in Table V and in Fig. 11.

The final series of experiments examined the effects of several oxidizing and reducing agents most generally under conditions which produced optimum results with the least amount of alkali, i.e., 275°F with 6% of NaOH. Efforts to induce sulfonation of the lignin component as advocated by Kvisgaard and Borregaard (7) utilized sulfite/bisulfite at pH 6.3 and sodium sulfite in the presence of 6% of alkali. The results of these experiments are summarized in Tables VI and VII.

TABLE IV

JET/ALKALI TREATMENT OF SOUTHERN PINE STONE GROUNDWOOD

Set No.	Fiber Composition	Materials Added Before Jet Cooking, % based on fiber	Processing Temp., °F	Dwell Time in Jet Cooker, sec	Basis Wt., g/sq m	S.E.	Thickness, µm	S.E.	Density, g/cc	Breaking Length, km	S.E.	TEA, g cm/sq cm	S.E.	Stretch, %	S.E.	Tensile Stiffness, kg/cm	S.E.	Tear Factor (single sheet)	S.E.	MIT Folding Endurance, double folds	S.E.	Bendtsen Air Permeability, ml/min	S.E.	Brightness, %	S.E.	Opacity, %	S.E.	Scattering Coeff., sq cm/g	S.E.
12	Control — 100% kraft	--	--	--	62.7	0.28	107.2	0.95	0.585	5.23	0.056	85.24	3.753	3.57	0.125	353	11.9	120.9	7.23	407	39.1	266	6.5	86.8	0.13	72.1	0.75	313	9.6
25	Control — 50/50 untrd. groundwood/kraft	--	--	--	64.5	0.13	146.3	2.09	0.441	3.49	0.118	42.28	5.827	2.49	0.260	267	1.2	89.0	0.93	30	2.1	339	8.8	61.8	0.21	87.1	0.38	488	5.7
26	Control — 80/20 untrd. groundwood/kraft	--	--	--	64.6	0.15	158.5	1.72	0.408	2.99	0.054	27.37	1.740	1.98	0.077	229	3.4	54.2	1.20	6	0.3	320	7.2	56.8	0.19	90.9	0.10	543	2.7
27	Control — 100% untrd. groundwood	--	--	--	63.6	0.11	170.0	0.07	0.374	2.46	0.089	13.02	1.735	1.26	0.116	203	6.9	24.2	0.63	1	0.0	340	2.2	54.8	0.11	93.0	0.09	586	2.6
28	80/20 Treated groundwood/kraft	None	300	6	63.9	0.10	164.6	0.51	0.388	2.78	0.078	20.87	2.040	1.65	0.150	220	2.9	51.7	0.86	6	0.3	341	3.5	54.6	0.09	92.9	0.16	556	6.5
29	100% Treated groundwood	None	300	6	63.1	0.46	174.8	1.48	0.361	2.51	0.081	14.21	1.310	1.39	0.078	200	4.6	26.3	0.95	1	0.0	339	8.5	52.2	0.11	94.5	0.27	583	10.1
30	80/20 Treated groundwood/kraft	NaOH, 6.0	300	6	63.0	0.15	149.4	0.51	0.422	3.08	0.066	22.23	1.387	1.62	0.083	250	5.9	56.7	1.80	6	0.4	240	7.6	50.9	0.19	93.3	0.15	536	5.1
31	100% Treated groundwood	NaOH, 6.0	300	6	63.0	0.10	155.4	0.95	0.406	2.81	0.024	15.19	0.700	1.31	0.044	235	5.0	25.1	0.32	1	0.0	218	4.2	48.1	0.05	95.2	0.20	568	7.1
32	80/20 Treated groundwood/kraft	NaOH, 12.0	300	6	63.4	0.23	155.4	4.36	0.408	3.42	0.095	26.81	2.866	1.78	0.133	274	3.7	50.5	1.00	9	0.6	202	5.2	46.8	0.08	93.0	0.13	489	3.3
33	100% Treated groundwood	NaOH, 12.0	300	6	63.5	0.13	158.5	1.72	0.401	3.06	0.052	15.97	1.251	1.27	0.065	282	8.6	25.8	0.39	2	0.1	175	1.5	44.1	0.05	95.0	0.24	523	8.3
34	80/20 Treated groundwood/kraft	NaOH, 12.0	300	13	63.0	0.09	145.3	0.51	0.434	3.43	0.051	27.16	1.068	1.79	0.049	275	3.6	50.0	2.99	11	0.4	191	5.1	45.3	0.09	93.3	0.25	490	6.4
35	100% Treated groundwood	NaOH, 12.0	300	13	63.4	0.13	154.9	1.39	0.409	3.17	0.095	66.75	1.196	1.28	0.048	232	8.3	25.9	0.80	2	0.2	172	2.9	42.5	0.12	94.8	0.22	503	7.1
36	80/20 Treated groundwood/kraft	None	275	6	64.5	0.22	176.3	1.02	0.366	2.85	0.101	26.23	2.402	2.00	0.105	212	5.7	54.0	1.58	5	0.3	400	8.7	55.5	0.16	91.5	0.21	537	6.1
37	100% Treated groundwood	None	275	6	64.1	0.12	188.5	0.95	0.340	2.39	0.024	16.60	1.017	1.59	0.071	182	3.2	24.0	0.38	1	0.0	441	4.2	53.3	0.10	93.7	0.09	579	2.2
38	80/20 Treated groundwood/kraft	NaOH, 6.0	275	6	63.5	0.16	151.4	1.02	0.419	3.32	0.064	27.33	2.107	1.87	0.104	268	5.5	51.7	3.24	7	0.3	232	4.1	48.8	0.11	93.4	0.28	510	8.5
39	100% Treated groundwood	NaOH, 6.0	275	6	63.0	0.13	160.5	0.95	0.393	3.07	0.036	17.51	0.899	1.38	0.054	252	9.5	23.5	0.59	1	0.2	242	8.2	45.7	0.21	95.2	0.13	531	3.9
40	80/20 Treated groundwood/kraft	NaOH, 12.0	275	6	63.7	0.17	149.4	0.51	0.426	3.38	0.029	23.69	0.886	1.64	0.037	291	2.3	52.8	1.07	10	0.6	208	5.6	46.9	0.10	93.4	0.09	506	2.1
41	100% treated groundwood	NaOH, 12.0	275	6	62.8	0.33	157.0	0.96	0.400	3.10	0.059	16.91	1.101	1.35	0.051	260	5.4	25.5	0.0	2	0.2	215	6.0	44.3	0.07	94.9	0.16	522	5.0
42	80/20 Treated groundwood/kraft	NaOH, 6.0	250	6	64.4	0.13	147.8	0.95	0.436	3.11	0.028	22.08	0.581	1.59	0.042	264	5.8	52.8	1.70	7	0.4	225	1.5	50.4	0.08	92.7	0.24	519	6.4
43	100% Treated groundwood	NaOH, 6.0	250	6	62.9	0.30	152.9	0.95	0.411	2.81	0.038	15.19	1.096	1.31	0.067	236	2.7	23.5	0.59	1	0.2	216	3.6	47.9	0.09	94.7	0.13	553	4.5
44	80/20 Treated groundwood/kraft	NaOH, 12.0	250	6	63.9	0.19	143.8	0.63	0.445	3.32	0.054	26.37	0.879	1.75	0.035	271	2.3	[illegible]	0.63	5	0.4	193	2.7	47.9	0.13	92.8	0.11	503	3.6
45	100% Treated groundwood	NaOH, 12.0	250	6	63.1	0.23	150.9	1.02	0.419	3.08	0.051	17.46	0.935	1.35	0.049	244	[illegible]	[illegible]	0.63	2	0.2	209	5.2	45.0	0.07	95.5	0.23	560	9.2

NOTE: The initial fiber consistency in jet cooking was 5% in all cases.

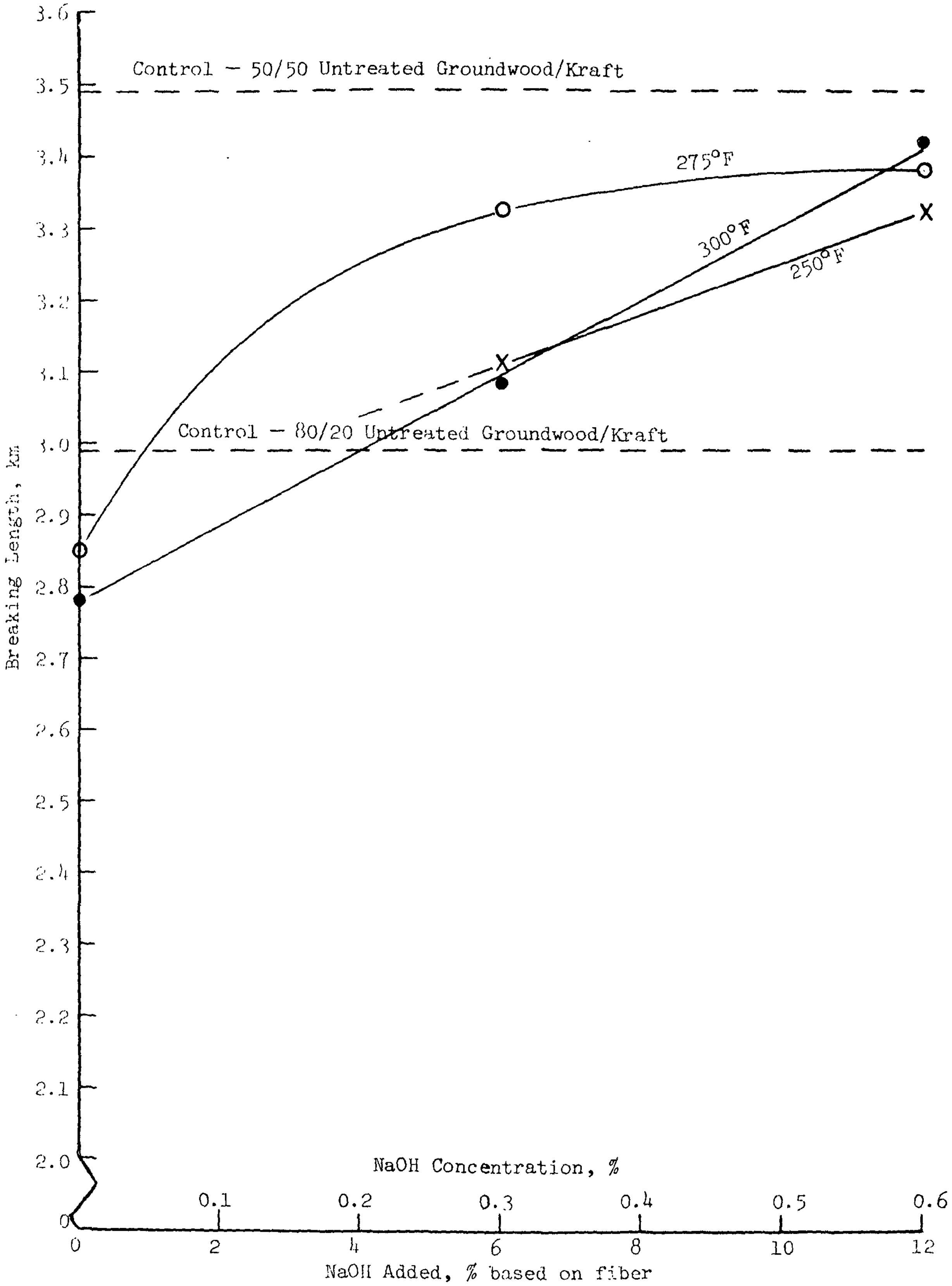

Figure 1. The Effect of Alkali Level and Processing Temperature on Breaking Length (80/20 Blends of Southern Pine Groundwood/Kraft)

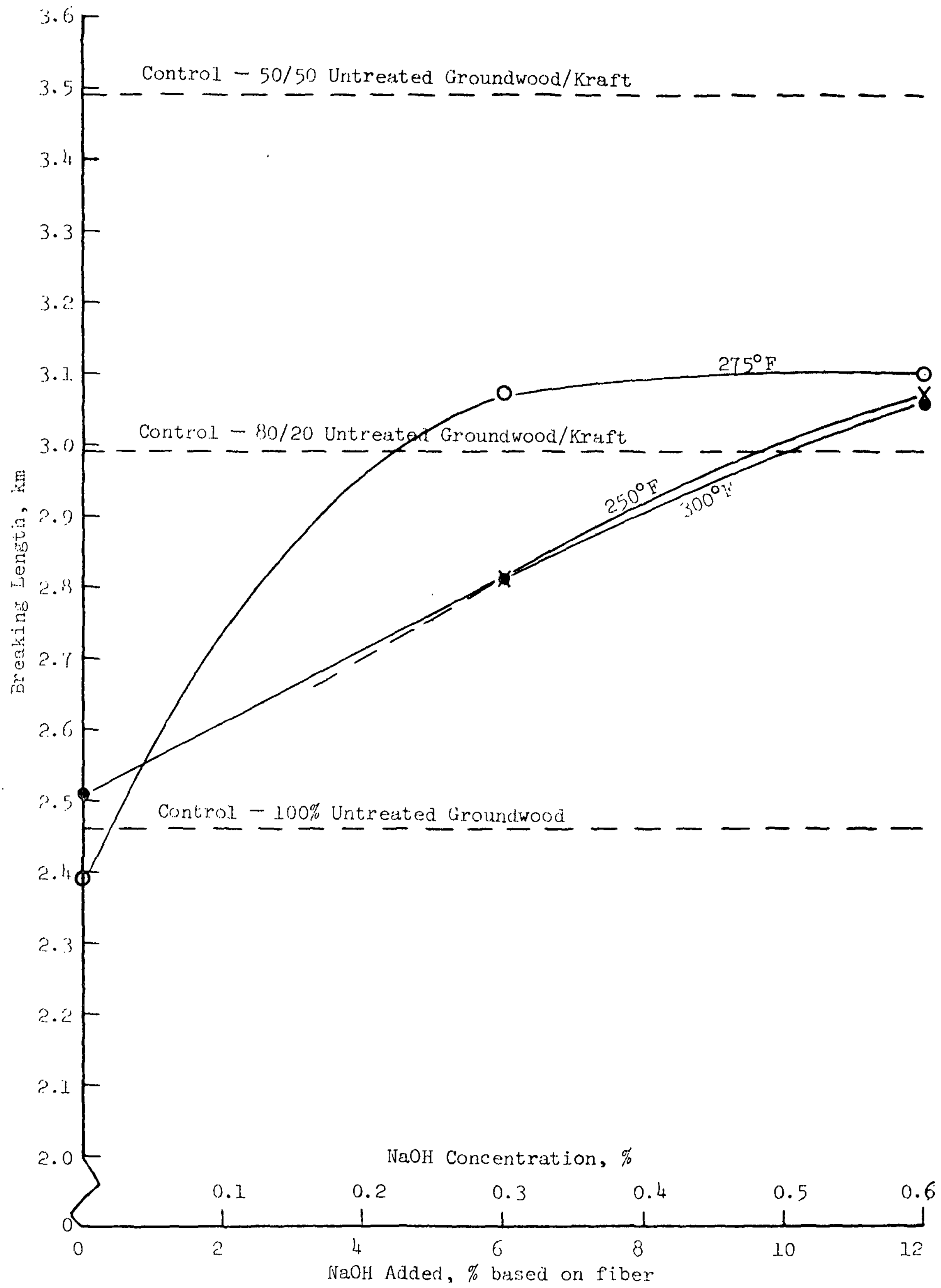

Figure 2. The Effect of Alkali Level and Processing Temperature on Breaking Length (100% Southern Pine Groundwood)

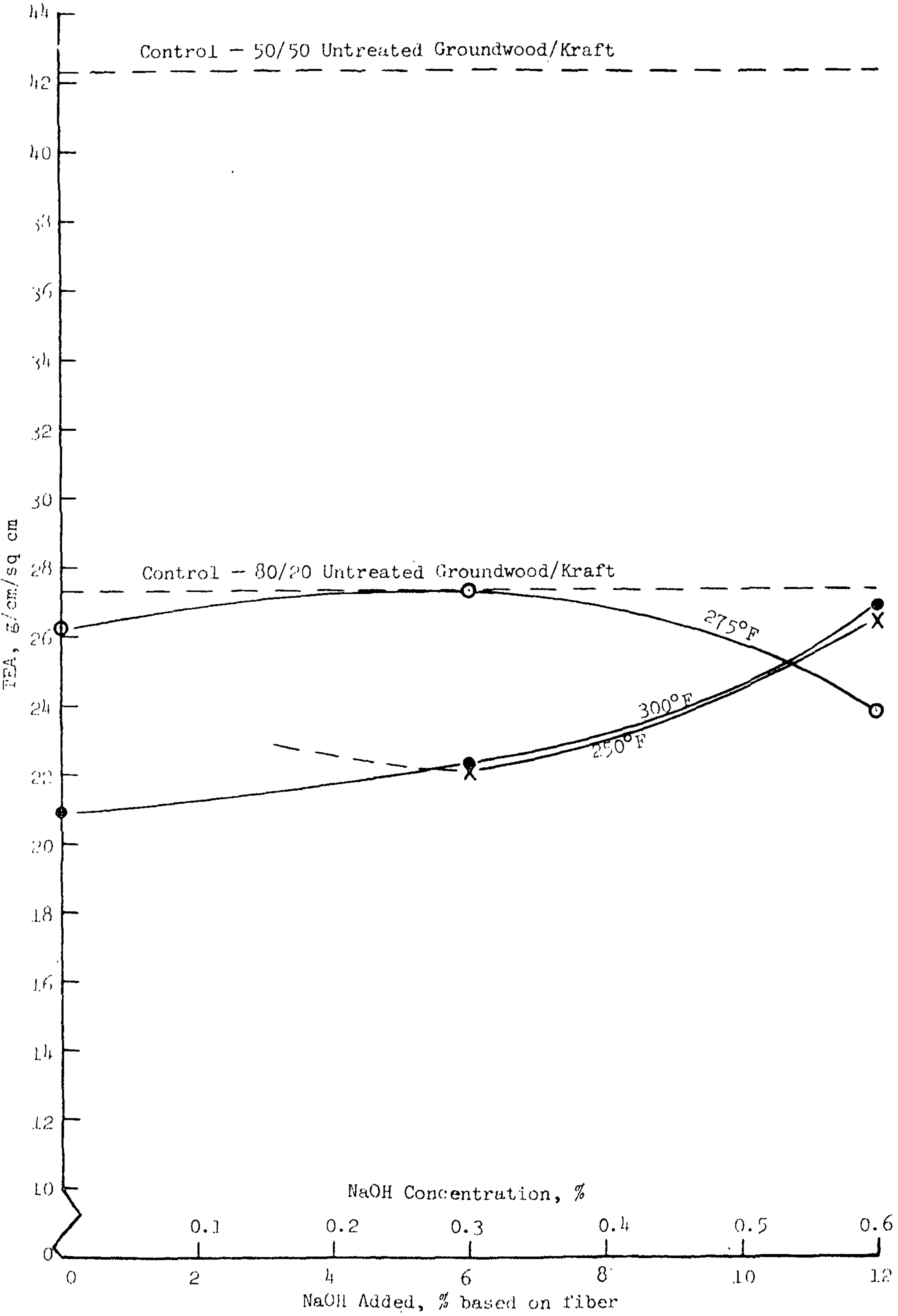

Figure 3. The Effect of Alkali Level and Processing Temperature on Tensile Energy Absorption (80/20 Blends of Southern Pine Groundwood/Kraft)

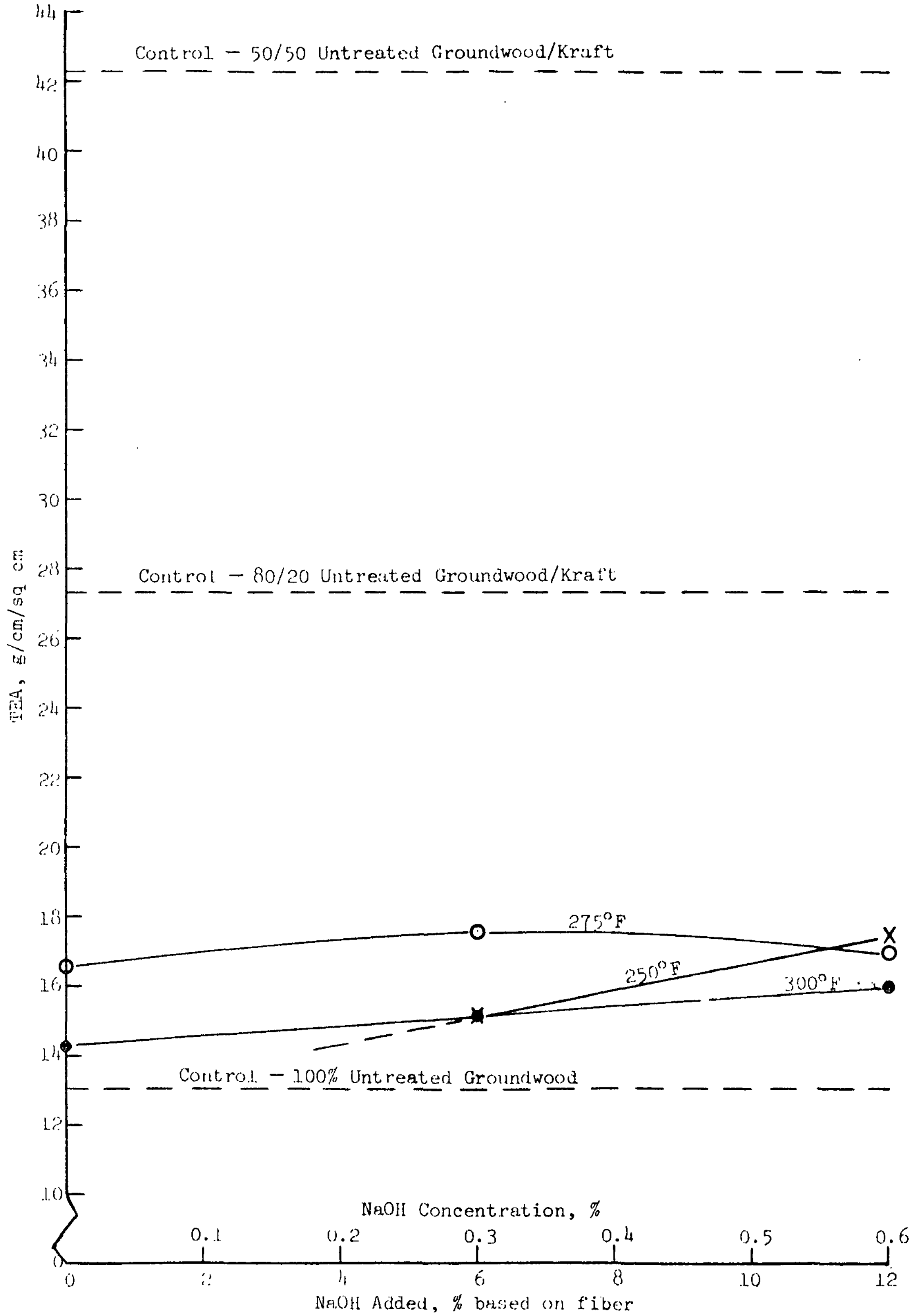

Figure 4. The Effect of Alkali Level and Processing Temperature on Tensile Energy Absorption (100% Southern Pine Groundwood)

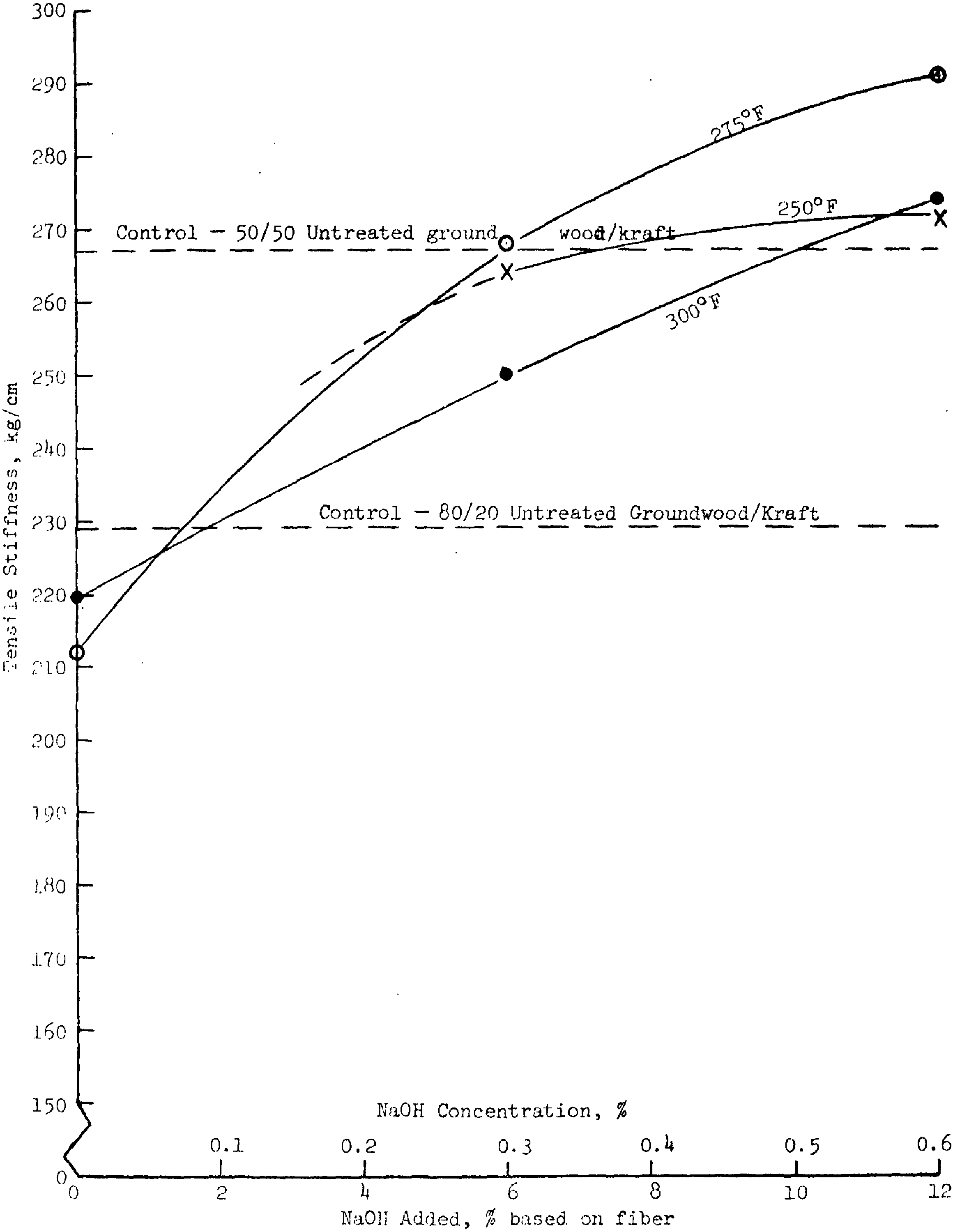

Figure 5. The Effect of Alkali Level and Processing Temperature on Tensile Stiffness (80/20 Blends of Southern Pine Groundwood/Kraft)

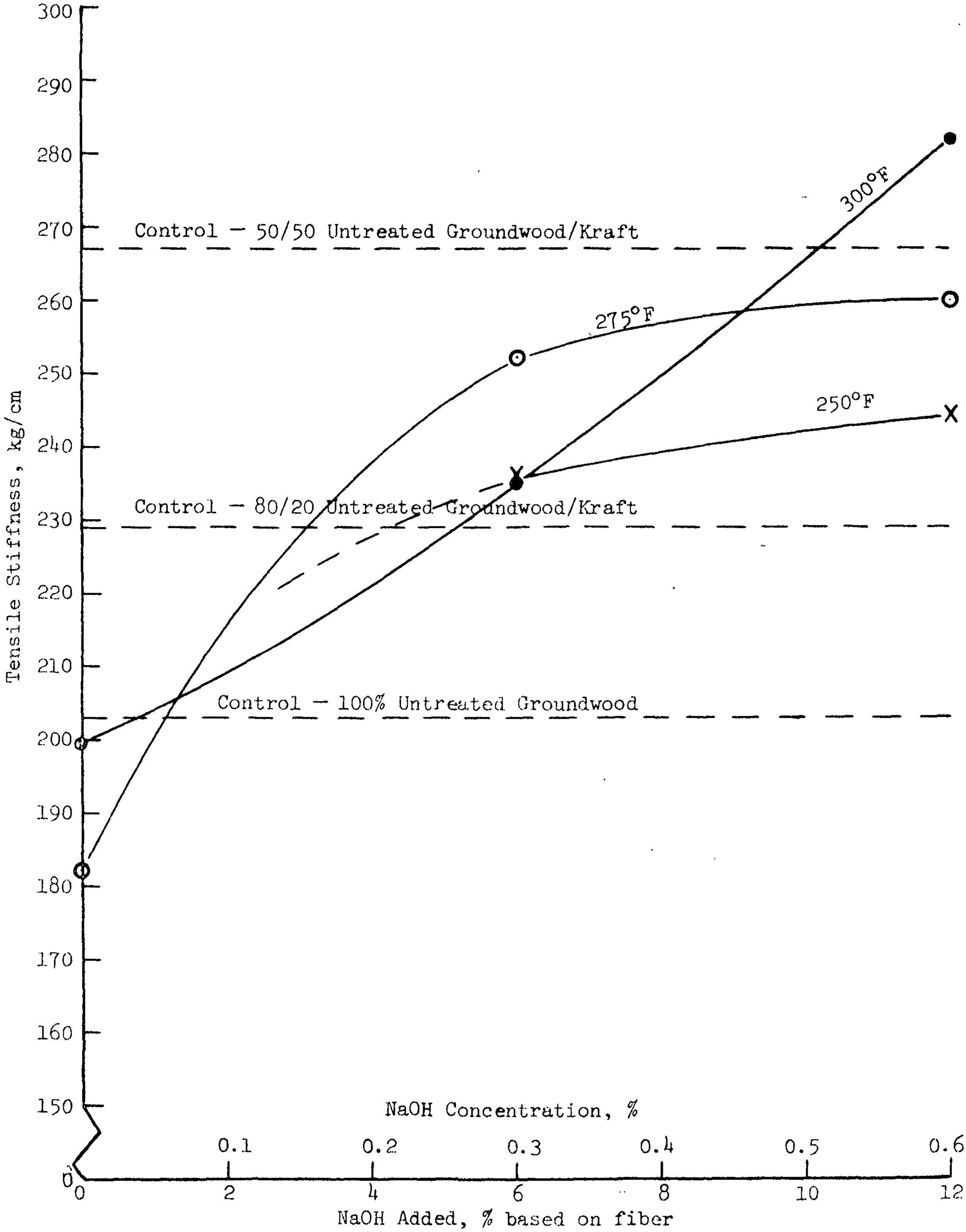

Figure 6. The Effect of Alkali Level and Processing Temperature on Tensile Stiffness (100% Southern Pine Groundwood)

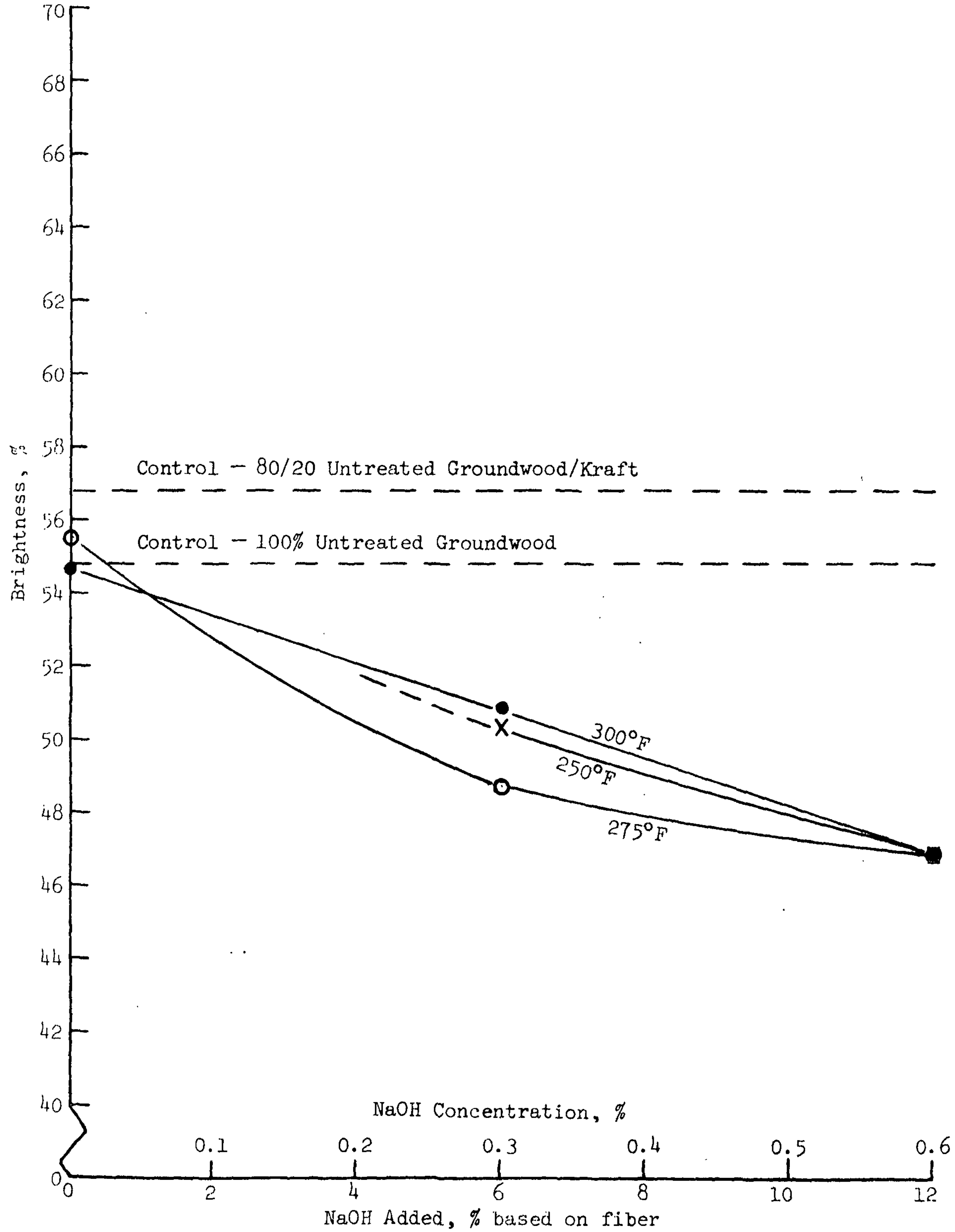

Figure 7. The Effect of Alkali Level and Processing Temperature on Brightness (80/20 Blends of Southern Pine Groundwood/Kraft)

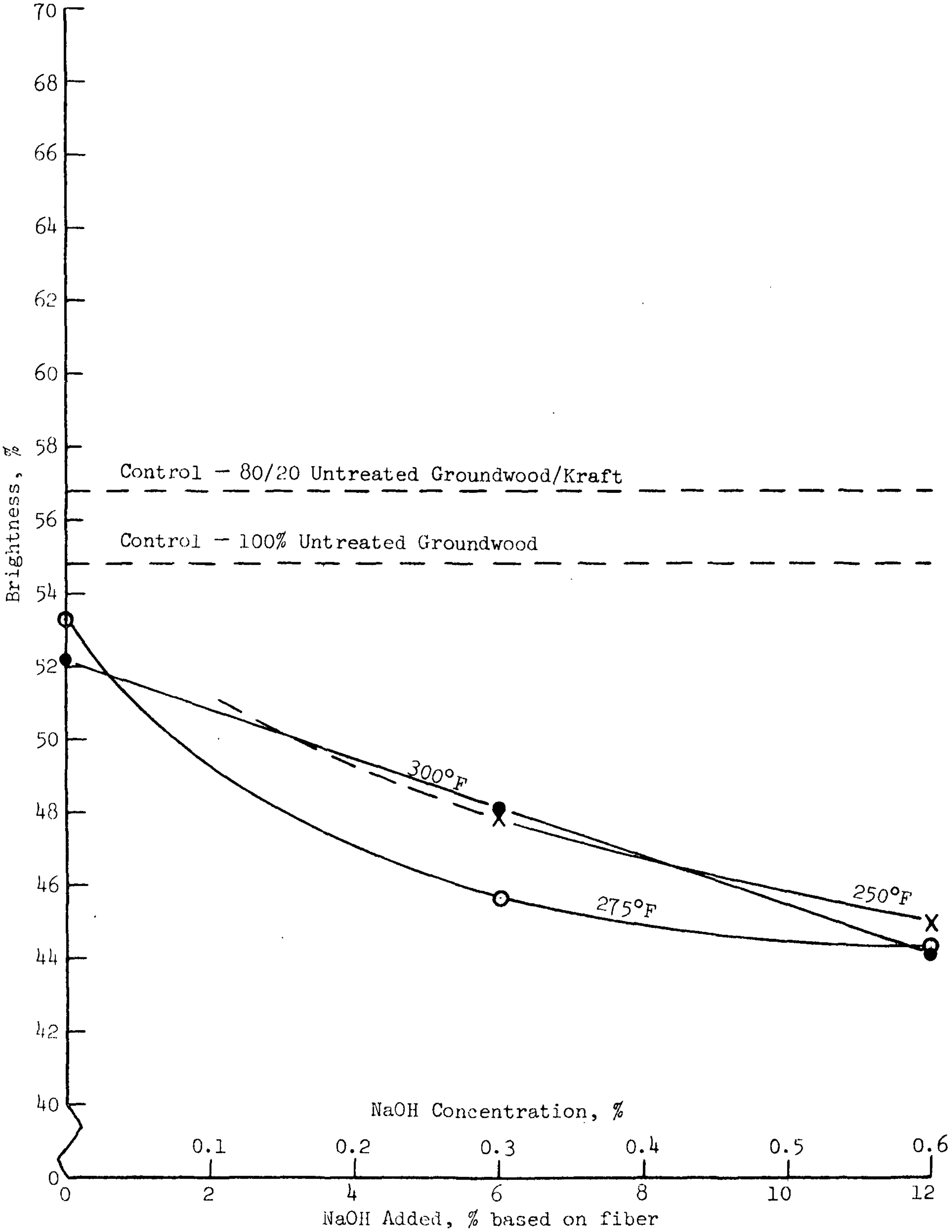

Figure 8. The Effect of Alkali Level and Processing Temperature on Brightness (100% Southern Pine Groundwood)

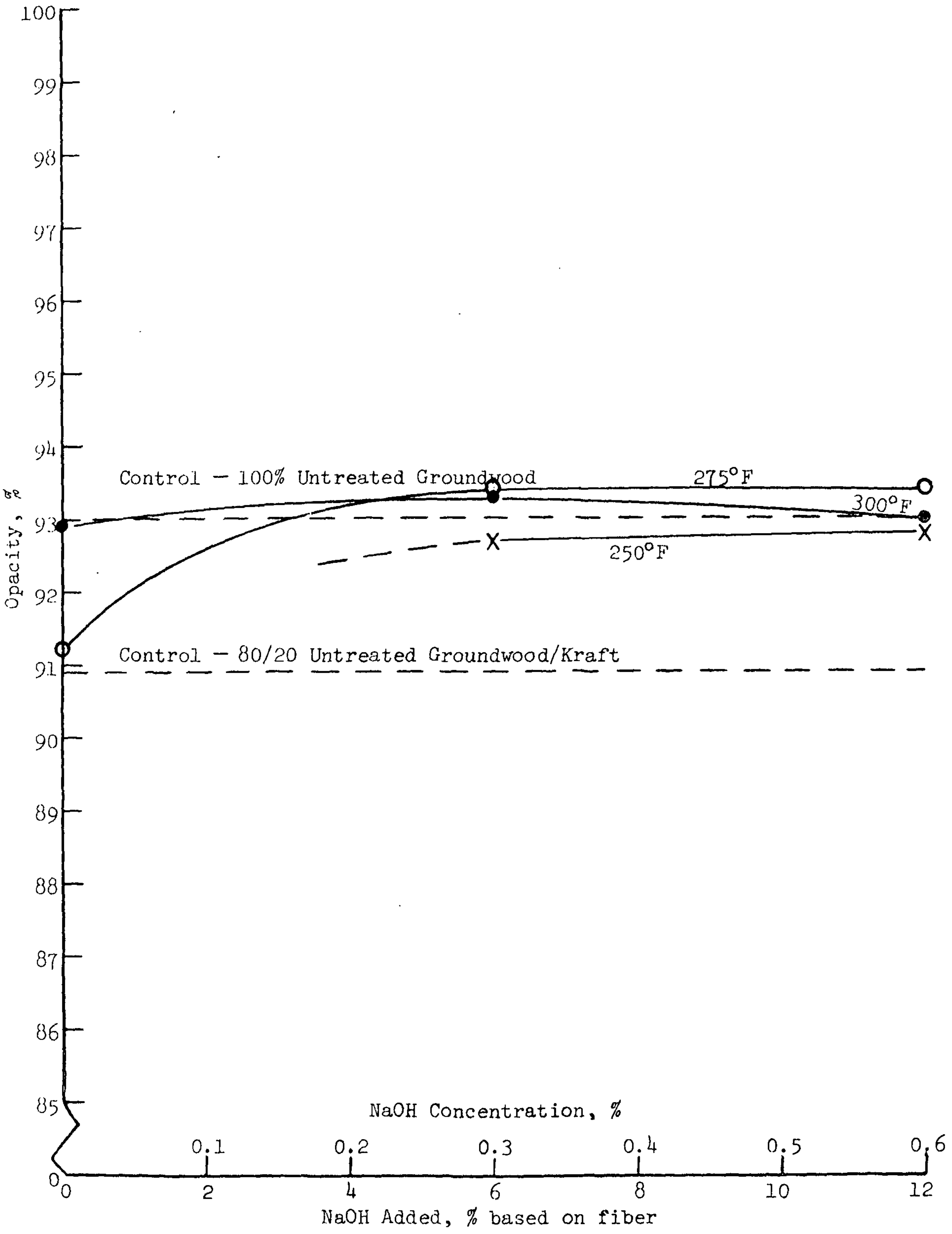

Figure 9. The Effect of Alkali Level and Processing Temperature on Opacity (80/20 Blends of Southern Pine Groundwood/Kraft)

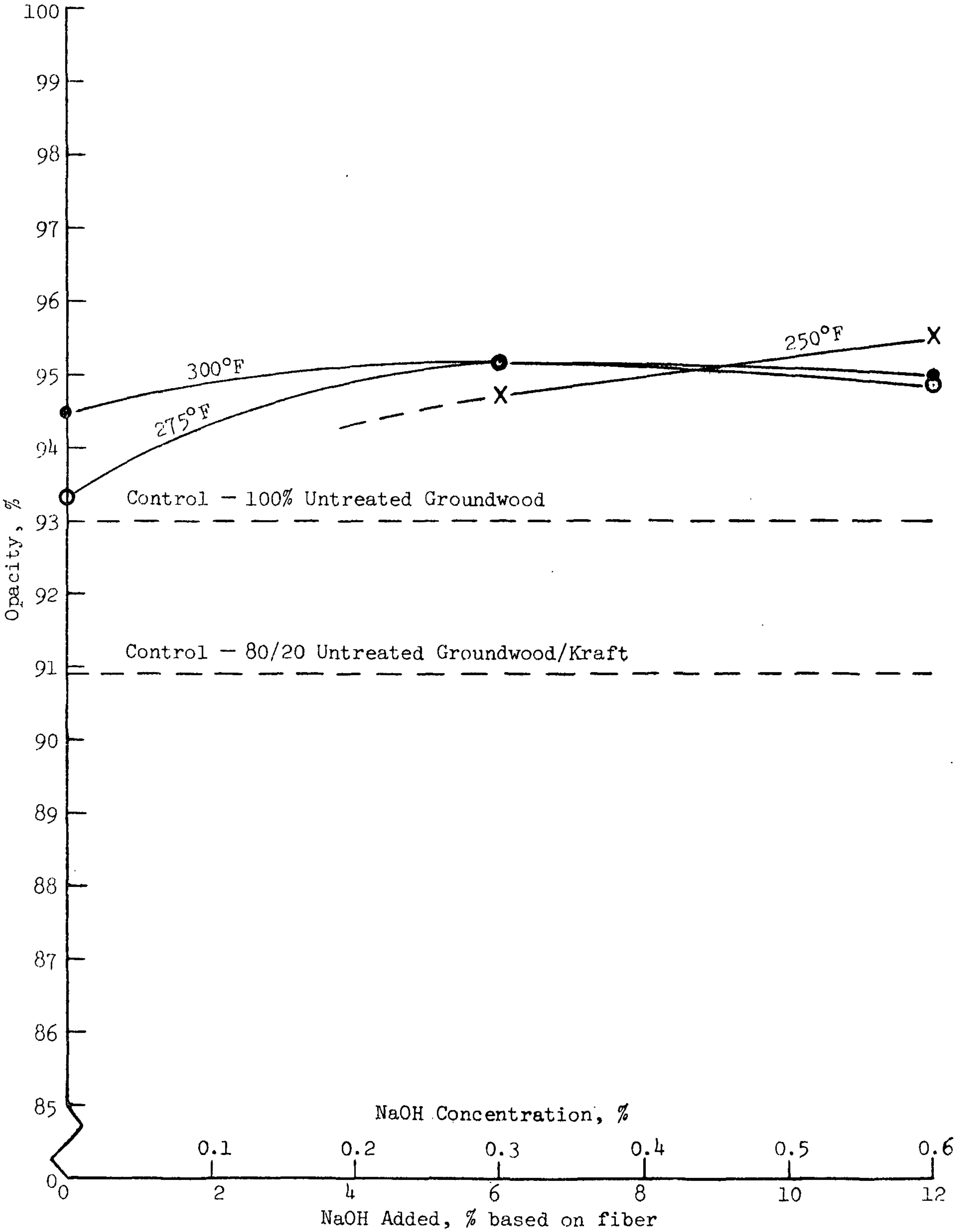

Figure 10. The Effect of Alkali Level and Processing Temperature on Opacity (100% Southern Pine Groundwood)

TABLE V

GROUNDWOOD SUSPENSION DATA — JET/ALKALI-TREATED SOUTHERN PINE STONE GROUNDWOOD

Pulp No.	NaOH Added, % based on fiber	NaOH Concn. in Soln., %	Processing Temp., °F	Dwell Time, sec	pH of Pulp Slurry		Total Solids in Pulp Slurry, %	Soluble Solids in Pulp Slurry, %	Yield, %	Free NaOH		Combined NaOH		Total NaOH	
					Before Cook	After Cook				Meq/ 100 ml	Mg/g	Meq/ 100 ml	Mg/g	Mg/g	% Accounted for
6	None	--	300	6	7.5	7.8	4.28	0.04	99.1	--	--	0.27	2.52	2.52	--
7	6.0	0.3	300	6	13.0	13.0	4.65	0.46	98.0	3.01	25.9	2.24	19.2	45.1	79.6
8	12.0	0.6	300	6	13.3	13.3	4.46	0.78	97.0	8.68	77.9	2.42	21.7	99.6	92.9
9	12.0	0.6	300	13	13.3	13.3	4.45	0.79	96.7	6.43	57.8	2.20	19.8	77.6	72.4
10	None	--	275	6	8.2	7.7	4.54	0.06	99.3	--	--	0.26	2.29	2.29	--
11	6.0	0.3	275	6	13.2	13.0	4.52	0.52	96.3	3.39	30.0	2.16	19.1	49.1	86.8
12	12.0	0.6	275	6	13.3	13.3	4.78	0.80	97.8	9.31	77.9	2.49	20.8	98.7	92.2
13	6.0	0.3	250	6	13.3	13.0	4.43	0.23	96.1	3.23	32.8	2.02	20.5	53.3	94.2
14	12.0	0.6	250	6	13.7	13.4	4.69	0.84	96.5	8.89	75.8	2.21	13.9	94.7	88.4

NOTES: The initial fiber consistency was 5% in all cases.
The freeness of these pulps was 60-65 ml CF.

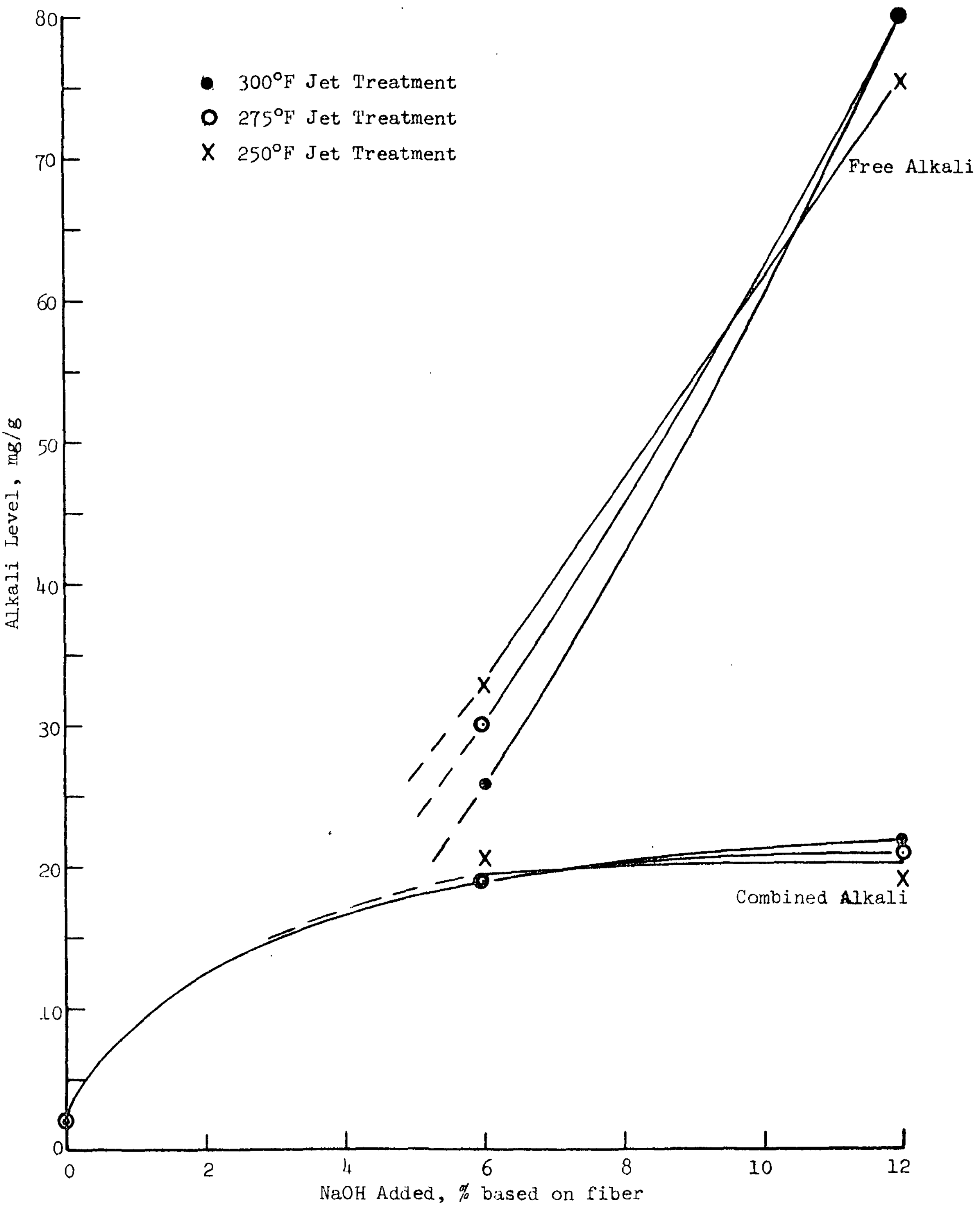

Figure 11. Free and Combined Alkali as a Function of Alkali Addition Level

TABLE VI

MODIFIED JET TREATMENT OF SOUTHERN PINE STONE GROUNDWOOD

(Steam jet treatment for six seconds at 275°F)

Set No.	Fiber Composition	Materials Added Before Jet Cooking, based on fiber	Basis Wt., g/sq m	S.E.	Thickness, µm	S.E.	Density, g/cc	Breaking Length, km	S.E.	TEA, g cm/sq cm	S.E.	Stretch, %	S.E.	Tensile Stiffness, kg/cm	S.E.	Tear Factor (single sheet)	S.E.	MIT Folding Endurance, double folds	S.E.	Bendtsen Air Permeability, ml/min	S.E.	Brightness, %	S.E.	Opacity, %	S.E.	Scattering Coeff., sq cm/g	S.E.
25	Control – 50/50 untrd. groundwood/kraft	--	64.5	0.13	146.3	2.09	0.441	3.49	0.118	42.28	5.827	2.49	0.260	267	1.2	89.0	0.93	30	2.1	339	8.8	61.8	0.21	87.1	0.38	488	8.7
26	Control – 80/20 untrd. groundwood/kraft	--	64.6	0.15	158.5	1.72	0.408	2.99	0.054	27.37	1.740	1.98	0.077	229	3.4	54.2	1.20	6	0.3	320	7.2	56.8	0.19	90.9	0.10	543	2.7
27	Control – 100% untrd. groundwood	--	63.6	0.11	170.0	1.07	0.374	2.46	0.089	13.02	1.735	1.26	0.116	203	6.9	24.2	0.63	1	0.0	340	2.2	54.8	0.11	93.0	0.09	586	2.6
38	80/20 Treated groundwood/kraft	NaOH, 6.0	63.5	0.16	151.4	1.02	0.419	3.32	0.064	27.33	2.107	1.87	0.104	266	5.5	51.7	3.24	7	0.3	232	4.1	48.8	0.11	93.4	0.28	510	8.5
39	100% Treated groundwood	NaOH, 6.0	63.0	0.13	160.5	0.95	0.393	3.07	0.036	17.51	0.899	1.38	0.054	254	9.5	23.5	0.59	1	0.2	242	8.2	45.7	0.21	95.2	0.13	531	3.9
46	80/20 Treated groundwood/kraft	4:1 $NaHSO_3/Na_2SO_3$, 3.0; pH 6.3	63.5	0.14	166.6	0.62	0.381	2.94	0.045	21.53	1.215	1.68	0.064	234	3.0	55.4	0.59	6	0.3	415	7.4	57.8	0.18	91.4	0.27	529	8.8
47	100% Treated groundwood	4:1 $NaHSO_3/Na_2SO_3$, 3.0; pH 6.3	63.7	0.08	184.9	1.48	0.344	2.53	0.026	13.21	0.637	1.27	0.047	203	9.4	24.8	0.77	1	0.0	405	4.7	55.7	0.17	93.9	0.15	589	6.5
48	80/20 Treated groundwood/kraft	NaOH, 6.0; Na_2SO_3, 3.0	64.2	0.16	161.0	1.30	0.399	3.02	0.086	24.79	1.912	1.83	0.080	234	4.1	56.4	0.91	7	0.4	228	8.5	53.8	0.14	91.4	0.24	529	7.0
49	100% Treated groundwood	NaOH, 6.0; Na_2SO_3, 3.0	64.7	0.12	166.6	1.02	0.389	2.64	0.090	13.82	1.705	1.23	0.090	229	4.5	24.1	0.38	1	0.1	172	2.1	50.3	0.11	93.4	0.18	547	4.7
50	80/20 Treated groundwood/kraft	NaOH, 6.0; Na_2SiO_3, 5.0; H_2O_2, 3.0	63.8	0.17	163.1	0.52	0.391	2.90	0.034	21.59	0.707	1.70	0.032	236	3.3	52.1	1.15	5	0.2	255	3.1	59.4	0.11	89.9	0.22	559	6.0
51	100% Treated groundwood	NaOH, 6.0; Na_2SiO_3, 5.0; H_2O_2, 3.0	63.4	0.23	171.2	1.30	0.371	2.36	0.066	11.68	1.255	1.20	0.079	206	3.5	24.3	0.63	1	0.0	258	10.9	56.9	0.12	91.7	0.15	591	5.7
52	80/20 Treated groundwood/kraft	NaOH, 6.0; $NaBH_4$, 0.5 + SO_2[a]	63.3	0.15	154.4	0.95	0.410	3.06	0.110	22.73	2.781	1.71	0.144	244	2.2	54.4	1.28	8	0.3	199	4.1	53.4	0.11	91.1	0.22	512	5.4
53	100% Treated groundwood	NaOH, 6.0; $NaBH_4$, 0.5 + SO_2[a]	64.0	0.29	166.1	1.30	0.385	2.60	0.113	12.90	1.772	1.21	0.104	223	3.2	24.1	0.62	1	0.0	196	2.7	50.6	0.14	93.6	0.12	560	3.8

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[a] pH adjusted to 5.0 with SO_2.

NOTE: The initial fiber consistency in jet cooking was 5.0% in all cases.

TABLE VII

GROUNDWOOD SUSPENSION DATA — MODIFIED JET TREATMENTS OF SOUTHERN PINE STONE GROUNDWOOD

(Steam jet treatment for six seconds at 275°F)

Pulp No.	Agents Added, % based on fiber	pH of Pulp Slurry Before Cook	pH of Pulp Slurry After Cook	Total Solids in Pulp Slurry, %	Soluble Solids in Pulp Slurry, %	Approx. Yield, %
15	4:1 Blend of $NaHSO_3/Na_2SO_3$	6.5	6.8	4.31	0.20	95.4
16	NaOH, 6.0; Na_2SO_3, 3.0	13.4	13.2	5.11	0.75	95.2
17	NaOH, 6.0; Na_2SiO_3, 5.0; H_2O_2, 3.0	12.2	11.4	5.21	0.69	98.5
18	NaOH, 6.0; $NaBH_4$(as Borol), 0.5 + SO_2 to pH 5.0	13.7	13.5	5.35	0.84	98.2

NOTES: The initial fiber consistency was 5% in all cases.
The freeness of these pulps was 50-60 ml CF.

DISCUSSION

As indicated in the experimental section of the report, the conditions utilized in preparing thermomechanical pulps were probably not optimum for aspenwood. This is based primarily on the tendency for the experimental products to lack higher tear strength (Table I) which characterizes thermomechanical pulps (4-6). Further, rather extensive disk refining was required to develop tensile strength to a level which equalled or exceeded that of the chemimechanical reference pulp. Under these conditions, sheet density was quite high and porosity low. Examination of several experimental thermomechanical pulps under the microscope prior to disk refining indicated a reasonable fiber length but the fibers appeared to be rather inflexible and were greatly shortened in subsequent disk refining. However, in spite of these deficiencies, Set 9 was considered acceptable since it would serve primarily as a base line in comparing the effects of subsequent alkaline treatments.

The jet/alkali processing of both the chemimechanical and thermomechanical pulps produced substantial improvements in strength properties as shown in Table II. Actually, the increment of improvement in tensile attributable to the jet/alkali treatment was somewhat higher in the case of the thermomechanical pulp (61-65% vs. 31-37%). However, it becomes apparent in Sets 21-24 that thermomechanical pulping of aspen with alkali can produce greater strength improvements depending upon the alkali concentration.

In comparing the jet/alkali-treated thermomechanical pulp (Sets 19 and 20) with the alkaline thermomechanical pulp at the same effective alkali concentration (Sets 21 and 22), the jet/alkali treatment holds a slight advantage in breaking length and tensile stiffness but the alkaline thermomechanical pulp provided nearly equivalent strength at lower density and higher brightness. Further, the alkaline thermomechanical pulp produced opacities and scattering coefficients which exceeded those of the 80/20 and 100% chemimechanical papers (Sets 11 and 14-16). When the alkali concentration was increased as in Sets 23 and 24 so as to provide an addition level equivalent to that utilized in the jet/alkali process, the resulting product approached a translucent glassine paper in appearance with tensile strength and stiffness properties far exceeding those of the 100% kraft controls. Under these conditions the all-groundwood paper (Set 24) exceeded the blend containing 20% of kraft (Set 23) in breaking length, TEA, tensile stiffness, and folding endurance. Indeed, the folding endurance was 3-4 times that of the 80/20 blend and the 100% kraft control. As might be expected, the paper was of very high density and low porosity, brightness, and opacity.

The yield values in Table III show a general advantage for the jet/alkali process over the alkaline thermomechanical treatments. Under conditions producing roughly equivalent strength (Pulps 2 and 5), the jet/alkali treatment provided a 3% advantage in yield. However, of perhaps greater interest is the yield obtained with Pulp 3 corresponding to Set 24 in Table II. As previously indicated, this hardwood thermomechanical pulp provided tensile and folding strengths well in excess of those provided by the 100% softwood kraft controls; however, the fact that these properties were attained at 82% yield appears quite promising. It is recognized, of course, that the thermomechanical pulps were rather extensively disk refined. Presumably a compromise in strength, density, and optical properties could be achieved at higher yield by thermomechanical pulping with a modest level of alkali followed by a reduced level of refining.

The results in Table IV and Fig. 1-10 again reflect a low level of responsiveness for softwood groundwood to the jet/alkali process in spite of increased temperatures and alkali levels compared to the earlier work (1). The best results obtained in the current program were produced at the maximum processing conditions of dwell time, temperature, and alkali addition level (Sets 34 and 35). The concentration of alkali in solution in that case was 0.6%. However, the strength levels attained under these conditions were only moderately higher than those of the respective 80/20 and 100% groundwood controls (Sets 26 and 27; Fig. 1 and 2). From this standpoint, the southern pine groundwood was even less responsive than the northern softwood utilized in the earlier work in which case alkali concentrations in excess of 0.1% produced tensile strengths exceeding that of the 50/50 groundwood/kraft controls. In the present work, the 50/50 controls were exceeded only in tensile stiffness (Fig. 5 and 6).

The difference in responsiveness in the softwood species may be related to the thickness and uniformity of the cell wall and to the proportion of early and latewood present in the samples. The thick-walled structure of southern pine summerwood compared to that of spruce or balsam fir could conceivably inhibit penetration of alkali and thereby reduce the effectiveness of the process. This would suggest that even more drastic processing conditions would be required for southern pine but the economics of such treatments would probably be prohibitive unless the fiber consistency could be further increased in the jet processing operation.

Another difference between the earlier work with softwood and the current study lies in the effect of the steam jet treatments without alkali. The strength properties of the untreated northern groundwood controls (Table IV; Report Two) were somewhat lower than those of the southern pine groundwood.

Subsequent treatment of the northern wood in the jet cooker without alkali provided rather marked increases in breaking length, TEA, and tensile stiffness. In contrast, jet treatment of the southern pine groundwood without alkali tended to reduce strength below the levels of the untreated controls as indicated in Fig. 1-3 and 5-6. Accordingly, the apparent response to jet/alkali treatment was diminished somewhat by a lower base line. In the final analysis, the maximum strength levels obtained with the two softwood species were not greatly different but the processing conditions required to reach these levels differed considerably.

In line with the lack of responsiveness indicated in the strength properties, the groundwood suspension data (Table V, Fig. 11) show a high level of free alkali and a low level of combined alkali. The combined alkali which proved relatively insensitive to the processing conditions appears to level off at approximately 20-25 mg/g. This level is approximately one-half of that found previously for the more responsive aspen stone groundwood (3).

In an effort to enhance the effectiveness of the jet/alkali process for southern pine, several reducing and oxidizing agents were utilized in the jet treatments with and without alkali. Jet treatment with 6% of alkali at 275°F was selected for most tests considering the economics and the slight advantage offered by this temperature at the lower alkali level. While sodium sulfite and sodium borohydride were previously found to promote strength in aspen (3), none of the agents tested were found effective for southern pine (Table VI). This includes possible sulfonation at pH 6.5 and 13.4. In fact, strength properties were moderately lower in the presence of these agents.

In review, the jet/alkali process was not found to be unique in its effectiveness for improving the properties of aspen mechanical pulps. Thermomechanical pulping with sodium hydroxide provided equivalent or greater strength improvements depending upon the concentration of alkali. The thermomechanical and jet/alkali processes produced roughly equivalent strength properties at equal alkali concentration (0.3% in solution) although the jet/alkali treatment afforded somewhat higher yield. Strength properties exceeding those of the 100% kraft controls were attained by thermomechanical pulping with 1.1% alkali in solution (7.5% addition). In that case, a dense glassinelike paper was produced with a breaking length of 8.29 km and a folding endurance of 1462 double folds. These strength levels were obtained at a yield of 81.9%.

The jet/alkali treatment of southern pine stone groundwood failed to provide substantial improvements in strength properties at alkali addition levels up to 12% and at temperatures up to 300°F. On this basis, southern pine was judged to be less responsive than the northern softwood previously examined on the project (1). Incorporation of sodium sulfite and sodium borohydride failed to enhance the effectiveness of the jet/alkali process for pine in contrast to earlier results with aspen (3).

FUTURE WORK

Several methods for improving the strength properties of aspen stone groundwood and mechanical pulps have been developed under Project 2948. Refinement of these methods to meet the specific needs of a given paper grade or product would lie beyond the scope of this program. In contrast, efforts to improve the properties of softwood groundwood have met with only moderate success due probably to differences in chemical composition and morphology. Softwood groundwood has failed to adequately respond not only to high processing temperatures and to relatively high levels of alkali but also to inorganic oxidizing and reducing agents utilized in conjunction with the jet/alkali process. The utilization of higher alkali and other chemical levels would become economically infeasible at the existing maximum fiber consistency utilized in jet/alkali processing; however, the addition levels could possibly be reduced if the jet cooker were reconstructed to accommodate higher consistencies. Modification to accommodate consistencies of 10-15% would appear to be a worthwhile consideration.

One approach for improving the properties of softwood groundwood which has not been examined would consist of treatments with organic lignin softeners and solvents such as dimethyl sulfoxide and formamide. Conceivably, treatment with agents of this type for short time intervals as afforded by steam jet treatment would promote adequate softening without excessive loss in yield. Another possibility which may already be in the process of investigation elsewhere is thermomechanical pulping with alkali and other lignin reactive materials. In consideration of these points, it is recommended that the project be extended to permit continued examination of means to improve the quality of softwood groundwood.

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