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Cold Caustic Soda Pulping of Eucalyptus Saligna

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COLD CAUSTIC SODA PULPING OF

EUCALYPTUS SALIGNA

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TABLE OF CONTENTS

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SUMMARY

A survey has been prepared covering the literature on the cold caustic soda pulping of Eucalyptus saligna. The survey was broadened to include pulping of all species of Eucalyptus by this particular process.

Experimental pulping of Eucalyptus saligna by the cold caustic soda process under a variety of conditions as well as pulping of aspen wood under one condition led to the following conclusions:

(a) Eucalyptus saligna is suitable for the manufacture of cold caustic soda pulp.

(b) Alkali concentration of 30 grams per liter on full size chips of Eucalyptus saligna produces the best strength properties and fairly good yield.

(c) The use of crushed chips is not advisable at higher alkali concentrations since a loss of strength results. Where low alkali concentrations are used, the crushing of chips improves liquor penetration with a reduction in the quantity of screen rejects.

(d) In no case did the Eucalyptus pulps reach the strength of aspen pulp under the conditions of the experiment.

I. A Brief Description of the Genus Eucalyptus.

Eucalyptus is a large genus of trees of the family of Myrtaceae and is indigenous, with a few exceptions, to Australia and Tasmania.

The ecualypti are rapid in growth. Many species of this genus attain great height, Eucalyptus amygdalina, the tallest known tree, growing as much as 480 ft.

An essential oil is obtained by aqueous distillation of the leaves of this and other species of eucalyptus. This oil consists of many different substances, the most important of which is eucalyptol, a volatile oil, which represents about 70% of the total.

As is well known, eucalypti are the chief species used in pulp and paper making in Australia. There are 400 species of eucalypti, but less than twenty are used in the manufacture of pulp and paper in Australia (11). Experiments to ascertain their utility for pulp and paper manufacture began there as early as 1920. However, it was not until 1938 that the first commercial production of eucalyptus pulp began. Today about seventeen species are used for pulping in different parts of the Commonwealth (18).

Eucalypti thrive well in sub-tropical areas but they will also grow in cold and tropical climates. However, eucalyptus is exigent about the physical conditions and less demanding about the chemical conditions of the soil on account of the tap roots of the tree which need a highly permeable soil (17).

Since 1854, Eucalyptus has been successfully introduced into the South of Europe, Algeria, Egypt, Tahiti, California, South America, South Africa,

India and other countries which have suitable climatic and soil conditions for its successful growth.

Eucalyptus was first brought to Brazil by the Jesuits in 1800, but it was the Companlria Paulista de Estradas de Ferro which was chiefly responsible to introduce the economic planting of the eucalyptus in the State of Sao Paulo and in other parts of Brazil. The progress has been so rapid that there exists over 40 million eucalypti in Brazil today. It is believed that Latin America has no other source so abundant and valuable as eucalypti for meeting the needs of the pulp and paper industry (17).

Eucalyptus fibers are only about one millimeter long but they are very narrow and can be made into a very strong sheet depending on pulping conditions. E. delegatensis, E. dalrympleana, E. oreodes and similar types have fibers with thin walls which are flexible and up to 1.5 mm long. The diameter is between 15-30 microns. The wood has a cellulose content of 50% (1).

II. A Brief Description of E. saligna.

E. saligna is a native of the semi-tropical regions of New South Wales and Southern Queensland, where it is known as Sydney Blue Gum.

It thrives well in sub-tropical and moist mountain areas of South Africa where the trees are now about 40 years old; 10,000 acres have been planted with this species by the Department of Forestry, Union of South Africa. The tree grows very rapidly and adds eight feet in height and one inch in diameter each year (7).

Large areas have been planted with Eucalyptus saligna in Zululand, and Northeastern Transvaal and it has been successfully introduced into Uganda, Kenya, Tanganyka and recently into Nigeria (20). In Latin America one of the species chiefly available is E. saligna. The selection of this species has proved extremely satisfactory in this region (16).

E. saligna grows up to a height of 100 ft.; the circumference of the trunk increases to 26 ft. (3). The Forestry Service in Brazil has established that of all the eucalypti planted there, Eucalypti saligna and grandis gave the best pulp yields. These woods are of medium density and of sufficiently light color to make bleaching easy; they can supply as good a pulp as the best employed in Australia. Trees, eight years of age, gave the best results for pulping (17).

III. Pulping of Eucalyptus saligna by Various Processes.

III.-A. Early Investigations on Chemical Pulping.

The technical literature contains a few publications dealing with the pulping of E. saligna by kraft, soda, sulphite and neutral sulphite semichemical processes, even as early as 1927.

Navarro (12) in his pulping studies of E. saligna and eucalypti species by the sulphite and kraft processes, carried out at the Forest Products Laboratory, Madison, stated that some of his experiments were unsuccessful. However, the best results were reached when E. saligna was pulped to a yield of 47.6%. The age of the tree was 15 years. The investigation also reported that if

the woods were much older, the fibers become plump and the ability to form up properly in papermaking is diminished. The fibers of the younger woods produced a sheet with a formation similar to that of strawpulp. Navarro made fiber measurements of the E. saligna pulp and established that it had an average length of 0.90 mm. A chemical analysis of the wood gave the following results:

Hot water solubility	3.52%
1% NaOH solubility	17.43%
Lignin	33.01%
Cellulose	54.75%
Pentosans	16.50%

The breaking length of the paper was 4985 m.

Other anonymous investigators (2) pulped six year old E. saligna from Zululand by the soda process using 20% sodium hydroxide at a temperature of 160°C for five hours. The results of the experiments showed that a well digested pulp with a yield of 55% could be obtained. The dimensions of the fibers were between 0.8 - 2.1 mm (average 1.4 mm) in length and between 0.0102 - 0.033 mm (average 0.0163) in diameter. The pulp produced a fairly soft, opaque and pale brown paper of good strength but the pulp appeared slightly shivy due to the knotty nature of the wood. Bleaching of this pulp with 20% bleaching powder (on the original weight of wood), gave a yield of 42% (on the original wood). The bleached pulp had the following composition:

Ash	0.33%
Alpha cellulose	85.00%
Beta cellulose	10.02%
Gamma cellulose	4.80%
Copper number	2.04%
Phloroglucinol absorption	1.60%

Soda absorption value	2.09%
Acetone extract	0.46%

Both bleached and unbleached pulps produced papers of similar strength and character.

III.-B. Recent Investigations on Chemical Pulping.

Chittenden, Coomber and Corney (7) pulped E. saligna of about seven years of age from South Africa by the soda and sulphite processes in the laboratories of the Imperial Institute in 1948. The pulping of the wood by the soda process under mild conditions produced a well digested pulp with a fairly good yield. Handsheets made from the pulp indicated good formation but owing to the short fiber nature of the pulp, the paper had low strength properties.

Sulphite digestion of this wood under average conditions resulted in satisfactory yields. However, a small amount of the pulp was improperly cooked. The pulp had also poor strength properties. All the pulps responded readily to beating. A chemical analysis of the sawdust gave the following results expressed on the moisture free material:

Ash	0.7%
Resin (including waxes and fats)	13.0%
Alkali solubility (1% NaOH for 1 hr. at 100°C)	13.2%
Cellulose	54.9%

A microscopical examination of the fibers showed the following results:

	Max.	Min.	Average
Length in mm	1.4	0.6	1.0
Diameter in microns	32	12	19

The results, therefore, indicated that the wood had a fairly high cellulose content and a satisfactory low alkali solubility whereas, the resin content was high.

Chidester and Schafer (8) of the Forest Products Laboratory, Madison, carried out sulphite and sulphate digestions of E. saligna. The sulphite pulping trials indicated that satisfactory chemical pulps could be produced which were suitable for blending with groundwood pulp for the manufacture of newsprint and similar papers. Kraft cooks of E. saligna using 15.6% active alkali as sodium oxide based on the wood,produced a slightly stronger pulp than sulphite cooks. A yield of 48% was reported for the kraft pulp.

Jayme and Branscheid (10) carried out mild sulphite digestions of E. saligna and concluded that the wood gave very strong pulps. The maximum cooking temperature was 120°C - 125°C for a maximum total period of nine hours (six hours at maximum temperature). The cook produced an average yield of 57% and the amount of screens was low. The pulps were mechanically refined very readily and at 65 - 70° Schopper-Riegler, had strength properties comparable to those of spruce sulphite pulps. The investigation also revealed that under optimum conditions, the unbleached pulp had a breaking length of 9450 m, a tearing resistance of 145.5 cm-g/cm, a bursting strength about 5 kg/sq. cm., and a folding endurance of over 3000 double folds. In concluding, the authors stated that a paper of high strength properties could be made from this pulp without the addition of long-fibered cellulosic materials.

III.-C. Recent Investigations on Semichemical Pulping.

Carvalho (6) carried out pulping experiments of E. saligna from Brazil by the neutral sulphite and kraft processes. The neutral sulphite digestion was carried out by treating the chips with 19.7% sodium sulphite expressed

as sodium oxide (on the basis of dry wood), at a temperature of 175°C for four hours. The resultant pulp had a permanganate number of 39.2 and a yield of 57%. Pulping the wood by the kraft process, with 14.83% sodium hydroxide and 29.5% sodium sulphide (expressed as sodium oxide on a dry wood basis), gave a permanganate number of 11.9. Carvalho claimed that the eucalyptus kraft pulp had greater strength properties than imported spruce sulphite.

Francesco and Ceregiolo (14), pulping E. saligna by the neutral sulphite semichemical process, stated that pulp similar to poplar semichemical and superior to beech and chestnut semichemical could be produced.

III.-D. Commercial Production of Pulp from E. saligna.

In spite of the abundant resources of this species in Brazil, South Africa and in other countries, only small scale commercial production of pulp and paper from this wood has been undertaken. A mill in Jundiai, Brazil, manufactures soda pulp from E. saligna and uses 25% imported chemical pulp in the furnish. Another mill at Caseras, Sao Paulo, produces 30 tons of writing, printing and toilet paper from 75% E. saligna and 25% conifer pulp (17).

IV. Cold Caustic Soda Pulping of Eucalyptus Species.

IV.-A. The Cold Caustic Soda Pulping Process.

The cold soda pulping process for wood chips was developed at the Forest Products Laboratory, Madison. Reports were first published in 1951.

Cold soda pulps are produced predominatly from hardwoods by a mechano-chemical process. Pulps of high yields in the range of 88 - 90% are obtained. The cold caustic soda process differs from other methods in that the impregnation of chips is done generally at room temperature.

Penetration is an important variable and depends on the concentration of caustic soda and the time of treatment. Penetration of the liquor into the chips is achieved either at atmospheric or at elevated pressure.

The concentration of caustic soda in the liquor is varied between 20 and 75 grams per liter, depending on the properties of the raw material or the type of pulp to be produced. The soaking period in caustic soda solution is between two or three hours and is followed by a fiberizing stage as in all semichemical processes.

Very little is known about the chemical mechanism of the pulping process. It is believed that caustic soda attacks the fiber bonds by reaction with the acetyl and other acid groups which are reactive even at room temperature, thereby tending to disrupt the fiber bond (13).

IV.-B. Cold Caustic Soda Pulping of Eucalyptus saligna.

Considerable work on cold soda pulping of E. saligna has been sponsored by Parsons and Whitemore, New York, since 1955 but nothing pertaining to this work has yet been published. It was also stated that an active project for the construction of a cold soda newsprint mill is under way (15) using E. saligna as the raw material.

Chidester and Schafer (8) reported that cold soda pulping experiments

were made on a mixture containing 25% each by weight of E. saligna, E. tereticornis, E. alba and E. kertoniana. The chips were steeped in caustic soda solution having a concentration of 75 g/l and the ratio of steeping liquor to wood was 35%. The soaking period was for about two hours at atmospheric pressure. After the soaking period, the chips were fiberized. The yield of pulp obtained was about 90 percent.

The pulp was semi-bleached with 15% of chlorine as calcium hypochlorite in a single stage to a brightness of about 70 percent. News-type paper was made entirely from this pulp and was comparable to standard newsprint, although the opacity and oil penetration were low (8).

IV.-C. Cold Caustic Soda Pulping of Other Eucalyptus Species.

Somerville and Pearson (19) pulped old and regrowth trees of E. regnans, E. obliquas and E. gigantea by the cold soda process in the laboratory and on mill scale trials. Their investigations led them to believe that the pulps from chips in the green state gave the same strength as that from air-dried chips. Higher soaking temperatures about 60^{o}C produced stronger but duller pulps. Freeness had a definite influence on the strength properties of the pulp. At reduced freeness, the burst factor, tear factor, breaking length, drainage time and wet tensile strength increased while bulk decreased.

Bhat and Gupta (4) in their cold soda pulping of E. globulus at room temperature using 25,50 and 75 grams per liter of caustic soda for periods of 2,4,8 and 24 hours produced pulps suitable for the production of cheap grades of writing and printing papers, especially when these were blended with long-fibered pulps such as bamboo. Yields of pulps obtained were between 80 - 83%.

Bugg and Pearson (5) stated that the cold soda pulp from E. regnans had much higher strength properties in burst and tear factors than groundwood pulp from the same tree. The cold soda pulp had higher freeness than groundwood pulp and the energy consumed was just half of that needed for grinding of mechanical pulp.

The study also disclosed that the addition of 20% cold soda pulp to the newsprint furnish made possible an increase of 100 ft. per minute of running speed on the paper machine, resulting in an annual increase in production of over 2,000 tons of newsprint (5).

V. Conclusion.

This literature survey, pertaining to pulping of eucalyptus and E. saligna in particular, has shown that, in the opinion of several workers, E. saligna is an excellent raw material for the manufacture of pulp and paper.

In countries like Brazil, and parts of Africa, where E. saligna is planted on a large scale, this tree could be a valuable source of raw material for pulp and paper in the near future.

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Experimental Design

Objective of the Project:

The purpose of this investigation was to ascertain whether suitable cold caustic soda pulps could be prepared from Eucalyptus saligna.

Experimental Procedure Planned for this Study:

It was planned to carry out cold caustic soda pulping of this wood, using full size and crushed chips. The two pulping variables to be studied will be the effect of alkali concentration and the type of chips viz., full size or crushed. The concentrations of the caustic liquor to be used will be 15, 30 and 60 grams per liter. The steeping of the chips in the caustic liquor at various concentrations will be done at room temperature and atmospheric pressure. The period of soaking of chips will be two hours in all cases.

At the end of the steeping period the residual alkali in the liquor will be estimated. The chips will then be fiberized in a single disk refiner.

The yields of refined and screened pulps will be determined. The strength of the pulps will be evaluated by the beater method according to TAPPI standard procedure. The freeness of the pulps at various times of beating will be recorded.

In addition, it was planned to pulp aspen chips using the best conditions obtained from cold caustic soda pulping of Eucalyptus saligna for a comparative study.

Experimental Work

Raw Material, Method and Equipment Used

I. Wood:

The wood chips of Eucalyptus saligna were obtained from the U. S. Forest Products Laboratory, Madison, Wisconsin. The length of full size chips ranged from one-half to three-quarters of an inch. The crushed chips for the experiments were obtained by passing the full size chips of Eucalyptus saligna through a Bauer refiner using devil-tooth plates, pattern #6995 at a clearance of 0.150 inch. The diameter of the crushed chips was about 0.25 inch. The aspen chips which were used in the experiment were obtained from the Department of Paper Technology, Western Michigan University, Kalamazoo, Michigan, and were from one-half to three-quarters of an inch in length.

II. Preparation of Cold Caustic Soda Pulps

Seven pulping experiments were done. Six of these were carried out with Eucalyptus saligna and one using aspen full size chips. Full size chips of Eucalyptus saligna were used in experiments I, II and VII and crushed chips were used in experiments III, IV and V.

Pulping Procedure:

In all experiments the two variables studied were the effect of alkali concentration and the condition of chips whether full size or crushed. The other variables viz., time of impregnation two hours, temperature 23^{o}C, and liquor to wood ratio 5:1, were kept constant.

For each experiment an equivalent amount of 500 grams of oven-dry chips was weighed out and placed in a plastic bucket. The various amounts of alkali

were then added separately to the weighed chips to obtain an alkali concentration ranging from 15 grams per liter to 60 grams per liter.

pH of Liquor:

The pH of the liquor was determined at the start and end of the steeping period by means of a Beckman pH meter equipped with a glass electrode.

Residual Alkali:

After the impregnation period the excess liquor was separated by filtration and 10 ml of this liquor was titrated against standard hydrochloric acid, and the amount of residual alkali was calculated.

Refining:

With the excess liquor removed, the chips after steeping were refined repeatedly in a single disk Bauer refiner using for the first pass 0.005 inch and for the second and third passes 0.002 inch clearance.

Screening of Refined Pulps:

The refined pulps were screened through a ten-cut flat screen. The screen rejects in experiments I, IV and VII were further refined for one more pass at 0.002 inch clearance and again screened in order to get enough pulp for beater evaluation.

Yield:

After screening, the yields of the screened pulp and rejects were determined.

III. Evaluation of Pulps for Strength Properties by the Standard Beater Method: (T 200 M-45)

For the strength evaluation by the beater method 360 grams of oven-dry screened pulp was used except in experiment I where unscreened pulp was used. The screened pulp and screen rejects were blended in the desired quantities so as to obtain sufficient pulp for the test.

Beating Procedure:

The different pulps were beaten in a valley beater for 0, 5, 15, 25, 35, 45 and 55 minutes except aspen pulp which was beaten for 45 minutes only. The freeness values of the pulps at these intervals were determined according to TAPPI standard method T227 M-50.

Forming of Handsheets:

Handsheets were prepared in accordance with TAPPI standard procedure T205M-58 and these were conditioned in a constant temperature and humidity room as specified by TAPPI standard practice.

Testing of Handsheets:

The handsheets were tested for basis weight, caliper, tensile strength, bursting strength, tearing resistance and folding endurance, according to TAPPI standard procedure T220M-53.

Presentation of Results

Experimental conditions, alkali consumption and yield are shown in Table I A. The values for freeness and physical properties of handsheets are given

in Tables I through VII. Breaking length, burst factor, and tear factor values were calculated based on oven-dry weight. The double folds were determined at a constant temperature and relative humidity of 70°F and 50 per cent respectively.

The values for breaking length, burst factor and tear factor plotted against freeness in ml are shown in Figure I. Beating time versus breaking length, burst factor and tear factor are shown in Figure II. Freeness plotted against beating time is given in Figure III.

Discussion of Results:

I. Pulping Results :

a) Alkali Consumption:

Alkali consumption of pulps ranged from 4.2 - 6.9 per cent based on dry wood. Alkali consumption increased with increase in concentration of liquor. The lowest alkali consumption was in experiment I where a low quantity of alkali was applied with full size chips. The highest alkali consumption of 6.9 per cent was observed when a concentration of 60 grams per liter was used in experiment VII. The alkali consumption of pulp using 30 grams per liter concentration was within a narrow range of 5.6 - 5.9 per cent. Aspen chips in experiment VI consumed 5.0 per cent of alkali based on dry wood.

b) Screen Rejects:

The amount of screen rejects was high when relatively small quantities of caustic soda were used (experiments I and IV). This condition was obviously the result of inadequate liquor penetration.

c) Yield:

The yield of pulps was in the range of 83-90 per cent based on oven-dry wood, if determined before screening. Increased use of alkali resulted in decreased yield.

d) Freeness:

Aspen pulp was the lowest in freeness under the conditions of the experiment. Unbeaten aspen pulp had a Canadian freeness of 340 ml. All Eucalyptus pulps were much higher in freeness which ranged from 600-740 ml. The freeness drop with beating was more pronounced in Eucalyptus pulps prepared from crushed chips than from full sized chips. This may be due to better liquor penetration or may be the result of more fines in the pulp.

II. Strength Characteristics:

Evaluation of the seven experimentally produced pulps by the beater method yielded the following results:

a) The pulp produced from aspen chips was stronger than the six pulps prepared from Eucalyptus saligna.

b) When adequate liquor penetration was achieved, pulp from full size chips was stronger than pulp from crushed chips. This was seen in experiments II and III where full sized and crushed chips were used respectively. The loss in strength observed in experiment III may be due to the reduction in fiber length as a consequence of crushing the chips.

c) At lower alkali concentrations, pulps obtained from crushed chips had better strength properties than pulps obtained from full size chips. This

is apparently due to better liquor penetration (see experiments I and IV).

d) The strength properties of the pulps increased by increasing alkali concentration of the pulping liquor. However, increasing the alkali concentration beyond 30 grams per liter did not show any marked improvement in the strength properties of Eucalyptus pulps.

Conclusions

a) Eucalyptus saligna is suitable for the manufacture of cold caustic soda pulp.

b) Alkali concentration of 30 grams per liter on full size chips of Eucalyptus saligna produced the best strength properties and fairly good yield.

c) The use of crushed chips is not advisable at higher alkali concentrations, since a loss of strength results. Where low alkali concentrations are used, the crushing of chips improves liquor penetration with a reduction in the quantity of screen rejects.

d) In no case did the Eucalyptus pulps reach the strength of aspen pulps under the conditions of the experiments.

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*EXPERIMENTAL CONDITIONS, ALKALI CONSUMPTION AND YIELD

Table 1A

Expt. No.	Wood	Type of Chips	Caustic Soda for Pulping g/liter	Caustic Soda for Pulping per cent on wood	Caustic Soda Consumed per cent on wood	pH of Liquor Start of Steeping	pH of Liquor End of Steeping	Screened Pulp per cent on wood	Screen Reject percent on wood	Total** Yield
I	E.saligna	full size	15	7.5	4.2	12.1	12.1	45.8	41.3	87.1
II	"	"	30	15	5.6	12.2	12.2	82.3	0.67	83.0
III	"	crushed	30	15	5.6	12.2	12.2	84.7	1.17	85.9
IV	"	"	15	7.5	5.9	12.3	12.0	77.1	10.9	88.0
V	"	"	22.5	11.25	5.6	12.4	12.3	89.0	1.3	90.3
VI	Aspen	full size	30	15	5.0	12.3	12.0	86.7	0.5	87.2
VII	E.saligna	"	60	30	6.9	12.6	12.5	79.3	3.3	82.6

NOTES: * In all experiments: Steeping period was 2 hours
Temperature was 23°C
Liquor to wood ratio was 5:1

** Total yield includes screen rejects

STANDARD BEATER EVALUATION OF COLD CAUSTIC SODA PULPS FROM EUCALYPTUS SALIGNA

EXPT. I. Full Size Chips

Concentration 15 grams per liter

Table I

Beating Time Min.	Freeness (C.S.F.) ml	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Length	Tear* Factor	M.I.T. Fold
0	720	Was not possible to form handsheets							
5	708	"		"		"			
15	640	"		"		"			
25	598	61.3	10.0	4.14	0.24	Could not be measured	419	15.3	couldnot be measured
35	520	62.1	9.0	3.62	0.28	"	438	15.8	"
45	460	60.0	8.2	3.47	0.29	"	761	13.7	"
55	355	62.0	7.6	3.11	0.32	"	1019	16.1	"

* Notes that the values were calculated on oven-dry basis weight.

EXPT. II. Full Size Chips

Concentration 30 grams per liter

Table 2

Beating Time Min.	Freeness (C.S.F.) ml.	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Length	Tear* Factor	M.I.T. Fold
0	730	61.2	7.7	3.19	0.31	7.6	1972	37.6	0
5	730	62.1	7.6	3.11	0.32	10.3	2362	39.3	1
15	495	61.5	6.8	2.81	0.35	10.6	2655	39.0	1
25	463	61.3	6.4	2.65	0.38	15.9	3207	37.9	1
35	412	62.3	6.4	2.61	0.38	14.3	3320	37.9	1.2
45	328	59.0	6.1	2.63	0.38	10.1	3572	39.0	1.4
55	262	62.1	5.9	2.41	0.41	14.7	4417	37.0	1.6

* Notes that the values were calculated on oven-dry basis weight.

STANDARD BEATER EVALUATION OF COLD CAUSTIC SODA PULPS FROM EUCALYPTUS SALIGNA

EXPT. III. Crushed Chips

Concentration 30 grams per liter

Table 3

Beating Time Min.	Freeness (C.S.F) m/l	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Length	Tear* Factor	M.I.T. Fold
0	610	62.2	8.0	3.27	0.31	4.5	1867	45.5	0.6
5	488	61.3	7,7	3.19	0.31	5.6	2141	41.6	0.8
15	439	62.2	7.1	2.90	0.34	6.9	2640	43.4	0.8
25	385	61.3	6.5	2.69	0.37	9.3	2955	40.0	1.0
35	309	63.3	6.5	2.60	0.38	11.3	3392	38.9	1.2
45	226	63.4	6.1	2.44	0.41	12.9	3482	32.5	1.6
55	153	61.5	5.6	2.31	0.43	15.1	4002	28.0	1.8

* Notes that the values were calculated on oven-dry basis weight.

EXPT.IV. Crushed Chips

Concentration 15 grams per liter

Table 4

Beating Time Min.	Freeness (C.S.F.) ml	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Length	Tear* Factor	M.I.T. Fold
0	590	61.0	9.6	4.00	0.25	1.58	82	22.8	couldn't be measure
5	570	62.5	9.0	3.66	0.27	2.63	1050	24.5	"
15	490	59.5	7.9	3.37	0.30	2.65	1271	22.5	"
25	444	60.0	7.3	3.09	0.32	3.80	1688	20.0	"
35	319	62.0	7.1	2.91	0.34	4.59	1941	21.8	"
45	272	61.7	6.9	2.84	0.35	4.56	1735	21.7	"
55	177	59.3	6.5	2.78	0.36	5.89	2213	21.6	"

* Notes that the values were calculated on oven-dry basis weight.

STANDARD BEATER EVALUATION OF COLD CAUSTIC SODA PULPS FROM EUCALYPTUS SALIGNA

EXPT. V. Crushed Chips

Concentration 22.5 grams per liter

Table 5

Beating Time Min.	Freeness (C.S.F.) ml	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Factor	Tear* Factor	M.I.T. Fold
0	471	61.2	8.0	3.32	0.30	5.17	1882	33.2	1.0
5	428	62.0	7.5	3.07	0.33	5.82	2073	32.3	1.0
15	333	61.6	6.8	2.80	0.36	7.08	2062	27.6	0.4
25	288	61.2	6.7	2.78	0.36	7.47	2540	26.0	0.8
35	202	62.5	6.5	2.64	0.38	8.90	2700	25.4	1.0
45	160	62.5	6.3	2.56	0.39	9.99	2990	23.8	0
55	94	62.1	6.3	2.58	0.39	11.55	3311	24.9	0.6

*Notes that the values were calculated on oven dry weight.

STANDARD BEATER EVALUATION OF COLD CAUSTIC SODA PULPS FROM ASPEN

EXPT. VI. Full Size Chips

Concentration 30 grams per liter

Table 6

Beating Time Min.	Freeness (C.S.F.) ml	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Length	Tear* Factor	M.I.T. Fold
0	340	61.1	6.07	2.52	0.40	18.5	4310	59.7	7.0
5	288	61.3	5.46	2.26	0.44	19.7	4854	57.1	12.0
15	214	60.8	4.98	2.08	0.48	24.9	5687	49.0	12.2
25	160	62.8	4.88	1.97	0.51	28.2	5441	46.0	25.0
35	120	61.7	4.62	1.90	0.53	29.3	6111	41.0	58.0
45	84	62.8	4.50	1.82	0.55	30.6	6342	46.7	50.0

* Notes that the values were calculated on oven-dry basis weight.

STANDARD BEATER EVALUATION OF COLD CAUSTIC SODA PULP FROM EUCALYPTUS SALIGNA

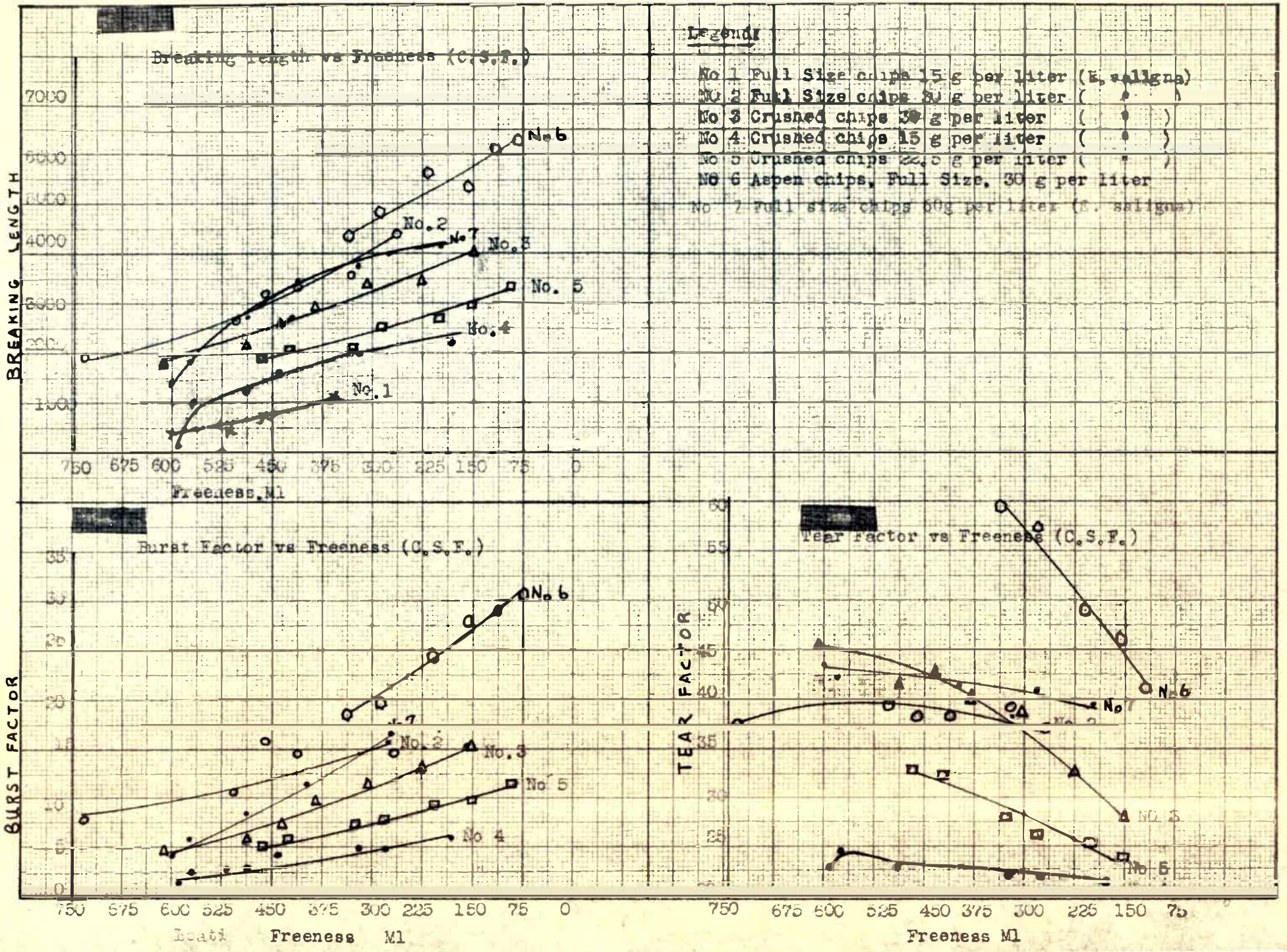
EXPT. VII Full Size Chips

Concentration 60 grams per liter

Table 7

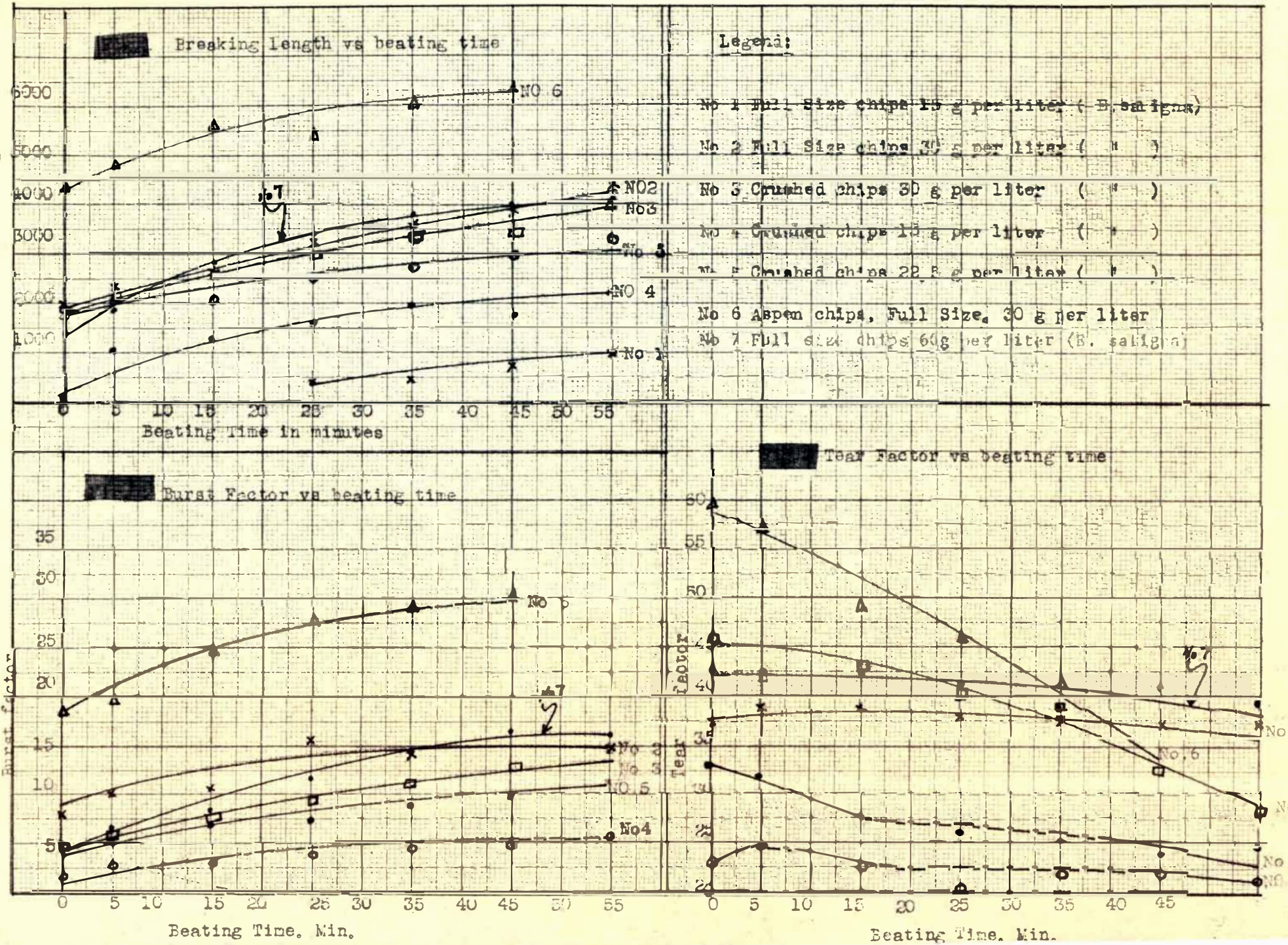
Beating Time Min.	Freeness (C.S.F.) ml	Basis Weight g/m^2	Caliper 0.001"	Bulk cc/g	Apparent Density g/cc	Burst* Factor	Breaking* Length	Tear* Factor	M.I.T. Fold
0	600	62.2	7.94	3.24	0.31	4.4	1040	43.7	0
5	575	62.6	7.46	3.03	0.33	5.9	1893	42.2	0
15	485	62.4	6.98	2.84	0.35	8.3	2743	42.5	1
25	400	63.0	6.61	2.66	0.38	11.5	3394	41.3	2
35	318	61.1	6.13	2.55	0.39	14.5	3722	38.8	2
45	275	60.4	5.57	2.34	0.43	16.5	3925	41.1	2
55	196	61.6	5.46	2.25	0.44	16.3	4124	39.6	2

* Notes that the values were calculated on oven-dry basis weight.


Breaking Length vs Freeness (C.S.F.)
BREAKING LENGTH
7000
6000
5000
4000
3000
2000
1000
No. 6
No. 2
No. 7
No. 3
No. 5
No. 4
No. 1
750 675 600 525 450 375 300 225 150 75 0
Freeness, Ml
Legend
No 1 Full Size chips 15 g per liter (E. saligna)
No 2 Full Size chips 30 g per liter (")
No 3 Crushed chips 30 g per liter (")
No 4 Crushed chips 15 g per liter (")
No 5 Crushed chips 22.5 g per liter (")
No 6 Aspen chips, Full Size, 30 g per liter
No 7 Full size chips 60g per liter (E. saligna)
Burst Factor vs Freeness (C.S.F.)
BURST FACTOR
35
30
25
20
15
10
5
0
No. 6
No. 2
No. 3
No 5
No 4
750 675 600 525 450 375 300 225 150 75 0
Freeness Ml
Tear Factor vs Freeness (C.S.F.)
TEAR FACTOR
60
55
50
45
40
35
30
25
No. 6
No 7
No. 3
No 5
750 675 600 525 450 375 300 225 150 75
Freeness Ml

Standard Beater Evaluation of Eucalyptus Saligna and Aspen Pulps

Fig. 17



Standard Beater Evaluation of Eucalyptus Saligna and Aspen Pulps

Fig. III