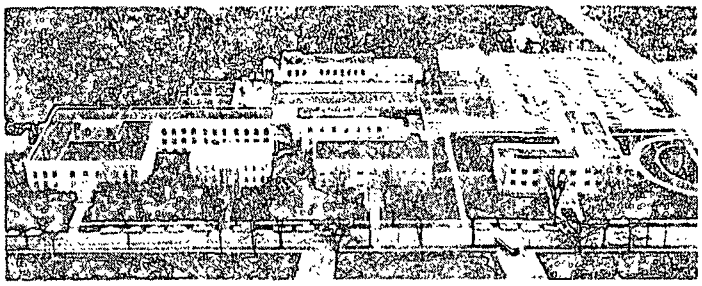

THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

EXAMINATION OF THE PULPING CHARACTERISTICS OF JUVENILE JACK PINE AND EASTERN LARCH WHOLE TREE CHIPS

Project 3364

Report One

A Progress Report

to

MEMBERS OF THE INSTITUTE OF PAPER CHEMISTRY

and

THE UNITED STATES FOREST SERVICE

March 16, 1979

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Appleton, Wisconsin

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SUMMARY

Whole tree chips made from juvenile tamarack (eastern larch) and jack pine, after some preliminary screening, were made into kraft and thermomechanical pulps for evaluation of physical properties. Small samples of jack pine normal wood and compression wood were analyzed for chemical makeup and made into kraft pulps which were also tested for handsheet quality.

The whole tree chips required more chemical for kraft pulping than equivalent chips made from mature stemwood. The kraft pulps from the two wood species were obtained at about the same yield and the pulp strength levels achieved were similar. Yields, as compared with more conventional wood chips, were about 8% lower and pulp physical properties 15-20% lower than would be obtained from stemwood pulps. Dirt content was high but was less noticeable after beating.

Institute thermomechanical pulping experiments were inconclusive because of laboratory equipment shortcomings. In general, raw material with this degree of contamination would be avoided for the production of TMP.

Jack pine compression wood had 25% more lignin than normal wood and was found to have less mannan and more galactan in the wood sugars. Pulp properties data favored the normal wood but the compression wood pulp was abnormally high in lignin content which makes the comparison of questionable value.

INTRODUCTION

The Institute was asked to determine the kraft pulping characteristics of whole tree juvenile eastern larch (tamarack) and jack pine chips provided by the U.S. Forest Service. In addition, a limited program was authorized to demonstrate the applicability of the thermomechanical pulping process (TMP) for this type of raw material. The Institute work in this area had the advantage of reference to similar experiments carried out for the Forest Service by CE-Bauer, Combustion Engineering, Inc., at their Springfield, Ohio pilot plant. A separate study of the influence of reaction wood on the kraft pulping characteristics of jack pine was requested.

As originally conceived, the degree of kraft pulping of the juvenile whole tree chips was to be chosen to simulate high yield linerboard quality kraft pulp. However, since the geographic area of growth of these two wood species is outside that where such a product is ordinarily manufactured, the target pulp quality was changed to a more delignified (ca. 50 kappa number) fiber suitable for unbleached bag paper.

EXPERIMENTAL

RAW MATERIALS

Two drums each of jack pine and tamarack chips were received in October of 1977. One drum of each was thoroughly mixed and packaged in polyethylene bags of about 0.04 cubic meter capacity and put in frozen storage. The remaining drums of chips were stored at 4°C until needed.

In July of 1978 some very wet small blocks of jack pine wood segregated into normal wood (NW) and compression wood (CW) were received at the Institute and reduced to thin chips the length of the as-received blocks.

KRAFT PULPING

The whole tree chips in cold storage were screened on a Sweco screen, using conditions similar to those employed at the CE-Bauer pilot plant. Screen sizes available were 1-inch, 0.5-inch, and 0.25-inch. Wood fragments rejected by the 1-inch screen were collected and given a single pass in a 47-inch Carthage chipper and returned to the screen. Material rejected at this point was discarded as were all particles passing the 0.25-inch mesh screen. The accepts were weighed, thoroughly blended, and returned to cold storage in polyethylene bags holding about 4000 g of o.d. chips. The as-received particle size distribution is given in Table I. Representative samples were hand sorted into the categories given in Table II, which shows their occurrence levels in the two species investigated. Figures 1 and 2 are photographs of the classified wood particles.

TABLE I

SCREEN DISTRIBUTION OF WHOLE TREE CHIPS

As-Received

Species	Jack Pine	Tamarack
On 1-inch, %	2.8	0.8
Through 1-inch, on 1/2-inch and 1/4-inch, %	87.3	97.0
Through 1/4-inch, %	9.9	2.2

*Oven dry solids basis.

TABLE II

COMPOSITION OF SCREENED WHOLE TREE CHIP SAMPLES*

Species	Jack Pine	Tamarack
Clean chips, %	43.4	50.8
Chips with bark, %	27.9	18.0
Knots, %	11.6	8.3
Twigs, %	13.9	14.2
Bark, %	2.3	8.1
Needles, %	0.9	0.6

*Oven dry solids basis.

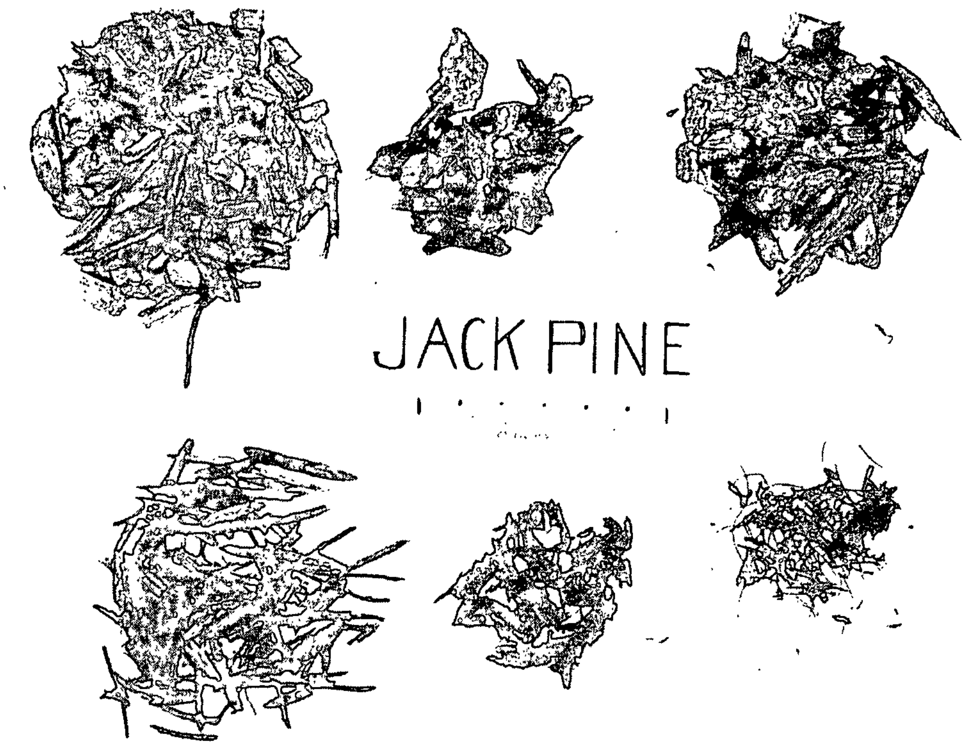

Figure 1. Composition of Juvenile Jack Pine Whole Tree Chips

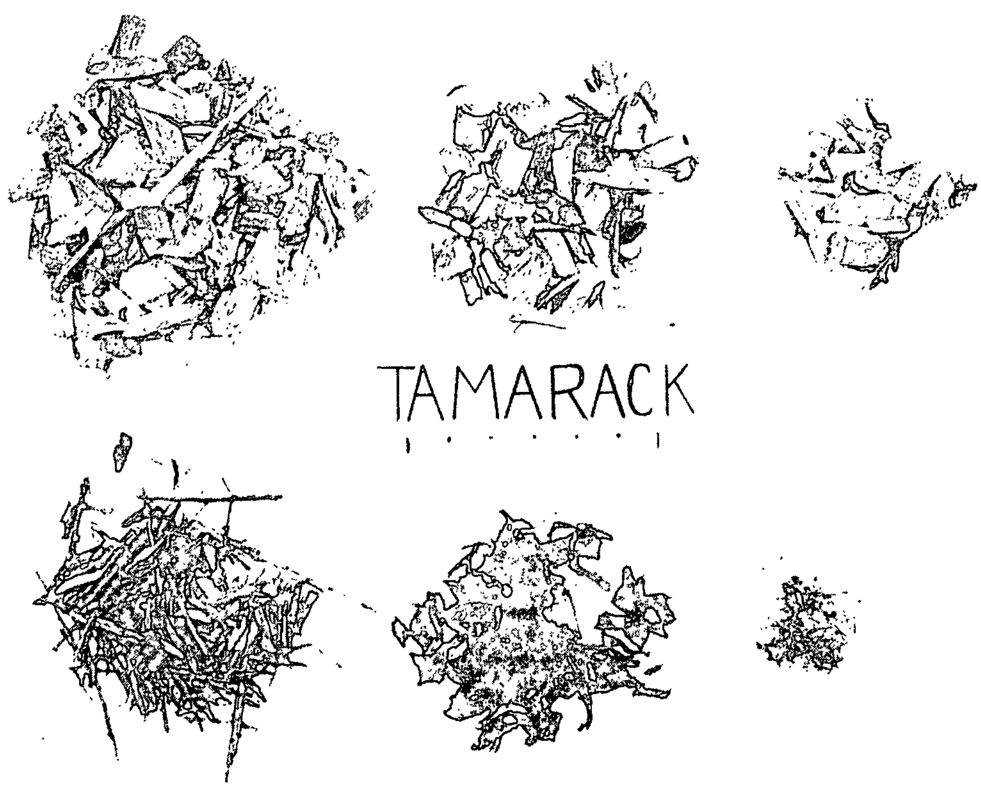

Figure 2. Composition of Juvenile Tamarack Whole Tree Chips

Exploratory digestions were made in a multiunit pulping apparatus described by Thode, et al. (1). Each vessel has a capacity of ca. 450 mL and can conveniently pulp ca. 75 g of wood (moisture-free basis). Of the combinations of usually adjusted variables (chemical dosage, maximum temperature, and time at maximum temperature) the chemical charge and time at maximum temperature were adjusted in an attempt to determine the pulping characteristics of these unconventional raw materials. After a number of digestions, the scatter in the data drew attention to the difficulties in charging the small (450 mL) vessels with samples having an acceptable level of homogeneity. The problem was compounded by some uncertainties as to the precise solids content of the small samples. The preliminary experiments did indicate the need for substantially more chemical for the whole tree chips than for typical coniferous pulpwood chips. Experience would indicate that a charge of 18% active alkali should be adequate to prepare a pulp of 50 kappa number at an H factor (2) of ca. 1800. The need for considerably more chemical than this was indicated and tried.

When a vertical stationary digester of ca. 0.06 cubic meter capacity was used (1), the larger raw material sample size was expected to overcome some of the problems of whole tree chip variability. This vessel was used to attempt to establish minimum and optimum chemical dosage-H factor relationships for both raw materials. Using data from the small digesters, a lower limit of 19% and an upper one of 25% active alkali as Na_2O were chosen. The goal of obtaining two pulps from each wood species, all at 50 kappa number, and comparing the resultant pulps was not realized (see Table III). From these results it is likely that the two pulps outside the kappa number range (a 65.4 kappa number jack pine cooked with 19% active alkali and a 61.8 kappa number tamarack cooked with 25% active alkali) could be obtained with small adjustments of H factor. However, when physical properties data were compared (Table IV), the differences were not such as to encourage the investment of the effort to repeat the cooks.

TABLE III

COOKING CONDITIONS AND PRODUCT VARIABLES

KRAFT PULPING OF JUVENILE WHOLE TREE CHIPS

Cook	115	113	116	114
Material	Jack pine		Tamarack	
Active alkali, as Na_2O, %	19	25	19	25
H factor	1408	897	1582	947
Time at max. temp., min	70	42	75	45
Yield, %	41.1	43.3	42.5	38.7
Kappa no.	51.1	65.4	61.8	48.9

<u>Constant Conditions</u>

Digester charge, g o.d.	4000
Sulfidity, %	28
Water ratio, mL/g o.d.	4
Maximum temp., °C	172
Time to maximum temp., min	90
Relief to 0 psig @ 100°C	

TMP PULPING

The apparatus first used in the TMP experiments is a laboratory Asplund mill. The defibrator portion is a horizontal pressure vessel which has a central shaft directly connected to a 5 hp motor. The shaft has five blades, each the same length as the chamber and each of a width sufficient to just clear the interior wall. Four equally spaced inserts in the chamber wall provide the equivalent of multiple refiner bars against which the rotating blades work to

TABLE IV

PROPERTIES OF JUVENILE WHOLE TREE CHIP KRAFT PULPS

Cook	116	114	115	113	Mill Data[a]
Wood species	Larch		Pine		Pine
Na_2O charge, %	19	25	19	25	--
H factor	1525	1052	1613	897	--
Yield, %	42.5	38.7	41.1	43.3	--
Kappa no.	61.8	48.9	51.1	65.4	33.5
	Properties at 600 mL CSF				
Beating time, min	0	3	2	8	
Sheet density, g/cc	0.637	0.615	0.580	0.650	0.675
Burst factor	50.3	54.8	51.0	54.3	74
Tear factor	109	109	105	89	120
Tensile strength, km	6.95	7.60	6.80	7.35	7.3
	Properties at 500 mL CSF				
Beating time, min	10	11	14	25	
Sheet density, g/cc	0.679	0.667	0.668	0.682	0.730
Burst factor	64.5	67.1	62.6	63.1	84
Tear factor	96.0	95.2	87.5	77.0	101
Tensile strength, km	8.71	8.96	8.60	8.48	9.2
	Properties at 400 mL CSF				
Beating time, min	36	28.5	31.5	37.5	
Sheet density, g/cc	0.737	0.723	0.716	0.692	0.760
Burst factor	77.5	77.6	69.1	65.6	84
Tear factor	80.8	84.0	80.2	75.7	94
Tensile strength, km	10.15	10.48	9.80	8.93	11.2

[a] Jack pine pulp of ca. 30 kappa number — unpublished data.

defiber the raw material. Attached to the defibrator chamber, by a valved, 2-inch pipe, is a chamber in which the raw material can be steamed prior to fiberizing.

In the experiments with the juvenile whole tree samples (and one of jack pine wood fragments hand separated from the debris) the equivalent of 100 g moisture free wood particles was charged to the preheat chamber where they were steamed at 30 psig for 6 minutes. They were then injected by differences in steam pressure into the whirling blades of the defibrator which already contained 800 mL of water. After 3 minutes of fiberizing at 30 psig steam pressure a blow line leading to a 12-inch Sprout Waldron disk mill was opened. The disk mill, fitted with No. 17804 plates, set at zero clearance, discharged into a container. Several such charges were accumulated, dewatered on a muslin covered wash box and heated in a microwave oven before being further refined. This secondary refining was carried out in a separate Sprout Waldron 12-inch disk mill fed by a rotating belt. Hot water addition was metered to the disks to produce a discharge consistency of 5%. The No. 17804 plates were set for a clearance of 0.010 inch. The pulps were next refined in a PFI mill at 10% consistency where they did not display a normal freeness drop. A set of handsheets were made from the trash-free jack pine. Limited data concerning these sheets appear in Table V.

An alternate technique utilized a set of metal mesh trays which could be filled with wood chips and stacked in a vertical stationary autoclave. Steam was admitted directly to the vessel and maintained at 30 psig for 15 minutes. The steamed chips were immediately fiberized at a clearance of 0.1-inch and a consistency of 5% in the Sprout Waldron refiner. After dewatering on muslin and warming in a microwave oven the pulps were returned to the disk refiner for a second pass through at 0.01-inch clearance. Handsheets were made for physical

TABLE V

TMP PHYSICAL PROPERTIES DATA

Pulp Sample Where Prepared	Barked[a] Jack Pine	Whole Tree Jack Pine			Whole Tree Eastern Pine			Mill Pulps[b]	
		IPC		Bauer Bros. Co.	IPC		Bauer Bros. Co.	Spruce	Aspen
Canadian freeness, mL	--	470	230	250	450	230	294	96	123
Bulk, cc/g	3.35	3.27	3.02	3.98	3.38	2.90	4.22	2.83	2.94
Tensile, breaking length, km	0.784	0.707	0.835	1.506	0.839	1.159	1.446	4.185	2.525
Burst factor	--	--	--	4.3	--	--	4.1	28	11
Tear factor	14.7	11.1	12.3	35	15.3	16.9	48	56	21

[a]Asplund mill.
[b]Pakulski, RM-Paper Industry, Nov., 1977.

properties measurements. The quality was so poor as to make handsheet formation and testing a problem. The data obtained are also shown in Table V.

KRAFT PULPING — JACK PINE NORMAL WOOD AND COMPRESSION WOOD

Samples of jack pine normal wood and compression wood were in the form of very thin slices about 1 inch long. Representative samples were analyzed and the chemical makeup of the two wood types is shown in Table VI.

TABLE VI

CHEMICAL ANALYSIS OF JACK PINE

Normal Wood (NW) and Compression Wood (CW)

Sample	NW	CW
Extractives[a], %	3.8	3.4
Klason lignin[b], %	27.5	35.3
Acid soluble lignin[b], %	0.34	0.4
Wood sugars[c], %		
Rhamnan	0.2	0.1
Araban	2.1	1.5
Xylan	7.6	6.0
Mannan	11.6	7.6
Galactan	3.2	8.6
Glucan	40.7	33.4

[a]T 222 os-74.
[b]T 204 os-76.
[c]Tappi 53(2):257-60.

Preliminary pulping experiments utilizing some juvenile jack pine whole tree chips freed of extraneous material indicated the need for an energy input equivalent to 1200 H factor at 19% Na_2O to pulp normal wood to a 50 kappa number. Since compression wood is known to be higher in lignin content than normal wood, an H factor of 1450 was chosen for it. All of the available sample was pulped in each case. The cooking conditions and product variables appear in Table VII. The normal wood kappa number was 58.8 and the compression wood was 120. Because the wood fragments were very thin and liquor penetration was not a limiting factor, even the 120 kappa number pulp fiberized without difficulty. Limited strength testing was undertaken, using the Jokro mill as a refiner. The test results are given in Table VIII.

TABLE VII

PULPING CONDITIONS AND PRODUCT VARIABLES

KRAFT PULPING OF JUVENILE JACK PINE

Experiment	1	2	3
Raw material	Jack pine chips-match stick size	NW	CW
a.d. wt. g	120	101	124
o.d. wt. g	44.5	85	114
H factor	1000	1255	1450
Unscreened yield, %	49.6	55.7	43.6
Kappa no.	67.7	58.8	120

<u>Constant Conditions</u>

Active alkali, as Na_2O, %	19
Sulfidity, %	28
Water ratio, mL/g o.d.	5
Max. temperature, °C	173
Time to max. temp., min	90

TABLE VIII

COMPARISON OF HANDSHEET PHYSICAL PROPERTIES

JUVENILE JACK PINE NORMAL WOOD AND COMPRESSION WOOD STUDY

Pulp	Normal Wood	Compression Wood	50/50 Mixture
Comparison at 0.82 g/cc sheet density			
Beating time, min[a]	26	13.5	20
Canadian Standard Freeness, mL	400	475	490
Burst factor	79.8	52.8	66.2
Tear factor	71.0	43.7	57.4
Breaking length (tensile) km	9.78	7.40	8.59
MIT fold	3800	1260	2900
Bendtsen porosity, mL/sec[b]	85	62	134
Comparison at 490 mL freeness			
Beating time, min[a]	24	13.2	20
Sheet density, g/cc	0.809	0.819	0.82
Burst factor	73.8	52.6	66.2
Tear factor	74.2	43.8	57.4
Breaking length (tensile) km	9.54	7.36	8.59
MIT fold	3460	1240	2900
Bendtsen porosity, mL/sec[b]	98	63	134
Zero span tensile strength, km (av.)	17.08	12.94	14.96

[a]In Jokro mill.
[b]For a 10 cm^2 area at an air pressure of 150 mm of water.

DISCUSSION OF RESULTS

KRAFT PULPING

The nonuniformity of the whole tree chips resulted in a great deal of scatter in the kraft pulping data. This was especially true of the work done in the small vessels of the multiunit digesting apparatus. It led to changes in pulping conditions, which, when made, did not always produce the expected results. As a consequence, many more cooks were performed than would have been necessary with a more homogeneous raw material. Figure 3 gives some idea of the range of kappa numbers at the same yield level obtained over a total of 9 multiunit and 7 vertical stationary digester cooks. This graph would indicate, on the basis of best fit linear regression calculations, that the jack pine had a slight yield advantage. Based only on the vertical stationary digester results such a conclusion would be difficult to defend.

An attempt was made to establish a minimum active alkali charge for effective kraft pulping of these raw materials. The assumption that 19% Na_2O was the minimum of active alkali needed to delignify these samples to 50 kappa number was partially based on previous Institute experience with conventional jack pine chips and it was felt that 25% would provide a safety factor. The preliminary pulping data provided the theoretical H factors for pulping to the target kappa number. It can be seen in Table III that only 2 of the pulps were in the 50 kappa number range. The comparison of physical properties made in Table IV would lead to the conclusion that neither the difference in raw material nor chemical charge was an important factor in determining pulp strength. There were even no major differences in properties between pulps in the 50 as compared with those in the 60 kappa number range, especially at the lower freeness levels. The data shown

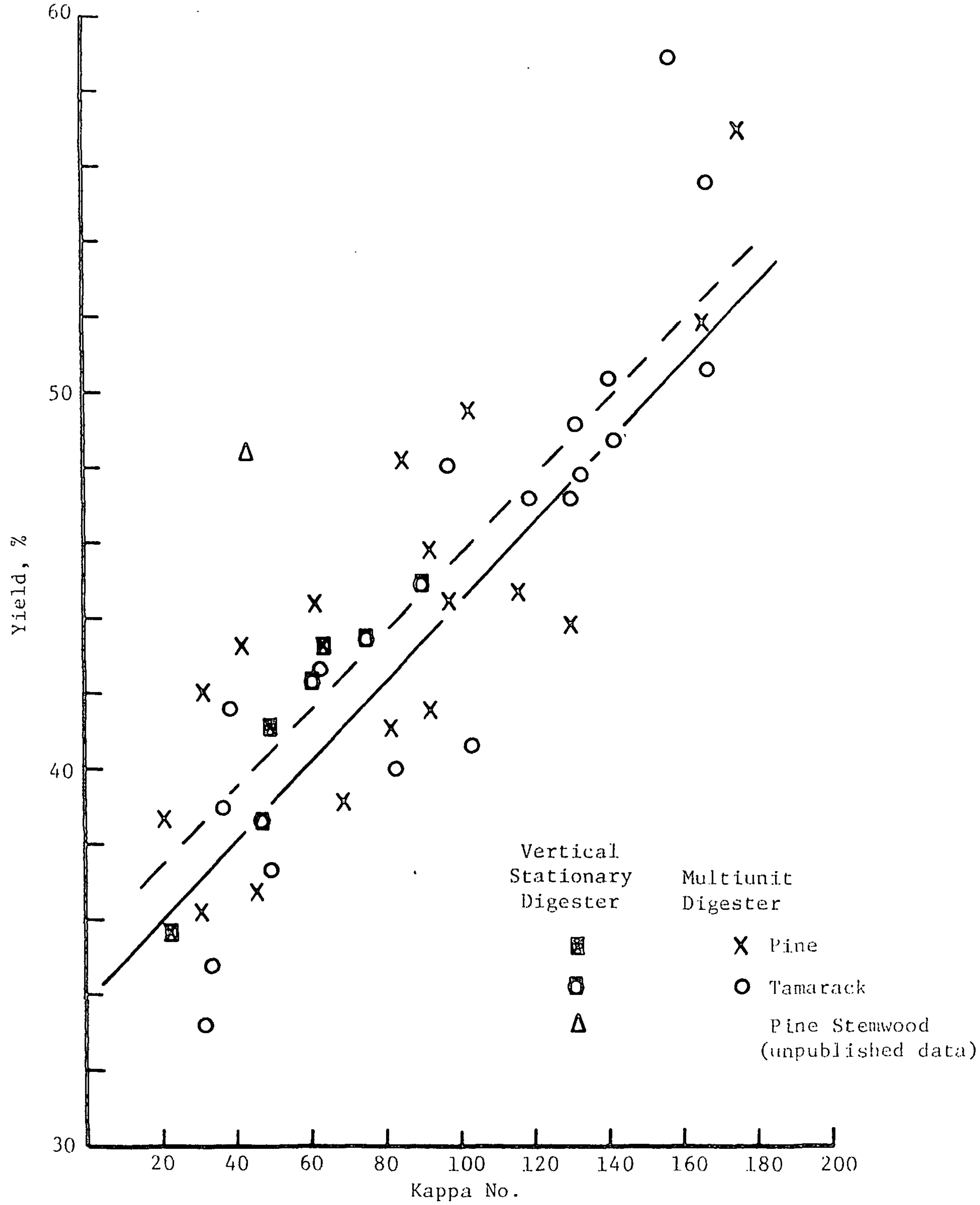

Figure 3. Juvenile Whole Tree Chip Pulping Study, Yield-Kappa Number Relationship

for comparison purposes are from unpublished test results on commercial, never-dried jack pine kraft pulp. The indications are that the whole tree juvenile pulps are about 20% lower in bursting strength and 12% deficient in tearing strength as compared with commercial pulp. Tensile strength differences are less than these amounts. These pulps contain considerably more dirt than commercial unbleached pulp. However, it was observed that, after beating, the dirt was apparently reduced in size to the extent that it became much less noticeable. Since it is unlikely that this raw material would comprise 100% of a mill's wood supply the lower yield and strength properties and higher dirt content may not be of overriding importance. It is our opinion that up to 25% of either of the whole tree chip samples could be incorporated into a more conventional softwood supply without a great deal of upset to a kraft pulping system.

THERMOMECHANICAL PULPING

The Institute's capability of producing a laboratory TM pulp of a quality comparable to a commercial product has never been established with any raw material. It is not surprising, therefore, that the whole tree chip pulps made in this investigation were weak as compared with pulps made in a pilot plant by CE-Bauer, Combustion Engineering, Inc. (The CE-Bauer pulps were, of course, distinctly inferior to softwood commercial pulps.) Efforts to improve the Institute's position in this pulping area, if successful, would permit examining these samples again at a later date. It is our considered opinion, however, that mechanical pulping would be a poor end use for whole tree chips. Even with improvements in equipment and techniques for dirt removal from pulp, the load on a mill system stemming from the use of whole tree chips of this nature would probably be too great to handle successfully.

JACK PINE COMPRESSION WOOD STUDY

A more generous sample of the raw material would have permitted a preliminary investigation of pulping parameters. Lacking this, a procedure was chosen and applied arbitrarily. The result was the accumulation of data of limited use. The analytical information is, of course, valid. It was also learned that the compression wood, even at a high lignin content, beat more readily than normal wood pulp. When the pulps were mixed in equal parts before beating, the results were almost identical to the theoretical values, based on individual results. The one exception is porosity. The anomalous value reported for the 50/50 mixture has no immediate explanation. The test is, however, very dependent on handsheet quality and the presence of a small pinhole in one sample could affect the results.

CONCLUSIONS

The following conclusions may be drawn from the experimental work covered by this report.

1. The composition of a supply of whole tree chips from juvenile wood stands will be highly dependent upon the kind of screening or classification included in the chip preparation and the decisions made in regard to the amount and kind of rejects.

2. Kraft pulps can be made from these raw materials which will be about 8% lower in yield than pulps from debarked coniferous pulpwoods of the same species.

3. Bursting and tearing strengths of the juvenile wood whole tree pulps will be 15-20% lower than conventional kraft pulps made from these two wood species. Tensile strength properties will be less different.

4. The juvenile wood whole tree kraft pulps will have a much greater dirt count than their conventional counterparts.

5. There should be little difference between tamarack and jack pine in ease of pulping, chemical requirements, yield, or pulp quality.

6. If the juvenile whole tree chips are used as a diluent to a larger stream of conventional chips, it is estimated that 10% would cause little upset in the process and that as much as 25% might be tolerated if the product is not intended for bleaching.

7. Whole tree chips would not be desirable as TMP raw materials because of the potentially troublesome contaminants (bark, needles, field dirt, etc.) which they would introduce to the papermaking process.

8. Jack pine compression wood differs substantially from normal wood in chemical composition. As expected, the lignin content is more than 25% greater. When the distribution of wood sugars is corrected for differences in lignin content it can be seen that mannan in the compression wood is 77% that of normal wood while the galactan content is more than three times greater.

9. Comparison of physical properties of pulps made from normal and compression wood should be made cautiously in view of the disparity in lignin contents.

10. A yield of only 43.6% for compression wood pulp of 120 kappa number would indicate that the yield at the same kappa number as the normal wood pulp would be at least 10% lower; i.e., about 33.5%.

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