TRIAL OF A DOUBLE-DRUM FLAIL DELIMBER/DEBARKER PROCESSING SMALL-DIAMETER FROZEN TIMBER: PHASE II

Size Distribution and Composition of Process Flows,
Chemical Pulping Trials

Forest Engineering Research Institute of Canada[1]

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DISCLAIMER

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ABSTRACT

The winter performance of a satellite chipping plant in Alberta was the subject of a four-week field trial undertaken in 1989 by the Forest Engineering Research Institute of Canada (FERIC). The plant employed a double-drum chain-flail delimber/debarker in series with a four-knife roadside disc chipper. The detailed analysis of the process flows and the evaluation of pulps prepared from some of the furnishes, conducted by the Pulp and Paper Research Institute of Canada (Paprican), are discussed in this report.

When small-diameter full trees—i.e. black spruce, and a spruce-pine blend—were processed, bark contents of 2.5 and 1.7% respectively (oven-dry basis) were realized in the product chips. Wood losses of 14.1 and 6.8% were incurred by the flail, compared to 3.3 and 2.1% by the chipper. (Not measured was the loss of material associated with the handling of stems into the flail.)

When lodgepole pine pulpwood logs were fed through the system, wood losses of 6.6 and 6.4% were incurred by the flail and the chipper respectively in producing chips with a bark content of 4.1%.

Chips produced from large-diameter aspen logs had a bark content of 4.2%; from fire-killed timber, 1.1%; and from western red cedar, 7.1%.

Chips made from spruce-pine logs that were debarked instead with a ring debarker contained 0.7% bark. Wood losses associated with ring debarking and roadside chipping were 3.9 and 0.8% respectively.

Kraft pulps prepared from the spruce-pine furnish and from the pine pulpwood were similar to those prepared from the logs debarked with the ring debarker, which suggests that the action of the flail was not deleterious to pulp quality.

Keywords: Delimbing, Debarking, Flail delimber-debarker, Chipping, Full-tree chips, Chip quality, Satellite operations, Pulpwood, Chemical pulping, Furnish, Pulp quality, Peterson Pacific 4800, Chain-flail delimber debarker, Morbark 22RXL Chiparvestor.

PREFACE

This, the second of two reports on winter trials with a satellite chipping plant, is concerned with the detailed analysis of the various process flows generated during the trials, and with the possible effects of a chain-flail delimber/debarker on pulp quality. It both complements and supplements the first report (Sauder and Sinclair 1989), which was prepared by the Forest Engineering Research Institute of Canada (FERIC), and which is concerned with the organization and conduct of the study, the performance and production of the equipment, and the associated economics of the operation.

ACKNOWLEDGEMENTS

The work described in this report entailed the careful handling and detailed analysis of a substantial amount of material, all of which was ably attended to by Mr. D.W. Dranfield and Ms. H.J.P. Herbert of Paprican. Their contributions are gratefully acknowledged. Also acknowledged and appreciated is the assistance provided by the Chemical Pulping Group and the Physical Testing Section at Paprican, Pointe Claire, which made and analyzed the pulps.

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INTRODUCTION

World demand for pulp and paper is expected to increase markedly over the next decade—to 285 million t by the year 2000, as compared to 192 million t in 1985 (Canadian Pulp and Paper Association 1987). The Canadian industry and economy stand to benefit, but only to the extent that economic sources of fibre can be found to support added capacity.

In many regions of the country the annual harvest is close to the allowable annual cut, leaving little margin for industrial expansion. Accordingly, attention has begun to focus on the development of methods and machines which favour increased utilization of the forest resource. One such approach entails the use of portable chain flails to delimb and debark full trees at the forest roadside. The practice is currently the subject of numerous field trials. By way of assessing the effect of winter conditions on performance, a satellite chipping plant, consisting of a chain flail close-coupled with a roadside chipper, was the subject of field trials during February and March 1989, at Hinton, Alberta. The main components of the system were a Peterson-Pacific Model 4800 chain-flail delimber/debarker, and a Morbark Model 22RXL Chiparvestor.

The study was funded by Forestry Canada and Alberta Forestry, Lands and Wildlife through a Canada/Alberta FRDA contract.

The organization and conduct of the field study was attended to by the Forest Engineering Research Institute of Canada (FERIC), in collaboration with the Hinton Division of Weldwood of Canada Limited, and has been documented by Sauder and Sinclair (1989). The task of evaluating the various process flows was undertaken by the Pulp and Paper Research Institute of Canada (Paprican), in Pointe Claire, Quebec, and is the subject of this report.

OBJECTIVES

The analyses carried out by Paprican had the following objectives:

- To assess the quality of the chips produced during the field trials in terms of their size distribution and bark content.
- To determine the composition of the various residue streams.
- To ascertain whether or not the action of a chain flail affects pulp quality.

SAMPLES

Twenty 205-L drums of material were shipped to Paprican's laboratory in Pointe Claire in March 1989. On receipt, the contents of each drum were inspected and crudely weighed (i.e., bag and contents together), and an inventory made of the delivered material.

The provenances of the samples were as follows:

- Spruce-pine - Full-tree black spruce, white spruce, and lodgepole pine, from the Hinton area.
- Black spruce - Full-tree black spruce from the Hinton area.
- Pine pulpwood - Delimbed small-diameter lodgepole pine pulpwood stems from the Grande Cache area.
- Aspen - Delimbed aspen logs from the Hinton area.
- Ring-debarked spruce-pine - Debarked, small-diameter, spruce and pine sawlogs from the Grande Cache area.
- Red cedar - Delimbed western red cedar logs from Prince George, B.C.
- Fire-killed timber - Delimbed spruce-pine stems that were salvaged from a 1988 fire near Hinton.

ASSESSING THE PROCESS FLOWS

Procedure

The procedures that were followed in assessing the chips, and in determining the composition of the residue flows, addressed two needs: that the sub-sample used in the analysis be representative of the parent furnish(es), and that the analysis itself should be sufficiently rigorous to provide the requisite information.

Sample Preparation. In some instances, the entire sample, as provided, was analyzed; however, when the amount of sample was in excess of that needed for analytical purposes, or when it was necessary to prepare a composite from two or more samples, a Model SP-1 Gilson sample splitter was used to obtain a suitably sized representative sub-sample of the parent furnish(es).

Analysis of Chips. A 2.5- to 3.5-kg oven-dry sample of chips was cross-classified, an analysis that entails classifying the sample on a Williams Classifier and then subsequently classifying each Williams fraction in a Domtar Chip Thickness Classifier. Each Domtar fraction is then sorted according to its constituents, i.e. wood, bark, and foliage. The procedure is described in detail in Appendix I. The trays on the Williams Classifier were fitted with 28.6-, 22.2-, 15.9-, 9.5-, 4.8-, and 3.2-mm perforations.

Analysis of Other Process Flows. A 3.0- to 4.0-kg sample was classified in a "green/fresh" state, for a period of 10 minutes, on a Williams Classifier. The contents of each tray were sorted according to constituent (wood, bark, and foliage), oven dried, and weighed. Bark that was attached to wood was scraped free during the sorting phase.

The debris from the flail ranged in size from fine particles of wood, bark, and foliage to sections of trees several inches in diameter by several feet long. In preparing sub-samples, due care was taken to ensure that large fragments were properly represented.

Results

Principal Findings. Figure 1 illustrates both the arrangement of the processing stages that comprised the system, and the source of the samples supplied for analysis. It should be noted that no samples were provided of the landing debris, i.e. the broken tops, branches, etc., which derived from the handling of stems adjacent to the feed of the flail. Figures 2 and 3 indicate the nature of the debris from the flail and the chipper respectively.

Data from the analyses of the chips and from the associated process flows are listed in Table 1; a number of inferences can be drawn.

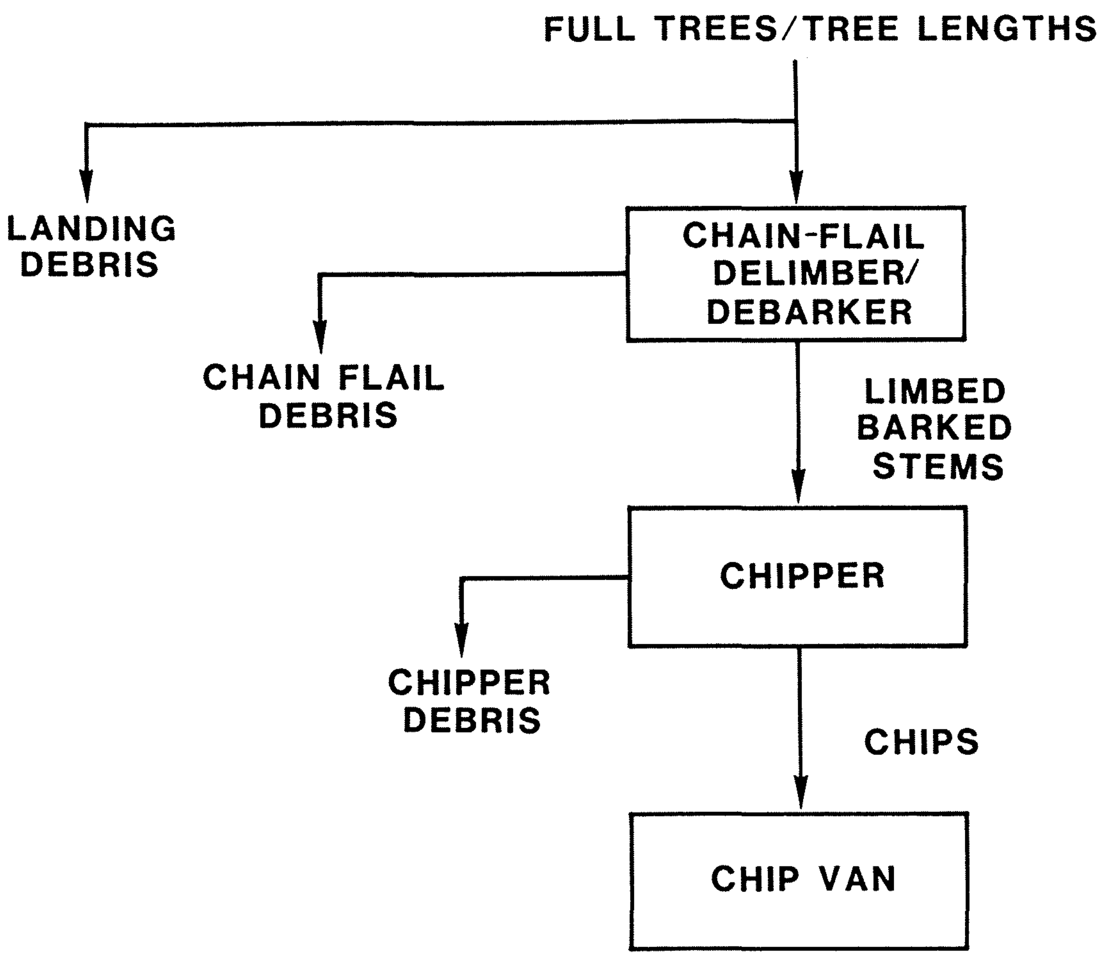

Figure 1. Diagram illustrating the flow of material to, through, and from the roadside chipping plant. Much of the feed was in the form of full trees. Note: The ring-debarked sawlogs were fed directly to the chipper and, as such, were not subjected to the action of the flail.

Figure 2. The extrusion of debris from the flail during the processing of spruce-pine full trees. Note the heterogeneous nature of the debris and, at the top left, the small-diameter material collecting at the feed to the flail—landing debris in the making.

Figure 3. Chipper debris accumulating during the processing of spruce-pine full trees. Large slivers were a feature of this material.

Table 1. Summarized Results from Analyses of Chips and Associated Process Flows

Item	Flail debarked						Ring debarked spruce-pine (%)
	Aspen (%)	Red cedar (%)	Fire-killed timber (%)	Black spruce (%)	Spruce-pine (%)	Pine pulpwood (%)	
Delimber/debarker debris							
Wood	23.4	-[a]	62.9	61.3	48.0	53.5	38.6[c]
Bark	76.6[b]	-	37.1	30.3	40.2	46.5	61.4[c]
Foliage	-	-	-	8.4	11.8	-	-
Chipper debris							
Wood	-[a]	-[a]	90.5	87.0	86.1	86.3	94.5
Bark	-	-	9.5	13.0	13.6	13.7	5.5
Foliage	-	-	-	-	0.3	-	-
Chips							
Inner bark	2.7	-	-	-	-	-	-
Outer bark	1.5	-	-	-	-	-	-
Total bark	4.2	7.1	1.1	2.5	1.7	4.1	0.7
Total bark (excluding fines)							
With flat screen	4.0	5.9	0.9	2.1	1.4	3.3	0.5
With disc screen	4.1	6.1	0.9	2.2	1.5	3.4	0.5
Foliage	-	-	-	-	-	-	-
Chip-size distribution							
Williams (% retained on)							
28.6 mm (1-1/8")	6.7	2.1	4.3	2.3	2.6	3.0	1.7
22.2 mm (7/8")	20.5	7.8	12.0	10.0	12.1	9.0	8.3
15.9 mm (5/8")	28.0	21.3	21.9	21.3	22.6	23.5	22.6
9.5 mm (3/8")	31.2	44.2	37.9	40.8	40.3	39.9	42.9
4.8 mm (3/16")	11.4	19.7	20.2	21.5	19.1	20.3	20.5
3.2 mm (1/8")	0.8	1.8	1.3	1.5	1.2	1.4	1.4
<3.2 mm (<1/8")	1.4	3.1	2.4	2.6	2.1	2.9	2.6
Domtar thickness							
>14 mm	1.7	0.8	0.7	0.2	0.2	0.4	-
12-14 mm	1.3	0.7	0.8	0.7	0.8	0.8	0.5
10-12 mm	2.0	1.7	2.8	1.3	1.3	1.6	1.1
8-10 mm	3.5	3.1	5.0	3.5	3.7	3.5	2.5
6-8 mm	15.5	11.0	11.5	11.6	13.0	10.1	10.8
4-6 mm	45.0	37.0	32.7	35.0	38.9	33.1	33.9
2-4 mm	27.0	36.9	35.7	36.9	34.2	37.5	39.8
0-2 mm	2.4	5.2	8.0	7.3	5.3	9.0	8.1
Fines	1.6	3.6	2.8	3.5	2.6	4.0	3.3
2-8 mm (preferred fraction)	87.5	84.9	79.9	83.5	86.1	80.7	84.5

[a] No sample supplied.
[b] The terms "bark content" and "foliage content" as used in this report are defined as follows:
Bark content (%) = (B • 100)/(B + F + W)
Foliage content (%) = (F • 100)/(B + F + W)
where
B = weight of bark (oven dry)
F = weight of foliage (oven dry)
W = weight of wood (oven dry)
[c] Debris from debarker only.

• Flail Debris. When the flail was used to process softwoods, the debris from the unit contained a high content of wood, ranging from roughly 50 to 60%. The processing of aspen saw a substantially lower content of wood, 23%, in this residue stream. The waste from the Nicholson Model 22A5 ring debarker at Grande Cache, through which softwood logs were processed, contained 40% wood, all of it derived from boles. By contrast, the waste from the flail (50 to 60% wood) also included wood from tops and branches. Accordingly, it can be inferred that the loss of bolewood incurred by the flail is probably similar to that of the ring debarker.

• Chipper Debris. The content of bark in the five samples of chipper debris provided for analysis was at least three times higher than that in the chips themselves. This suggests that the material rejected from the debris chute was derived primarily from the surface of the log rather than from its core. Inspection of the debris (Figure 3) revealed a significant content of large slivers, a product of the very low temperatures (subfreezing) which prevailed throughout most of the field work, and/or of the surface blemishes created by the action of the flail.

The virtual absence of foliage in the chipper debris testifies to its prior removal both by the flail and in the handling of stems between the stump and the flail.

• Chips. In analyzing the aspen chips, attention was paid to the amounts of inner and outer bark entrained in them. The inner bark of aspen is especially problematic in mill operations, and its level in the furnish was therefore the subject of discrete measurement. In analyzing the softwood furnishes, however, the determination of total bark was judged to be sufficient.

The lowest bark content, 0.7%, was obtained with the logs that had been debarked (in a frozen state) with the ring debarker. All of the other furnishes had bark contents in excess of 1%. Red cedar proved to be the most refractory, as evidenced in its bark content of 7.1%. Aspen and the delimbed pine pulpwood were also intractable, with bark contents in the order of 4%.

By comparison, the bark contents reported by Sauder and Sinclair (1989), as determined by Weldwood at its mill at Hinton, are lower than those shown in Table 1—the sole exception being the value for the ring-debarked small sawlogs.[1] The differences may be due to the fact that mill determinations are based on green weights, while those shown in Table 1 are based on oven-dry values. Further, given a mill's need to carry out many such analyses in a finite period of time, the time spent on any given sample must necessarily be kept within reasonable limits, a practice that stands to reveal trends, changes, and differences in bark content, but which probably leads to underestimates of absolute values.

The chips from such an operation would be screened before being pulped. If this could be effected in the field, rather than at the mill, the payload of acceptable chips would increase and, in all likelihood, the profitability of the operation as well. Efforts to develop such screens have not yet proved successful—evidence the failed attempt to employ a portable unit in

[1]Inner bark comprised the residual on these logs. Relatively moist, it would "inflate" an estimate employing green weights.

these trials (Sauder and Sinclair 1989). For the time being then, chip screening seems destined to be carried out at the mill. With regard to bark content, the data in Table 1 indicate that the removal of fines through either flat screening or disc screening would lower it but slightly.

All, some, or none of these furnishes might be acceptable to a mill, depending on its product(s) and methods of production. The amount of bark a mill can tolerate depends on the extent to which its pulping process can accommodate bark without unduly jeopardizing product quality or production, the nature of the bark itself (that of some species being less deleterious than others), and the mill's ability to remove bark at other stages in the stock preparation system (Christie and Smook 1974; Crellin 1983; Hatton 1985).

The situation is aggravated by the fact that the method used to determine bark content varies from mill to mill, hence the comparison of one mill's values with those of another is an exercise in uncertainty. What is certain, though, is that furnishes with low bark contents stand to find wider and more profitable use in pulp and paper manufacture than those with higher ones. Even so, the attainment of low bark contents, inherently desirable in itself, must be weighed against such other factors as the wood loss incurred in achieving them, the lower productivity of a debarking facility, etc.

The Hinton mill accepted almost all the softwood chips produced from the satellite chipping plant. The chips derived from fire-killed stems, however, were rejected because charcoal particles attached to the chips may have contaminated the pulp.

None of the chips, as sampled from the van, contained any foliage.

• Chip-Size Distribution. For many years, the Williams Classifier was widely used by the pulp and paper industry to classify samples of wood chips. The method entails sifting chips on a stack of trays, each of which is fitted with a different size of perforation. The trays are stacked according to hole size, with the largest topmost. In operation, the chips migrate downwards until their size exceeds that of the adjacent perforations. The method does not distinguish between the length, width, and thickness of a chip. Different combinations of screens can be used in fractionating the sample, a license that has led to varied practice and a consequent difficulty in making between-mill comparisons.

The last ten years have seen the introduction of several new types of classifiers, some of which classify chips according to thickness alone, while others employ perforated trays (as in the Williams method) as well as slotted (which classify chips according to their thickness). When used in combination, the slotted trays serve to identify overly thick material, the perforated to indicate the levels of pin chips and fines in a furnish. As a consequence of these developments, classification practices are now more varied than ever, and between-mill comparisons are even more difficult to make.

The data from such analyses are more readily interpreted in some instances than others. For example, chips prepared with a disc chipper are readily classifiable in terms of some intrinsic feature such as thickness—information which bears on their subsequent response to pulping operations. By contrast, it is not clear what inferences can or should be drawn from the classification of headrig chips, many of which have a curved profile and are of variable thickness.

Some mills are obliged to keep chip size within narrow limits. Failure to do so will lead to operating problems. Others can tolerate broader distributions, even though it generally invites sub-optimization. Such differences notwithstanding, it is generally accepted that a high content of fines in a furnish is prejudicial to pulping operations, and for this reason, nearly all mills stipulate that fines should not exceed more than 1.5% of the total furnish (Christie and Smook 1974). Except for the aspen produced in these trials, the percentage of material in the <4.8-mm fraction of the other furnishes was greater than 1.5%. This deficiency could be corrected by screening the chips at the mill—a likely scenario. Of greater concern, is the percentage of pin chips, i.e. percent retained on the 4.8-mm deck. The majority of mills specify that the percentage of such chips should not exceed 12%. All seven softwood furnishes prepared in these trials contained much higher amounts.

The problem could be remedied through screening, but the loss of such a large amount of fibre would penalize the economics of a satellite chipping operation. A more practical approach would be to reduce the production of pin chips by optimizing the trim of the chipper. The unit supplied for these trials was set to produce a 2.22-cm (7/8-inch) long chip. Had it been set instead to produce a 2.5-cm (1-inch) chip, as requested, and as is customary in winter operations, the percentage of pin chips would probably have been lower. Such an adjustment would also have been reflected in higher levels of oversize chips, i.e. >28.6 mm. But, inasmuch as the percentages of oversize chips were, for the most part, well below the "nominal" industry limit of 7%, larger amounts could have been tolerated. Other adjustments are worth exploring, e.g. the use of a different knife angle, and the provision of a back chamfer. The levels of pin chips and fines in the chips produced from the ring-debarked logs were equivalent to those in the chips prepared from the various flail-debarked softwoods. This indicates that while the production of pin chips and fines may have been related to the frozen state of the logs, the sub-optimal setting of the chipper, and/or the relatively small diameter of the logs themselves, it was *not* associated with the action of the chain flail.

Similar criteria apply in the interpretation of data from chip thickness analyses; namely, low contents of fines and of overs are desirable. In addition, rule of thumb has it that a "good furnish" should contain not less than 80% chips in the 2- to 8-mm thickness range, a requirement that all of the furnishes satisfied.

Sauder and Sinclair's data (1989) suggest that chip size was larger than that indicated in Table 1. The differences between the two sets of data are substantial and were the subject of review.

Identical classifiers were used in both sets of analyses. Procedures differed somewhat (e.g., in terms of sample size, and in the duration of screening), but not to the extent suggested by the data. Accordingly, attention focused on chip-sampling practices.

The data shown in Table 1 are based on the analyses of samples collected from chip vans during loading at the forest roadside. From time to time, replicates were taken, to provide some sense of sampling variation. By contrast, the samples analyzed by the mill were obtained with a mechanical chip sampler mounted in the wall of the millyard bin into which the chips were dumped. The unit works well, but must be in proper adjustment to ensure the acquisition of a representative sample. Samples collected when the unit is out of adjustment contain undue amounts of large chips. The differences between the two sets of data probably stem from this effect.[2]

• Wood Loss During Processing. Reference to Sauder and Sinclair's report (1989) provides the data needed to determine the wood loss sustained in the preparation of four of the furnishes. These losses are shown in Table 2.

Inspection of the data reveals that the flail was a prime source of wood loss, the amount varying from modest (7%) to substantial (14%) depending on the furnish. Wood loss incurred by the ring debarker (3.9%) was lower than that from delimbed logs fed through the flail (6.6%). No relationship was discerned between the bark contents attained with the flail and the wood loss incurred in achieving them.

In examining the wood losses shown in Table 2, the following considerations should be borne in mind:

— All of the values are based on partial audits of the harvest. Ideally, such estimates should be referenced to the total amount of wood harvested. In this study, no data were obtained on the harvested weights, nor on fibre losses upstream from the flail. Accordingly, the values shown for the flail are based on audits solely of the chips produced, and of the debris from the debarkers and the chipper.

Table 2. Wood Losses Incurred During Processing

Item	Spruce-pine (full tree) (%)	Black spruce (full tree) (%)	Pine pulpwood (limbed) (%)	Spruce-pine ring-debarked sawlogs (%)
With debris chute on chipper				
Bark content of chips	1.7	2.5	4.1	0.7
Wood loss [a]				
Chain flail	6.8	14.3	6.6	-
Ring debarker	-	-	-	3.9
Chipper	2.1	3.3	6.4	0.8
Total	8.9	17.6	13.0	4.7
Without debris chute on chipper				
Bark content of chips	2.0	2.9	4.8	0.7

[a] Wood loss is defined as the weight of wood in a given debris stream expressed as a percentage of the sum of the weights of wood in all of the debris streams and in the chips themselves. E.g., the wood loss incurred by the flail would be determined as $(W_{FD} \cdot 100)/(W_{FD} + W_{CD} + W_{CV})$
where
W_{FD} = weight (oven dry) of wood in flail debris
W_{CD} = weight (oven dry) of wood in chipper debris
W_{CV} = weight (oven dry) of wood in chip vans.

[2]Personal communication, B. Zieffle, Weldwood of Canada Limited, December 1989.

— Two of the three wood-loss estimates for the flail concern the processing of full trees. Inasmuch as tops and branches were entrained in the flail debris, they are also included in the wood-loss estimates. By contrast, the tops and branches associated with the ring-debarked logs were not entrained in the debarker's waste, and as such were not included in the wood-loss determination.

— Branches were not a feature of either the pine pulpwood or the ring-debarked logs, and hence a comparison of their respective wood losses holds interest. However, the fact that the pine pulpwood was of smaller diameter brings the comparison into question. Small-diameter logs have a higher surface-to-mass ratio than large ones, and thus the loss of surface wood translates to a higher percentage when it is incurred on a small log than on a large one.

The losses associated with the chipper were relatively low, except in the case of the delimbed pine pulpwood. It is not known why the pine pulpwood should have suffered a significantly higher loss. More readily appreciated is the higher wood loss incurred by the chipper in processing flailed wood as compared to unflailed, e.g. logs debarked with a ring debarker. The action of the flail damages the surface of the log, creating sites from which fragments are more readily formed, detached, and discharged as debris.

The wood loss incurred by the chipper could be averted by the use of a unit that is not equipped with a debris chute. However, given the substantial content of slivers in this fraction, and the higher levels of bark that would attend its utilization (see Table 2), the incentive to recuperate this material is slight.

Detailed Results. The compilations which follow are grouped according to the respective process outputs (i.e., ring-debarker debris, flail debris, chipper debris, and chips).

• Ring-Debarker Debris. The composition and size distribution of the debris sampled from a Nicholson 22A5 ring debarker are shown in Table 3. As earlier noted and discussed, this residue contained less wood than the flail debris. Oversize wood, as reflected in the 28.6-mm fraction, was present in significant amounts.

Table 3. Nicholson 22A5 Ring-Debarker Debris: Composition and Size Distribution

	Ring-debarked sawlogs	Wood	Bark	Foliage
Composition				
Sample, oven-dry weight (g)	3 266.4			
Wood (%)	38.6			
Bark (%)	61.4			
Foliage (%)	-			
Size distribution: Williams (% retained on)				
28.6 mm (1-1/8")		31.0	9.2	-
22.2 mm (7/8")		7.4	5.0	-
15.9 mm (5/8")		7.0	9.6	-
9.5 mm (3/8")		31.2	44.3	-
4.8 mm (3/16")		15.3	25.7	-
3.2 mm (1/8")		2.9	4.8	-
<3.2 mm (<1/8")		5.2	1.4	-

• Flail Debris. Data from the analysis of flail debris are compiled in Table 4. The high percentage of wood in the 28.6-mm fraction of most samples testifies to the heterogeneity of this material. The composition and size distributions of the replicate pair (spruce-pine) are judged to be reasonably similar.

Table 4. Flail Debris: Composition and Size Distribution

Item	Aspen			Fire-killed timber		
Composition						
Sample, oven-dry weight (g)		3 783.7			3 147.9	
Wood (%)		23.4			62.9	
Bark (%)		76.6			37.1	
Foliage (%)		-			-	
Size distribution						
Williams (% retained on)	Wood	Bark	Foliage	Wood	Bark	Foliage
28.6 mm (1-1/8")	6.3	18.2	-	31.7	5.4	-
22.2 mm (7/8")	7.6	7.4	-	4.5	8.9	-
15.9 mm (5/8")	10.8	12.0	-	12.0	15.8	-
9.5 mm (3/8")	24.9	17.6	-	25.1	32.3	-
4.8 mm (3/16")	41.2	21.6	-	23.1	27.7	-
3.2 mm (1/8")	2.0	3.5	-	2.6	6.0	-
<3.2 mm (<1/8")	7.2	19.7	-	1.0	3.9	-

	Black spruce			Pine pulpwood		
Composition						
Sample, oven-dry weight (g)		4 019.5			4 341.5	
Wood (%)		61.3			53.5	
Bark (%)		30.3			46.5	
Foliage (%)		8.4			-	
Size distribution						
Williams (% retained on)	Wood	Bark	Foliage	Wood	Bark	Foliage
28.6 mm (1-1/8")	64.3	5.1	-	75.0	15.5	-
22.2 mm (7/8")	5.4	6.1	15.2	2.3	3.5	-
15.9 mm (5/8")	2.2	11.9	13.8	2.2	9.8	-
9.5 mm (3/8")	5.0	32.7	51.9	6.1	25.3	-
4.8 mm (3/16")	9.4	36.0	17.1	11.5	28.9	-
3.2 mm (1/8")	0.9	6.8	2.0	0.9	4.2	-
<3.2 mm (<1/8")	12.8	1.4	-	2.0	12.8	-

	Spruce-pine Replicate 1			Spruce-pine Replicate 2		
Composition						
Sample, oven-dry weight (g)		4 403.3			3 072.1	
Wood (%)		52.4			41.7	
Bark (%)		36.8			45.1	
Foliage (%)		10.8			13.2	
Size distribution						
Williams (% retained on)	Wood	Bark	Foliage	Wood	Bark	Foliage
28.6 mm (1-1/8")	54.2	2.1	2.7	42.8	11.4	17.5
22.2 mm (7/8")	5.9	6.0	20.7	9.2	6.9	14.1
15.9 mm (5/8")	6.1	14.9	18.6	6.7	14.8	19.4
9.5 mm (3/8")	11.1	28.3	41.4	12.2	22.6	34.5
4.8 mm (3/16")	18.0	33.1	15.3	23.6	25.7	13.4
3.2 mm (1/8")	1.4	4.6	1.3	1.7	4.6	1.1
<3.2 mm (<1/8")	3.3	11.0	-	3.8	14.0	-

• Chipper Debris. Inspection of the data compiled in Table 5 indicates that bark generally constituted 10 to 15% of the debris from the chipper, and that its size distribution was similar to that of the associated wood. However, the proportion of wood to bark was significantly higher in the 28.6-mm fraction, where much of the wood was in the form of large slivers.

• Chips. Tables 6 to 10 provide results from the analyses of five samples of the aspen furnish, four of which were collected at the same time and from the same location in the van. Comparison of the replicates (Tables 7 to 10) provides some indication of the variation which can occur between single samples, and of the desirability of using a composite sample to characterize a large volume of chips.

Tables 11 to 16 pertain to the other six furnishes, some of which were sampled intensively. Each of the six analyses was carried out using a composite sample prepared from those provided for the purpose.

The distribution of data within each matrix testifies to the fact that "large" chips, as determined with a Williams Classifier, tend to be thick chips, as established with a Domtar Chip Thickness Classifier. It also holds that "small" chips are thin chips.

Comparison of the data in Tables 7 to 9 indicates little difference between these three of the four replicate aspen samples; bark contents were almost identical, as were the size distributions of the wood, and those of the bark as well. However, the fourth sample, taken at the same time and place, differed markedly from the others, as evidenced in the data compiled in Table 10, which indicate that the chips were substantially smaller and contained a higher content of bark. No less pronounced are the differences between the data shown for Load 1 (Table 6), and those for Load 4 (Tables 7 to 10). Accordingly, the preparation of a representative, composite sample is judged to be important in characterizing a furnish.

Inspection of the totalized data from the Williams analyses reveals that the size of bark particles associated with each furnish was smaller than the wood particles. Even so, the overlap between the respective distributions is substantial, and as such precludes the use of screening to segregate one from the other.

The totalized data from the thickness distributions indicate that the bark was thinner than the wood in all six softwood furnishes. Again, the overlap between the distributions of the wood and the bark in any of these furnishes is too large to permit a significant reduction in bark content through thickness screening. Aspen differed from the softwoods inasmuch as the distribution of its bark was generally similar to that of the wood, tending to be slightly thicker (rather than thinner) in all five of the samples.

Most of the bark in the chips was in the form of discrete particles. The percentage that was not (i.e., bark that was attached to wood) ranged from 0.1 to 0.8%, and averaged 0.4%. Loose bark ranged from 0.5 to 4.9%, and averaged 2.5%.

Table 5. Chipper Debris: Composition and Size Distribution

Item	Fire-killed timber			Black spruce		
Composition						
Sample, oven-dry weight (g)		3 400.6			2 970.3	
Wood (%)		90.5			87.0	
Bark (%)		9.5			13.0	
Foliage (%)		-			-	
Size distribution						
Williams (% retained on)	Wood	Bark	Foliage	Wood	Bark	Foliage
28.6 mm (1-1/8")	6.1	2.0	-	20.0	4.0	-
22.2 mm (7/8")	5.0	4.9	-	7.9	4.7	-
15.9 mm (5/8")	12.6	10.6	-	9.7	9.5	-
9.5 mm (3/8")	35.1	26.4	-	24.7	26.5	-
4.8 mm (3/16")	32.3	36.7	-	28.4	37.9	-
3.2 mm (1/8")	3.2	5.9	-	5.2	10.5	-
<3.2 mm (<1/8")	5.7	13.5	-	4.1	6.9	-

	Spruce-pine Replicate 1			Spruce-pine Replicate 2		
Composition						
Sample, oven-dry weight (g)		3 572.3			3 297.8	
Wood (%)		87.5			84.6	
Bark (%)		12.5			14.9	
Foliage (%)		-			0.5	
Size distribution						
Williams (% retained on)	Wood	Bark	Foliage	Wood	Bark	Foliage
28.6 mm (1-1/8")	9.1	2.5	-	20.0	5.1	-
22.2 mm (7/8")	7.9	5.3	-	8.0	7.0	16.5
15.9 mm (5/8")	11.6	15.4	-	11.3	16.0	13.5
9.5 mm (3/8")	28.7	32.7	-	24.8	30.7	45.9
4.8 mm (3/16")	33.9	30.8	-	27.3	29.6	22.9
3.2 mm (1/8")	2.1	5.0	-	1.7	4.8	1.2
<3.2 mm (<1/8")	6.7	8.3	-	6.9	6.8	-

	Pine pulpwood			Spruce-pine ring-debarked logs		
Composition						
Sample, oven-dry weight (g)		2 916.0			4 282.8	
Wood (%)		86.3			94.5	
Bark (%)		13.7			5.5	
Foliage (%)		-			-	
Size distribution						
Williams (% retained on)	Wood	Bark	Foliage	Wood	Bark	Foliage
28.6 mm (1-1/8")	10.1	1.9	-	23.4	5.0	-
22.2 mm (7/8")	7.7	5.0	-	9.1	9.2	-
15.9 mm (5/8")	13.5	15.1	-	15.3	20.9	-
9.5 mm (3/8")	28.5	25.9	-	18.0	31.4	-
4.8 mm (3/16")	30.4	31.9	-	30.6	26.9	-
3.2 mm (1/8")	2.8	5.4	-	1.7	3.0	-
<3.2 mm (<1/8")	7.0	14.8	-	1.9	3.6	-

Table 6. Composition and Percentage Size Distribution of Chips: Aspen, Load 1, March 8/89, Sample 1 of 1

Sample, oven-dry weight (g) 1 230.2

Bark content	
Loose (%)	4.9
Attached (%)	0.2
Total (%)	5.1

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	1.8	0.5	-	-	-	-	-	2.3	7.6
12-14 mm	1.1	0.1	0.3	-	-	-	-	1.5	1.6
10-12 mm	1.7	0.7	0.2	0.1	-	-	-	2.7	1.3
8-10 mm	1.4	1.3	0.6	0.4	-	-	-	3.7	9.6
6-8 mm	1.3	5.9	5.3	3.4	0.1	-	-	16.0	29.3
4-6 mm	0.5	9.1	15.0	14.3	3.0	-	-	41.9	29.2
2-4 mm	-	0.7	4.5	12.5	8.9	0.3	-	26.9	13.6
0-2 mm	-	-	-	0.2	2.0	0.6	-	2.8	2.7
Fines	-	-	-	-	-	0.3	1.9	2.2	5.1
Total									
Wood	7.8	18.3	25.9	30.9	14.0	1.2	1.9	100.0	
Bark	9.5	0.5	10.1	41.7	30.4	3.8	4.0		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 7. Composition and Percentage Size Distribution of Chips: Aspen, Load 1, March 8/89, Sample 1 of 4

Sample, oven-dry weight (g) 2 516.9

Bark content	
Loose (%)	2.6
Attached (%)	0.5
Total (%)	3.1

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	1.3	0.7	-	-	-	-	-	2.0	1.3
12-14 mm	0.3	0.2	0.1	-	-	-	-	0.6	2.1
10-12 mm	0.4	0.9	0.5	0.1	-	-	-	1.9	3.1
8-10 mm	0.8	1.3	0.7	0.2	-	-	-	3.0	10.1
6-8 mm	1.3	7.2	4.5	2.2	0.1	-	-	15.3	27.6
4-6 mm	1.0	12.1	19.1	13.5	1.3	-	-	47.0	38.0
2-4 mm	-	0.8	5.9	15.0	5.8	0.1	-	27.6	12.7
0-2 mm	-	-	-	0.3	1.3	0.1	-	1.7	1.4
Fines	-	-	-	-	-	0.1	0.8	0.9	3.7
Total									
Wood	5.1	23.2	30.8	31.3	8.5	0.3	0.8	100.0	
Bark	0.4	8.2	25.6	37.8	23.1	2.3	2.6		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 8. Composition and Percentage Size Distribution of Chips: Aspen, Load 4, March 8/89, Sample 2 of 4

Sample, oven-dry weight (g)	2 785.3
Bark content	
Loose (%)	2.2
Attached (%)	0.8
Total (%)	3.0

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.5	0.3	0.1	-	-	-	-	0.9	0.3
12-14 mm	0.1	0.3	0.3	-	-	-	-	0.7	0.5
10-12 mm	0.6	0.6	0.2	0.1	-	-	-	1.5	12.7
8-10 mm	1.0	1.9	0.9	0.3	-	-	-	4.1	9.5
6-8 mm	1.7	8.9	4.8	2.3	-	-	-	17.7	27.4
4-6 mm	1.1	14.6	19.1	15.2	1.1	-	-	51.1	33.0
2-4 mm	-	1.1	4.8	11.2	4.8	0.1	-	22.0	12.7
0-2 mm	-	-	-	0.1	1.0	0.1	-	1.2	1.1
Fines	-	-	-	-	-	0.1	0.7	0.8	2.8
Total									
Wood	5.0	27.7	30.2	29.2	6.9	0.3	0.7	100.0	
Bark	13.5	8.3	14.7	39.4	20.0	1.8	2.3		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 9. Composition and Percentage Size Distribution of Chips: Aspen, Load 4, March 8/89, Sample 3 of 4

Sample, oven-dry weight (g)	2 630.7
Bark content	
Loose (%)	3.0
Attached (%)	0.3
Total (%)	3.3

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.3	-	-	-	-	-	-	0.3	-
12-14 mm	0.3	0.4	0.3	-	-	-	-	1.0	1.5
10-12 mm	0.3	0.2	0.2	-	-	-	-	0.7	6.1
8-10 mm	0.7	1.0	0.8	0.3	-	-	-	2.8	9.2
6-8 mm	1.1	7.1	4.7	1.9	-	-	-	14.8	30.1
4-6 mm	0.8	16.0	20.3	15.0	1.0	-	-	53.1	36.5
2-4 mm	0.1	1.2	5.2	12.8	5.7	0.1	-	25.1	11.0
0-2 mm	-	-	-	0.1	1.1	0.1	-	1.3	0.6
Fines	-	-	-	-	-	0.1	0.8	0.9	5.0
Total									
Wood	3.6	25.9	31.5	30.1	7.8	0.3	0.8	100.0	
Bark	5.9	6.6	25.2	36.9	20.7	2.0	2.7		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 10. Composition and Percentage Size Distribution of Chips: Aspen, Load 4, March 8/89, Sample 4 of 4

Sample, oven-dry weight (g)	2 683.3
Bark content	
Loose (%)	3.6
Attached (%)	0.5
Total (%)	4.1

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.9	0.4	0.1	-	-	-	-	1.4	0.4
12-14 mm	0.8	0.3	0.5	-	-	-	-	1.6	0.7
10-12 mm	0.5	0.2	0.2	0.1	-	-	-	1.0	0.1
8-10 mm	1.4	1.0	0.9	0.3	-	-	-	3.6	3.3
6-8 mm	2.6	3.5	4.4	1.6	-	-	-	12.1	25.0
4-6 mm	1.7	7.7	15.9	14.9	0.9	-	-	41.1	41.3
2-4 mm	-	0.7	5.9	18.6	8.9	0.1	-	34.2	22.7
0-2 mm	-	-	-	0.4	3.1	0.3	-	3.8	4.1
Fines	-	-	-	-	-	0.1	1.1	1.2	2.4
Total									
Wood	7.9	13.8	27.9	35.9	12.9	0.5	1.1	100.0	
Bark	0.7	5.5	15.6	39.6	34.1	3.1	1.4		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 11. Composition and Percentage Size Distribution of Chips: Red Cedar, Composite of 8 Samples

Sample, oven-dry weight (g)	3 043.8
Bark content	
Loose (%)	-
Attached (%)	-
Total (%)	7.1

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.3	0.5	-	-	-	-	-	0.8	-
12-14 mm	0.3	0.1	0.3	-	-	-	-	0.7	5.3
10-12 mm	0.6	0.4	0.6	0.1	-	-	-	1.7	0.4
8-10 mm	0.4	0.8	1.2	0.7	-	-	-	3.1	2.5
6-8 mm	0.3	2.4	4.6	3.5	0.2	-	-	11.0	7.5
4-6 mm	0.2	3.3	11.4	19.0	2.2	-	-	37.0	29.9
2-4 mm	-	0.3	3.2	19.6	13.5	0.3	-	36.9	26.0
0-2 mm	-	-	-	0.4	3.8	1.0	-	5.2	9.6
Fines	-	-	-	-	-	0.5	3.1	3.6	18.8
Total									
Wood	2.1	7.8	21.3	44.2	19.7	1.8	3.1	100.0	
Bark	5.4	2.6	6.6	32.1	30.6	5.5	17.2		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 12. Composition and Percentage Size Distribution of Chips: Fire-Killed Timber, Composite of 6 Samples

Sample, oven-dry weight (g) 3 589.1

Bark content	
Loose (%)	1.0
Attached (%)	0.1
Total (%)	1.1

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.4	0.2	0.1	-	-	-	-	0.7	-
12-14 mm	0.4	0.3	0.1	-	-	-	-	0.8	0.3
10-12 mm	1.0	0.9	0.7	0.2	-	-	-	2.8	0.5
8-10 mm	1.2	1.7	1.5	0.6	-	-	-	5.0	1.0
6-8 mm	1.0	3.3	4.2	2.9	0.1	-	-	11.5	3.6
4-6 mm	0.3	5.1	10.5	15.3	1.5	-	-	32.7	7.0
2-4 mm	-	0.5	4.7	18.1	12.3	0.1	-	35.7	41.5
0-2 mm	-	-	0.1	0.8	6.3	0.8	-	8.0	30.6
Fines	-	-	-	-	-	0.4	2.4	2.8	15.5
Total									
Wood	4.3	12.0	21.9	37.9	20.2	1.3	2.4	100.0	
Bark	0.8	1.3	2.6	24.1	51.8	7.8	11.6		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 13. Composition and Percentage Size Distribution of Chips: Black Spruce, Composite of 27 Samples

Sample, oven-dry weight (g) 3 436.7

Bark content	
Loose (%)	2.1
Attached (%)	0.4
Total (%)	2.5

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	-	0.2	-	-	-	-	-	0.2	-
12-14 mm	0.2	0.2	0.3	-	-	-	-	0.7	0.1
10-12 mm	0.4	0.6	0.2	0.1	-	-	-	1.3	0.3
8-10 mm	0.8	1.0	1.1	0.6	-	-	-	3.5	3.8
6-8 mm	0.6	3.1	4.8	3.0	0.1	-	-	11.6	9.0
4-6 mm	0.3	4.5	11.4	16.9	1.9	-	-	35.0	21.7
2-4 mm	-	0.4	3.5	19.4	13.5	0.1	-	36.9	36.9
0-2 mm	-	-	-	0.8	6.0	0.9	-	7.7	13.7
Fines	-	-	-	-	-	0.5	2.6	3.1	14.5
Total									
Wood	2.3	10.0	21.3	40.8	21.5	1.5	2.6	100.0	
Bark	1.3	2.4	5.6	25.4	46.3	8.0	11.0		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 14. Composition and Percentage Size Distribution of Chips: Spruce-Pine, Composite of 26 Samples

Sample, oven-dry weight (g)	2 796.0
Bark content	
Loose (%)	1.2
Attached (%)	0.5
Total (%)	1.7

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.1	0.1	-	-	-	-	-	0.2	-
12-14 mm	0.3	0.4	0.1	-	-	-	-	0.8	1.1
10-12 mm	0.5	0.6	0.1	0.1	-	-	-	1.3	0.4
8-10 mm	0.4	1.8	1.1	0.4	-	-	-	3.7	6.0
6-8 mm	1.0	3.8	5.2	3.0	-	-	-	13.0	21.1
4-6 mm	0.3	5.1	12.0	19.4	2.1	-	-	38.9	14.5
2-4 mm	-	0.3	4.1	17.2	12.4	0.2	-	34.2	29.6
0-2 mm	-	-	-	0.2	4.6	0.7	-	5.5	11.8
Fines	-	-	-	-	-	0.3	2.1	2.4	15.5
Total									
Wood	2.6	12.1	22.6	40.3	19.1	1.2	2.1	100.0	
Bark	-	7.5	12.6	20.7	39.6	6.6	13.0		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 15. Composition and Percentage Size Distribution of Chips: Pine Pulpwood, Composite of 4 Samples

Sample, oven-dry weight (g)	5 618.5
Bark content	
Loose (%)	3.6
Attached (%)	0.5
Total (%)	4.1

Size distribution of chips [a]

Domtar thickness	Williams hole diameter 28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Total Wood	Total Bark
>14 mm	0.1	0.1	0.2	-	-	-	-	0.4	-
12-14 mm	0.3	0.4	0.1	-	-	-	-	0.8	0.1
10-12 mm	0.6	0.7	0.3	-	-	-	-	1.6	2.3
8-10 mm	0.5	1.3	1.3	0.4	-	-	-	3.5	2.3
6-8 mm	0.8	2.7	4.5	2.1	-	-	-	10.1	5.1
4-6 mm	0.6	3.6	12.5	15.3	1.1	-	-	33.1	15.8
2-4 mm	0.1	0.2	4.5	21.2	11.4	0.1	-	37.5	37.7
0-2 mm	-	-	0.1	0.9	7.8	0.8	-	9.6	16.6
Fines	-	-	-	-	-	0.5	2.9	3.4	20.1
Total									
Wood	3.0	9.0	23.5	39.9	20.3	1.4	2.9	100.0	
Bark	0.3	2.6	7.1	21.1	45.0	6.8	17.1		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

Table 16. Composition and Percentage Size Distribution of Chips: Ring-Debarked Spruce-Pine, Composite of 9 Samples

Sample, oven-dry weight (g)	2 669.9
Bark content	
Loose (%)	0.5
Attached (%)	0.2
Total (%)	0.7

Size distribution of chips [a]

Domtar thickness	Williams hole diameter							Total	
	28.6 mm (1-1/8")	22.2 mm (7/8")	15.9 mm (5/8")	9.5 mm (3/8")	4.8 mm (3/16")	3.2 mm (1/8")	<3.2 mm (<1/8")	Wood	Bark
>14 mm	-	-	-	-	-	-	-	-	-
12-14 mm	0.3	0.2	-	-	-	-	-	0.5	-
10-12 mm	0.2	0.4	0.4	0.1	-	-	-	1.1	1.6
8-10 mm	0.3	0.8	1.0	0.4	-	-	-	2.5	6.5
6-8 mm	0.5	3.4	4.4	2.5	-	-	-	10.8	8.2
4-6 mm	0.4	3.2	13.1	15.8	1.4	-	-	33.9	17.9
2-4 mm	-	0.3	3.7	23.3	12.4	0.1	-	39.8	31.0
0-2 mm	-	-	-	0.8	6.7	0.8	-	8.3	12.0
Fines	-	-	-	-	-	0.5	2.6	3.1	22.8
Total									
Wood	1.7	8.3	22.6	42.9	20.5	1.4	2.6	100.0	
Bark	1.6	2.2	8.1	28.3	32.1	8.1	19.6		100.0

[a] Data in matrix pertain to wood chips, i.e. do not include bark, for which only totals are given.

CHEMICAL PULPING TRIALS

The impact of the chain flail leads to some marring of the surface of the stem, and consequently to a modest increase in the wood lost as debris in a roadside chipping operation. As to whether or not any other penalties attend the practice, it remains to be shown. Of concern is the possibility that flail damage might also prejudice pulp quality. Hence, laboratory kraft pulping trials were carried out to complement the field work.

Ideally, such trials should be carried out with wood harvested from a single site, part of it being debarked with a flail before being chipped and the balance (constituting the "control") being debarked by hand prior to chipping. The exigencies of the field work precluded such an approach. Instead, the pulping trials were carried out using three of the furnishes produced during the study.

Procedure

The following three furnishes were used:

- Full-tree spruce-pine from the Hinton area.
- Delimbed lodgepole pine pulpwood stems from Grande Cache.
- Ring-debarked small-diameter spruce-pine sawlogs from Grande Cache.

The first two constituted "treated" samples, inasmuch as they were derived from stems that had been processed through the flail; while the third was considered to be the "control" because it had not been so processed.

Sample Preparation. As in the preparation of composite samples for chip-size analysis, the Gilson sample splitter was also used to prepare the three furnishes for pulping, 25 kg (green) each.

Each furnish was "screened" in 6-kg (green) increments on the Williams Classifier. On dismantling the trays, following 10 min of oscillation, the bark was hand sorted from the wood chips. The fractions <4.8 mm were discarded.

The remaining bark-free fractions were blended together and a 2-kg (green) sub-sample was set aside for analysis. The balance of the sample was stored in Paprican's cold room.

Chemical Pulping. Six "sighting" trials were carried out in 2-L bombs, and the results used as a guide in fixing the conditions employed in subsequent kraft pulping trials. These latter trials were carried out with a 20-L digester equipped with forced circulation, and entailed presteaming the chips for three 3-min cycles at 138 kPa before adding the cooking liquor.

The following pulping conditions were employed:

Active alkali (as Na_2O)	18%
Percent sulfidity	30%
Liquor-to-wood ratio	4:1
Time to temperature (170°C)	90 min
H factor	Varied as necessary to reach the desired target kappa number of 30—typical of bleachable softwood grades

Results

The size distributions and bark contents of the furnishes prepared for the pulping trials are compiled in Table 17.

The close comparison between the data compiled in Table 17 and their equivalent values in Table 1 testifies to the reproducibility of the analytical procedures employed in this work. As for the furnishes prepared for pulping, they were similar both with regard to their bark contents and their size distributions.

The results from the laboratory pulping trials are shown in Table 18. The data do not reveal any marked differences between the three pulps and as such provide no evidence to suggest that the action of the flail affected pulp quality. A similar inference can be drawn from the data plotted in Figure 4.

Table 17. Analysis of the Furnishes Prepared for Pulping

Item	Spruce-pine	Pine pulpwood	Ring-debarked spruce-pine
Flail processed	Yes	Yes	No
Bark content (%)			
Before sorting	1.6	3.9	0.8
After sorting	0.08	0.08	0.10
Chip size distribution			
Williams (% retained on)			
28.6 mm (1-1/8")	2.4	3.3	2.3
22.2 mm (7/8")	11.1	9.2	9.8
15.9 mm (5/8")	23.8	22.0	23.6
9.5 mm (3/8")	41.1	40.0	40.5
4.8 mm (3/16")	20.2	23.8	22.6
3.2 mm (1/8")	0.8	0.9	0.7
<3.2 mm (<1/8")	0.6	0.8	0.5
Domtar (thickness)			
>14 mm	0.4	0.9	0.3
12-14 mm	-	1.3	1.2
10-12 mm	2.0	1.7	1.1
8-10 mm	3.6	3.4	2.4
6-8 mm	11.6	9.8	9.2
4-6 mm	41.4	33.4	36.6
2-4 mm	34.7	39.0	40.4
0-2 mm	5.6	9.5	8.0
Fines	0.7	1.0	0.8

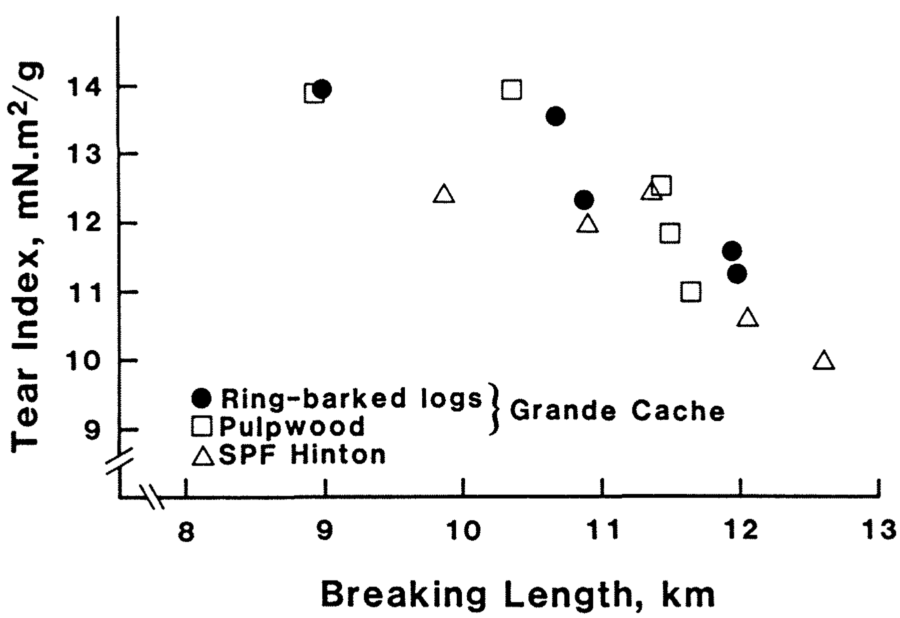

Figure 4. The relationship between tear and breaking length.

Table 18. Selected Results from Kraft Pulping Trials Using Chips Made from Flail- and Ring-Debarked Logs

Item	Spruce-pine	Pine pulpwood	Ring-debarked spruce-pine
Time @ temp. 170°C (min)	100	89	108
H factor	1 753	1 585	1 852
Kappa number	28.6	30.3	29.3
Total yield (%)	46.2	46.9	46.4
Rejects (%)	0.2	0.4	0.2
Handsheet properties [a]			
Bulk (cm^3/g)	1.40	1.41	1.41
Breaking length (km)	11.9	11.6	11.9
Burst index (kPa • m^2g)	10.0	9.8	10.0
Tear index (mN • m^2/g)	10.8	11.9	11.4
Stretch (%)	3.36	3.25	3.23
Zero-span B.L. (km)	21.5	20.7	20.8
Air resistance (s/100 ml)	37	23	31
Scattering coefficient (m^2/kg)	20.0	18.6	16.7
Tappi opacity (%)	89.5	87.3	85.3
Fibre properties (unbeaten pulp)			
Bauer-McNett fibre classification (% retained on)			
14 mesh screen	50.2	51.0	57.8
28 mesh screen	28.4	27.3	18.9
48 mesh screen	10.5	11.2	9.0
100 mesh screen	3.9	4.6	3.5
200 mesh screen	1.1	1.1	0.7
<200 mesh screen	5.9	4.8	10.1

[a] At 525 ml CSF; this being the approximate freeness mid-point in the PFI beating curves of these pulps.

CONCLUSIONS

The work described in this report both complements and supplements the findings of Sauder and Sinclair (1989).

Chips

The six softwood furnishes provided for analysis were similar in several respects:

- All furnishes contained a significant amount of fines (3 to 5%). The amount of fines is reducible through screening.
- All furnishes had high contents of pin chips, in the order of 20%. This is likely a product of chipping relatively small-diameter frozen wood. The fact the ring-debarked logs also yielded a high content of pins, indicates that the surface damage incurred by the flail was not associated with the high levels of small chips.
- By contrast, the levels of oversize chips in the softwood furnishes, in the range of 2 to 4%, were low.

- The fines fractions contained relatively high levels of bark, but not high enough to effect a significant reduction in bark content through their removal by screening.
- Not less than 80% of the chips in each furnish were in the 2-mm to 8-mm range of thickness, as required by most mills that screen chips according to thickness.

By comparison, the aspen furnish, the sole hardwood processed, contained much lower levels of fines and pin chips, and a somewhat higher level of overs. The 87.5% of chips in the 2-mm to 8-mm range was a maximum for these trials. The aspen logs were close to twice the diameter of the other stems and were longer. These are features which favour the production of acceptable-sized chips while minimizing the generation of pins and fines. Yet another factor that may have benefited the aspen trial was the somewhat higher air temperature that prevailed at the time.

Bark contents varied considerably, from a minimum of 0.7% in the chips prepared from frozen softwood logs that had been debarked with a Nicholson ring debarker, to a maximum of 7.1% in the red cedar chips. The bark contents of the other furnishes ranged from roughly 1 to 4%.

The chip-size distributions reported herein differ from those determined by the mill (Sauder and Sinclair 1989)—a consequence, it is thought, of a maladjustment in the mill's chip-sampling device. By being deficient in small-sized material, the mill samples would also contain less bark because bark is more highly concentrated in the small size classes than in the large; indeed, this is evidenced in the data.

Flail Debris

Softwood flail debris contained 50 to 60% wood, while that from the ring debarker contained 40%. The aspen debris was composed of the least wood at only 23%. The debris, both from the flail and from the debarker, was a heterogeneous blend of chunks (presumably topwood) mixed with a substantial amount of comminuted material.

Chipper Debris

The chipper debris contained from 85 to 95% wood, of which 10 to 20% was in the form of large slivers. Debris from fire-killed stems had a somewhat lower content of slivers. In some situations, the inclusion of this material with the chips might be worthwhile.

Process Wood Loss

The loss of wood to process residue was estimated for four of the furnishes prepared in these trials. However, because each furnish was the product of a singular set of conditions—some related to the trees themselves (e.g., to their species, size, form, state) and others to the trim and operation of the equipment—the associated wood losses cannot be compared to each other. Suffice it to say that the wood loss associated with the operation of a chain-flail delimber/debarker in series with a roadside chipper was found to range from 8.9% to 17.6% at sub-zero temperatures.

The estimates are based solely on the weight of recovered wood (i.e., the total of that recovered as chips, as residue from the chipper, and in the debris from either the chain flail or the ring debarker). They bear no relation to the weight of wood harvested, and as such provide no indication of the utilization realized in preparing a given furnish.

Chemical Pulping Trials

The action of the flail was not found to be deleterious to the quality of kraft pulp. Pulping trials indicate that pulps prepared from logs that had been processed through the flail were similar to those made from logs processed by a ring debarker.

The data obtained in these analyses provide some basis for assessing the role of satellite chipping operations in Canada. They point to the considerable benefits and potential of such practice, and they emphasize the need to further rationalize it.

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APPENDIX I

Analytical Procedures for Determining Chip-Size Distribution and Bark Content

1. The sample must be representative of the population from which it is taken. To this end, it is desirable to acquire the sample by means of splitting a much larger mass of chips (e.g., the contents of a 205-L drum) to a suitably sized amount.

   A 3.5-kg (oven-dry basis) sample (±0.5 kg) is required. If a larger amount of material is supplied, use the Gilson SP-1 sample splitter to reduce it.

   In general, subsequent analysis benefits from the sample being in an air-dried or oven-dried state; however, if the data are going to be used to set size specifications for chip screens, then the sample should be analyzed in a green (fresh) state.

2. Set up the Williams Classifier using the appropriate arrangement of trays. Canadian practice varies in this regard, but the most commonly used combinations are:
   i) 1-1/4" (31.8 mm), 1" (25.4 mm), 3/4" (19.0 mm), 1/2" (12.7 mm), 1/4" (6.4 mm), and 1/8" (3.2 mm).
   ii) 1-1/8" (28.6 mm), 7/8" (22.2 mm), 5/8" (15.9 mm), 3/8" (9.5 mm), 3/16" (4.8 mm), and 1/8" (3.2 mm).

3. Place the sample on the top tray of the Williams Classifier and run the unit for 10 minutes.

4. Classify each of the Williams fractions *separately* in the Domtar Thickness Classifier; 3 min of tumbling at the 2-mm setting, 2 min at the 4-mm, and 1 min at each of the subsequent ones.

   If further analysis (e.g., bark content) is *not* required, weigh each cross-classified fraction on its removal from the collection tray, and record the value. Place the fraction in a suitably identified plastic bag.

   If further analysis *is* required, there is no need to weigh the fraction; it can be bagged and labelled directly.

   Note: The action of the Domtar Classifier creates a modest amount of fines. By way of distinguishing what was present in the sample from that generated during the analysis, all weights of fines, except those tallied for the Retained on 1/8" (3.2 mm) and Passing 1/8" (3.2 mm) fractions, are ignored in the percentage distribution.

5. If a determination of bark content is also required, sort each cross-classified fraction into its respective constituents (as specified and required for the purposes at hand), sub-sampling as appropriate and necessary.

6. Measure and record the weights of the sorted constituents. Unsorted material should also be weighed and either tallied as "remainder" in the case of material from which a subsample has been taken and analyzed, or as "indeterminate" in those instances where the readily sorted fragments have been removed from the fraction and a visual estimate made of the bark content of the balance.

   Note: The bark content of the Passing 1/8" (3.2-mm) fraction is usually the subject of visual determination.

   Place each class/size of component in a separate, suitably labelled plastic bag. All such bags should then be stored in a single, larger, tagged bag.

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