Upgrading wood chips: the Paprifer process

R. W. Berlyn and R. B. Simpson

The Paprifer process can make use of whole-tree chips, raw mill chips, chips from partially decayed trees, and chips from logging residues.

Much of the world's pulp and paper is produced from wood chips, the cost and quality of which have a marked effect on the profitability of a mill and on the marketing of its products. In recent years, the search for higher quality and/or cheaper sources of fiber has stimulated interest in developing better methods for upgrading chips.

Ideally, wood chips should be relatively uniform in size, free from both oversized and undersized material, and sturdy enough to withstand the effects of handling. Furthermore, they should be of uniform moisture content and free of such contaminants as bark, foliage, decay, or inorganic material (*1*). The extent to which these requirements can be relaxed depends on the cost of the furnish, the mill's tolerance for less-than-ideal raw material, and the quality demands of its products.

When the quality of a given source of chips deteriorates, attention generally focuses on the tuning and maintenance of the associated chip-making and chip-handling equipment. If this equipment is already in good adjustment, further improvements in chip quality are possible only through the use of methods developed expressly for upgrading wood chips.

Requirements of a chip upgrading system

A high level of chip quality requires a chipper that is in good operating condition. This keeps the production of substandard material at a minimum (*2*). However, even under the best of conditions, a certain percentage of chipper output will inevitably be oversized and undersized. Thus, the segregation of poorly sized and acceptably sized materials is a necessary feature of a chip upgrading system (*3*). Moreover, since the operation of conventional barking machines is influenced by external factors, such as the season of the year, the state of the wood (frozen or thawed, seasoned or fresh), and the character of the bark, the performance of such equipment fluctuates. As a consequence of these fluctuations, minute to significant amounts of bark may be present in conventional chips (*4*), the amount depending on the season and on the state and character of the material.

A chip upgrading system should also be capable of removing contaminants from a furnish, both organic (bark, rot, and foliage) and inorganic (stones, grit, and tramp metal). Further, since the effectiveness of a sorting process is predicated on the expectation that the constituents of the feed will be present in a discrete form, it is also important that the system provide for the detachment of one material from another i.e.the severing of bark from wood and the reduction of conglomerates.

Methods for upgrading chips have been developed, are commercially available, and should find wider use as industry reliance on alternative and often inferior sources of fiber increases.

Methods and practices

Screening

Screening is the oldest and most widely practiced method of upgrading, and vibratory and shaking screens have long been employed for this purpose by the industry. Their effectiveness depends on such factors as (a) careful selection of screen aperture size, (b) ensuring that the flow onto the screen deck is uniform and within the design capacity of the unit, and (c) attention to any tendency for "blinding." In recent years, chip thickness has come to be recognized as a more important parameter of "size," and there has been a consequent shift to disc screening in certain sectors of the industry (*5*). As this newer technology evolves, this trend seems likely to continue. Screening is effective in removing oversized and undersized material from a chip furnish, and if contaminants are present in these fractions, they too will be removed.

Screening is not especially effective, however, in reducing the levels of contaminants in a furnish. Stones, tramp metal, and plastic that are too large to be screened away as fines and too small to be scalped off with the oversized material are carried through with the screened chips. In the case of bark, a significant percentage may be bonded to the wood, and little if any is dislodged by the action of the screen. Further, since there is invariably a considerable overlap in the size distribution of the wood chips and that of the loose particles of bark in a furnish, screening is rarely effective in segregating one from the other. The slight reductions that do accompany screening reflect the fact

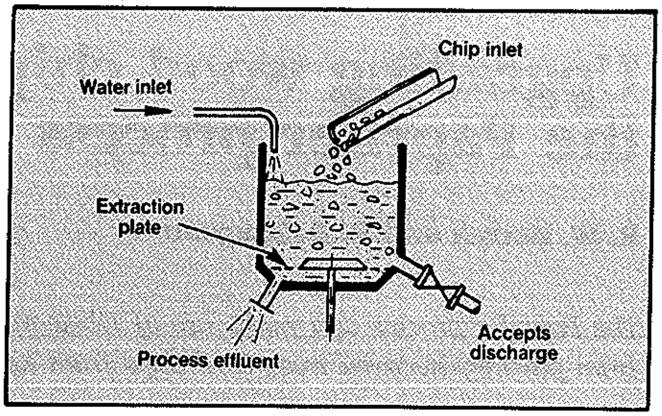
Berlyn is senior research engineer at the Pulp and Paper Research Institute of Canada, 570 St. John's Blvd., Pointe Claire, Que., Canada H9R 3J9. Simpson is senior design engineer at Hymac Ltd., 2995 Le Corbusier, Laval, Que., Canada H7L 3M3.

that the size distribution of bark tends to be shifted slightly towards the smaller particle sizes. Notwithstanding the nature of the problem, much interest has focused on the use of screens to segregate bark from wood.

Chip washing

Chip washers are routinely employed in advance of refiner pulp operations. Their purpose is to remove inorganics from the furnish and thereby prevent damage to the refiner plates. Although designs differ, all washers use a water bath through which the chips are passed and rely on the sinkage of the contaminants (stones, etc.) to segregate them from the furnish. They are effective in removing inorganic contaminants but not organic ones. Since little or no energy is imparted to the slurry, there is no tendency for bark to be detached from chips. Moreover, since the density of bark is usually less than one, loose bark particles do not sink and, instead, tend to carry through the bath with the chips.

1. Sectional view of a pulper being used to upgrade chips on a batch basis. Water is added continuously to replace the water that is drawn off with the comminuted bark and foliage through the extraction plate.



Miscellaneous methods for segregating bark and other contaminants from wood chips

In the past 20 years, several attempts have been made to develop a method for removing bark from wood chips (*6*). The principal impetus for these attempts stems from the associated development of roadside chippers capable of converting the entire above-ground portion of the tree or components thereof into wood chips. The attractions of such practice are several and significant:

- Increased utilization of forest resources through the use of tops and branches that are otherwise left on the forest floor, where they impede regeneration (natural or managed)
- The use of stands currently considered unmerchantable by virtue of small tree size or high contents of decay
- Less labor used in the forest
- Simplified wood handling in the forest
- Provision of low-cost fiber to the mill in many situations (*7–10*).

Notwithstanding these advantages, the use of full-tree chips by the industry is not widespread because they contain levels of contaminants that are too high for most pulping and papermaking operations. The development of a technique that could substantially reduce the high percentage of bark, foliage, and other contaminants in these chips would greatly augment the industry's fiber supply.

The effectiveness of any sorting process depends on the existence of some property or combination of properties that allow one material to be distinguished from another. Properties that are commonly used to purify or otherwise enhance a given commodity include size, shape, weight, color, and density.

Unfortunately, the properties of wood chips and their contaminants do not differ enough to provide a satisfactory degree of segregation. The problem is one of variability. Wood, bark, and to a lesser extent, foliage are each highly variable, possessing properties that span broad and overlapping ranges, thereby precluding the ready detection and segregation of one from another. Accordingly, effective upgrading can only be achieved by inducing some singular difference that can then be exploited, and it is this approach that underlies many of the developments to date.

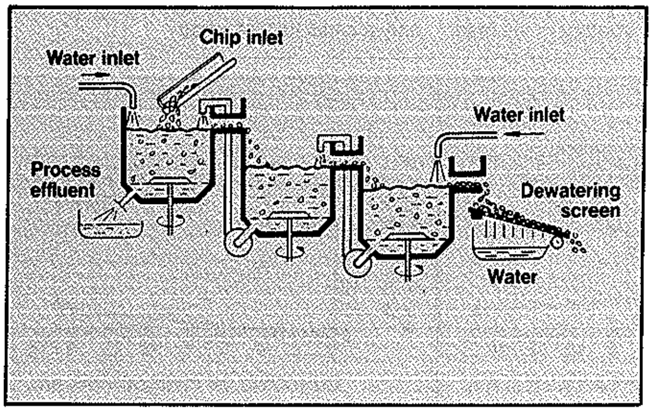
The Vac-Sink process (*11, 12*) employed an induced difference in specific gravity to sort discrete particles of bark from wood chips. The difference was effected by subjecting chips and bark to a vacuum and then expelling them onto the surface of a water bath. The wood chips tended to absorb water and sink, while the bark did not (*10, 11*). The application of the method was limited to southern pines. Performance suffered from the fact that those chips that were somewhat dry absorbed water less readily, tended to float, and were lost to the reject fraction. There was one commercial application of this process, and it is no longer operational.

In yet another method—compression debarking—chips and bark were fed in a monolayer into the nip between one or more pairs of rolls. The action of the rolls promoted (a) the detachment of bark from the wood, (b) adhesion of some of the bark to the roll surfaces (subsequently doctored off as "rejects"), and (c) comminution of the friable (nonadhering) fragments of bark (*13–15*). The use of this method in conjunction with pretreatments, such as steaming to plasticize the bark, and in combination with other stages of treatment, such as drubbing to further comminute the bark and screening to segregate comminuted material from the wood chips, was studied in detail (*16–18*) and led to the installation of a mill prototype that was operated for several years (*19*). Good performance reputedly depended on the smoothness of the roll surface, a condition that was difficult to maintain.

Mechanical attrition has also played a role in a number of other developments. In one of the first, developed by Bauer Brothers, slow-speed impact breakers were employed for the dual purpose of detaching bonded bark from wood chips and then reducing the bark and other loose contaminants into small-sized particles that could be readily segregated from the larger ones (the wood chips) by screening (*20*). Similar effects are attributed to the process developed by Kone (*21*), in which chips, bark, and foliage are fed through a horizontally mounted, rotating cylindrical drum partially filled with grinding media. On being discharged from the drum, the chips are screened to remove comminuted material. In a method developed by Rader (*22*), the furnish is treated in a device similar to a screw press. Fragmented material is removed afterwards through screening.

The success of all three methods is predicated on mechanical attrition effecting (a) the detachment of bark from wood and (b) the communition of the contaminants. Steaming in advance of the attrition stage favors both detachment

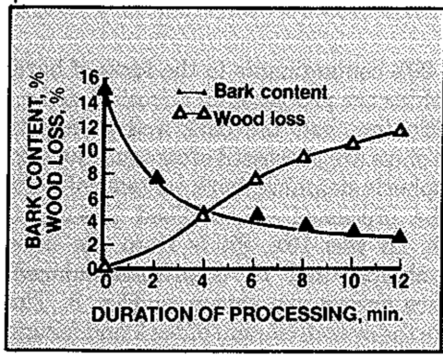
2. Pulpers arranged in series for processing chips on a continuous basis. Process effluent is treated to remove the comminuted material and is then recycled to the pulpers.



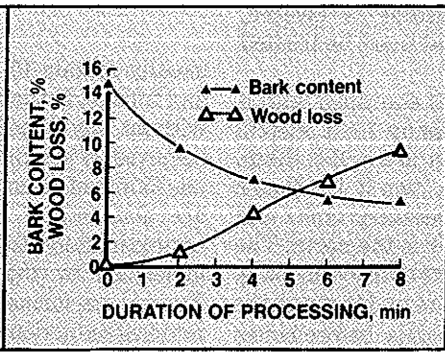
I. Effect of Paprifer treatment on chip-size distribution

Williams classification, mm	*Fraction retained, %* *Before treatment*	*After treatment*
32	10.9	5.4
19	28.6	18.8
13	27.8	29.9
10	17.2	23.5
5	13.0	21.8
3	0.4	0.2
<3	2.1	0.4

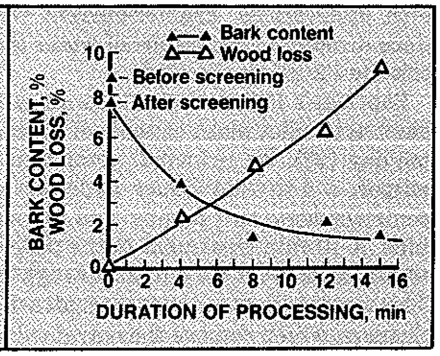
3. Full-tree softwood chips (60/40 mixture of jack pine and black spruce). Bark content of processed chips decreases with the duration of processing. Concurrently, the wood loss (fiber) increases. The curves are based on data obtained with the laboratory pilot plant.



4. Full-tree hardwood chips (mixed species). Bark content and wood loss change more slowly than with softwood (Fig. 3).



5. Chips from unbarked hardwood boles. Screening the chips before treatment in the pilot plant had little effect on bark content or on the observed relationships between bark content, wood loss, and the duration of processing.



and comminution. An unwelcome side effect is the tendency of such attrition to promote chip breakage, which displaces the chip size distribution curve towards the smaller size fractions and is reflected in significant loss of wood as fines during subsequent screening.

Detachment and comminution of contaminants can also be realized in a less drastic manner, using a simple arrangement of industry-proven equipment. The method and the results obtained with it are the subject of the following review.

The Paprifer process

The Paprifer process, a joint development of the Pulp and Paper Research Institute of Canada (Paprican) and the Forest Engineering Research Institute of Canada (Ferican), also exploits the fact that most of the organic contaminants in a chip furnish tend to be weaker than the wood chips. These contaminants are thus susceptible to being broken down into small particles that are readily segregated from the larger wood chip particles (*23*). The method entails three stages of treatment:

- Conditioning, through either several weeks of pile storage or several minutes of atmospheric steaming, which weakens the bark and the other contaminants and makes them easier to comminute (*24, 25*)
- Vigorous agitation in water to (a) break attached bark free from wood, (b) comminute the discrete organic contaminants, (c) modify chip size, making them smaller and more uniform, and (d) reduce variations that commonly occur in the moisture content of wood chips
- Washing, through suitably sized holes, to segregate the comminuted material from the wood chips.

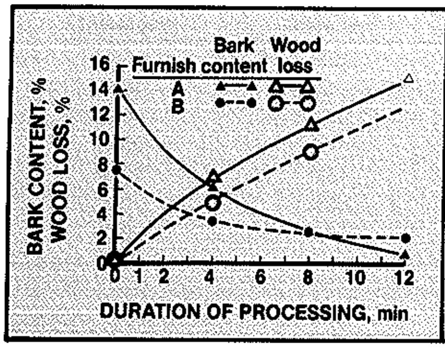
The use of water is important to process performance. Water serves as a washing agent and further weakens the bark, making it easier to comminute.

Process configuration

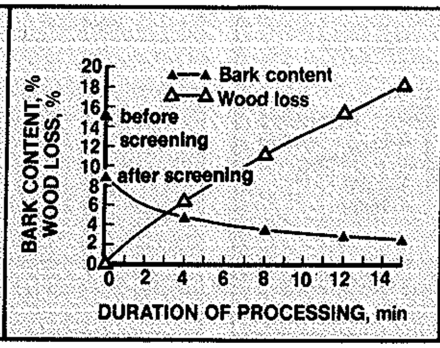
The method can be set up in a number of ways. In its simplest configuration, it could consist of a single pulper operated on a batch basis, as seen in **Fig. 1.** The impeller breaks free and comminutes the weaker constituents of the slurry, and the perforated extraction plate allows small-sized material to be continuously removed from the tub. The process effluent is treated to remove entrained solids and is recycled to the water inlet. The upgraded chips are discharged at regular intervals through the accepts line.

Batch-type operation can be automated and is suitable

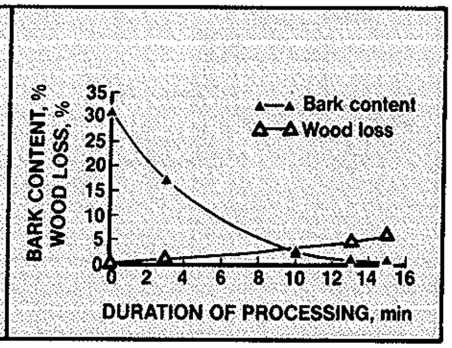
6. Two different softwood furnishes, both prepared from mixtures of logs and slabs. A high content of bark in the feed does not preclude the attainment of low bark content in the processed chips. Similarly, a low level of bark in the feed does not guarantee an equivalent degree of upgrading.



7. Chips from unbarked poplar logs. The chips used in this trial were derived from large-diameter logs (>40 cm). In this case, thickness screening before treatment was effective in removing large fragments of bark, reducing the bark content in the feed from 15.0% to 8.8%.



8. Chips prepared from logging residue. The high content of bark and foliage in unscreened chips prepared from lodgepole pine tops posed no problems in upgrading. Very low bark contents were obtained with only a small loss of wood.



for modest outputs, up to 100 o.d. metric tons of treated chips per day. For larger tonnage, continuous processing is preferred. This provides savings in both capital and operating costs. Continuous processing is achieved by arranging several pulpers in series, with the flow out of the first unit passing to the second, and so on, as illustrated in **Fig. 2.** In such applications, counter-current washing is favored, since it reduces the volume of water that must be treated prior to its being recycled.

Paprican's Pointe Claire laboratory is equipped with a batch-type pilot plant capable of processing 1 o.d. metric ton/day (*26*). Its principal components are a 2-ft-diam. pulper, a 4-ft-wide Bauer hydrasieve, two 3 in. Bauer centricleaners, two pumps, and the necessary tanks and bins. A 10-min treatment in the pulper is the norm. The water flows out of the pulper through the extraction plate. This water is then fed over the hydrasieve and through the cleaners, which remove the entrained solids, before being recycled to the pulper. No water is bled from the system, but a small flow of makeup is required to compensate for the water absorbed by the chips during their treatment in the plant.

Process performance

The laboratory pilot plant has processed more than 1000 batches of chips and in one instance was operated nonstop for five days to demonstrate the feasibility of continuously recycling the process water. The plant offers considerable experimental latitude. Factors that can be varied include the duration of treatment in the plant, the rpm of the rotor, the size of holes in the extraction plate, the flow of water through the extraction plate, and the temperature of the process water. Process performance can be quantified in terms of the bark content obtained and the wood loss incurred for any combination of these operating factors at any stage during the course of a trial. (Bark content and wood loss are defined in the appendix.) The results suggest that the process can broaden the use of alternative and cheaper sources of fiber and enhance existing sources of supply.

Full-tree softwood chips

Much of the experimental work has centered on upgrading eastern Canadian, full-tree, softwood chips. These furnishes

II. Effect of rot removal treatments on kraft pulping yields

Treatment	Total pulp yield, %
None	36.5
Dry screening	37.5
Paprifer	39.4

usually contain 15–20% contaminants in the form of bark and foliage. If the chips are processed in a fresh state i.e., without any conditioning, half the bark and foliage is removed. When the chips are processed after conditioning, i.e.,15 min of atmospheric steaming, bark contents of 2–3% are obtained in the processed chips. Wood losses are approximately 10%. Of this 10%, 3% is from the fines generated by the chipper and 7% is process induced. Typical performance curves are shown in **Fig. 3.** The marked reduction in the overall content of bark and foliage that occurs during the early minutes of processing indicates the rapid removal of foliage and the more readily comminuted fragments of bark, such as inner bark and the thinner forms of bark found on the branches and the younger portions of the stem. However, the thick, well-developed outer bark is particularly resistant to comminution. Cones also resist breakdown and are best removed with a disc-type scalping screen before processing. As processing proceeds, wood losses increase, with each incremental reduction in bark content taking longer and incurring a correspondingly larger loss of wood. Chip-size distribution is altered as a consequence of the treatment, with the chips tending to be smaller and more uniform after processing, as seen in **Table I.**

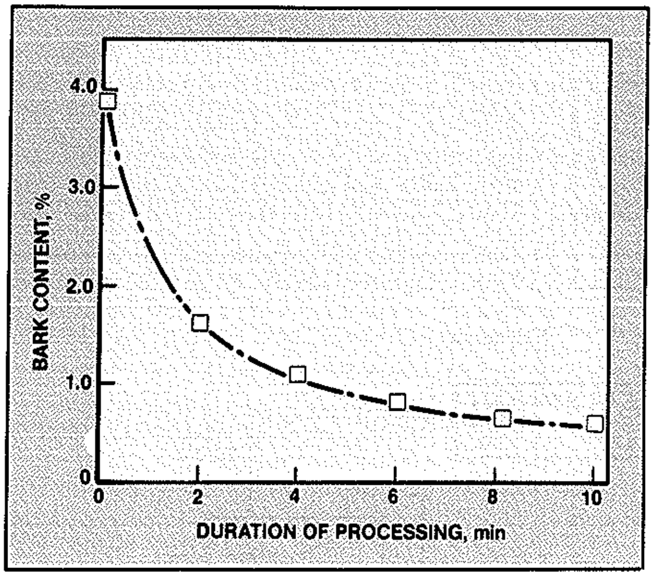
Full-tree hardwood chips

The combined content of bark and foliage in full-tree hardwood chips also ranges between 15–20%. Such furnishes are more difficult to upgrade, since they generally contain tougher bark than softwood. Experience to date suggests that the level of bark readily obtained in upgraded hardwood furnish falls between 4–5%, as seen in the results shown in **Fig. 4** obtained in trials with mixed hardwood furnish (oak, maple, hickory, poplar, ash, and beech).

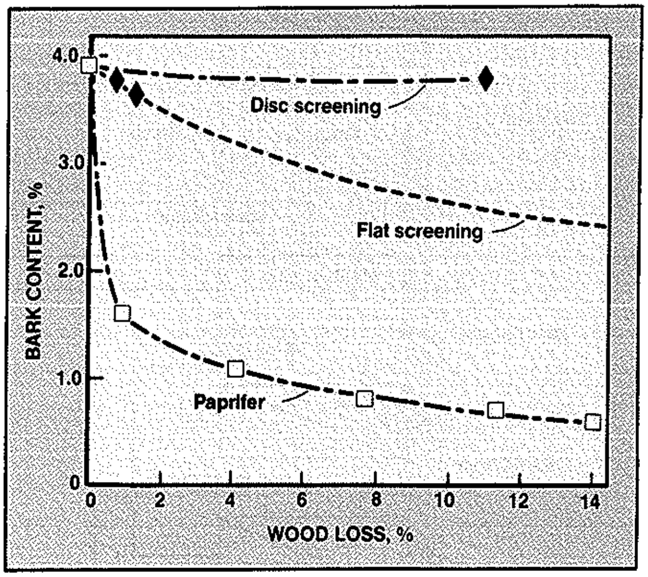
Mixed hardwood chips from unbarked boles

Chips prepared from unbarked boles of mixed hardwoods

9. Barky hardwood sawmill chips. Notwithstanding the low bark content in the feed, the shape of the curve relating bark content to duration of processing is identical to that obtained with much barkier furnishes, **i.e.**, a marked reduction in bark content during the first minutes of processing followed by a gradual leveling off.



10. Barky hardwood sawmill chips. The relationship of bark content to wood loss for the Paprifer process and two methods of screening indicates that the Paprifer process offers a substantial reduction in bark content for a modest loss of wood.



benefited from treatment in the pilot plant. The data shown in **Fig. 5** indicate that an input bark content of 7.7% (after screening) was reduced to 3.9% following only 4 min of treatment, during which a wood loss of 2.4% was incurred. Extending the treatment time to 12 min reduced the bark content even further, to 1.7%, while increasing the overall wood loss to 6.7%.

Softwood chips from unbarked logs and slabs

The two sets of results presented in **Fig. 6** show that a low bark content in the feed (Furnish B) does not necessarily signal a correspondingly lower one in the output (Furnish A). For example, the bark on a log of large diameter constitutes a smaller percentage of the log's weight than that on one of small diameter, but such bark is also likely to be thicker (tougher) and less easy to comminute. Accordingly, barky chips from large-diameter logs may respond less well to upgrading than those from small-diameter logs.

Poplar chips from unbarked boles

Chips prepared from unbarked poplar bolewood contained substantial amounts of thick (intractable) bark. This bark was difficult to break down but was subject to removal nonetheless through thickness screening before treatment in the pilot plant (**Fig. 7**).

Chips from logging residue

Conventional harvesting practices generate substantial volumes of tops and branches, which are abandoned as residue, since they cannot be handled in the normal manner. Although the chips produced from such material contain large amounts of bark and foliage, they can be upgraded with good results using the process. The data plotted in **Fig. 8** were obtained in trials with a furnish prepared from lodgepole pine tops. The high content of bark and foliage in the feed, 30.7%, presented no problems and was reduced to 0.3%, while incurring a process-induced wood loss of only 3.7%.

Substandard sawmill chips

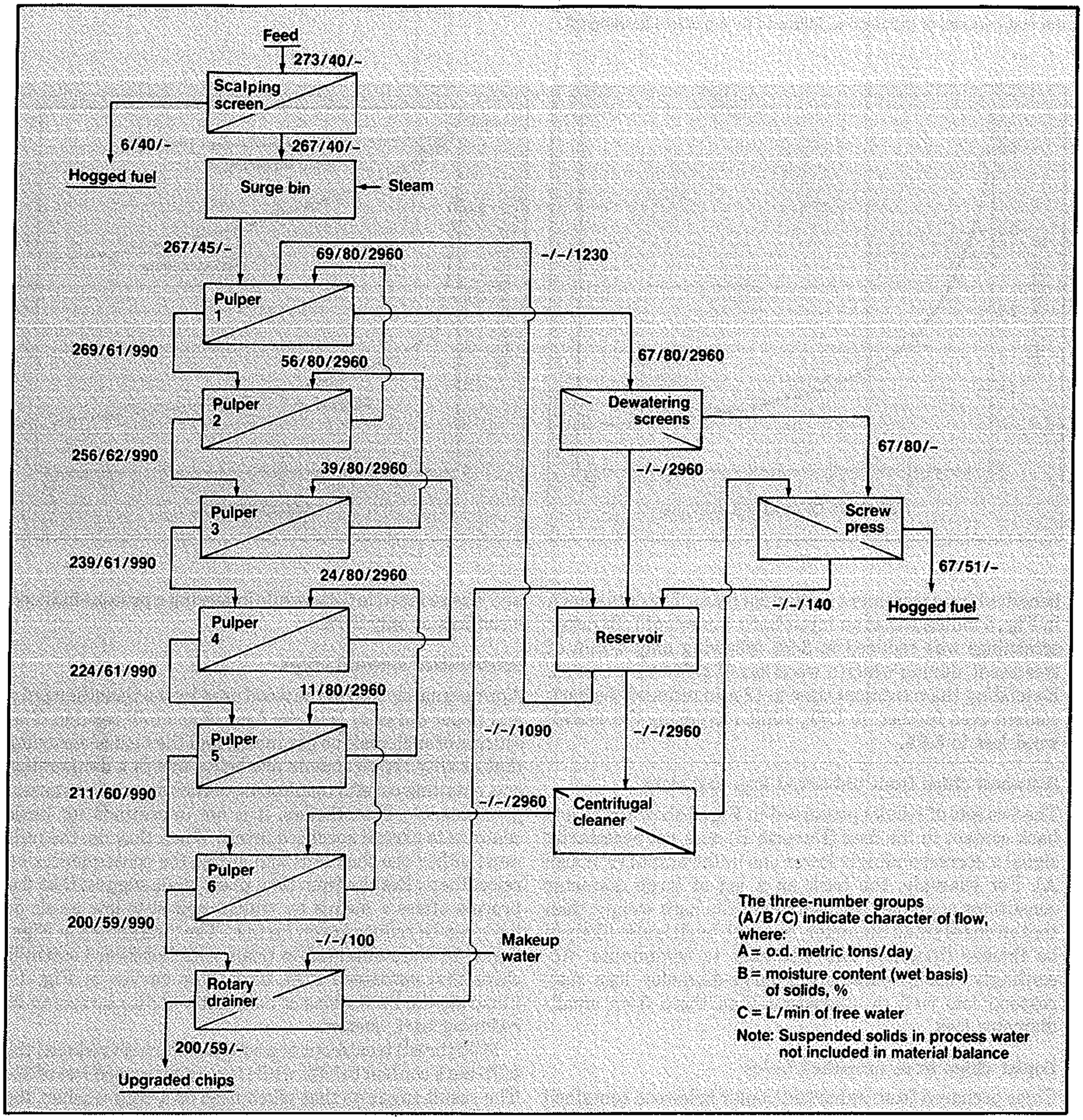
Approximately half of the wood used by the Canadian pulp and paper industry is in the form of sawmill residue. The sources of such residue are many, and the task of ensuring that quality requirements are being met is a demanding one, entailing careful monitoring of each supplier, bonuses, penalties, etc. Nonetheless, it is not uncommon for bark contents to exceed specified levels. When they do, the mill must either use the chips and suffer the consequences or reject them. Results from pilot plant trials suggest that the process offers a means by which modest-to-low levels of bark can be reduced even further. The data shown in **Figs. 9** and **10** were obtained in trials with hardwood sawmill chips that contained 3.9% bark. The curves in Fig. 10 illustrate the limitations of both flat and disc screening in reducing bark content.

Mild (brief) treatment of a softwood furnish reduced the 0.9% bark content to 0.3% while incurring a wood loss of 3%. The result suggests that when used as a chip washer, the process would not only remove inorganics but reduce bark content as well.

Rot removal

Some furnishes contain a substantial percentage of rot. Much of the poplar resource in Canada is overage and suffers from high levels of decay. The presence of rot in large amounts can lead to lower yields on pulping and/or to inferior pulp quality. Chip screening is effective in removing rot because a significant percentage of it is reduced to small particles during the chipping operation. To the extent that larger fragments may still be present in the furnish, the process can effect their removal. **Table II** provides data on three kraft pulps made from a mix of coastal hemlock and fir chips. One pulp was prepared from

11. Flow diagram of a Paprifer installation for the continuous processing of chips. Six pulpers are arranged in series, with countercurrent washing serving to remove the comminuted material. The projected daily output of the plant is 200 o.d. metric tons of upgraded, full-tree, softwood chips and 73 o.d. metric tons of hogged fuel.



unscreened chips, the second from screened material, and the third from chips that were screened and then treated in the Paprifer pilot plant. The benefits realized in pulp yield through screening (1%) were improved by a further 2% following subsequent treatment in the pilot plant. Such gains in yield should also correspond to a reduction in chemical consumption. Trials with partially decayed poplar were equally successful.

Grit removal

Grit entrained in chips can contribute to increased wear on mill equipment, and in some instances these effects are so pronounced as to preclude the use of otherwise cheaper furnish, such as full-tree chips. Although dry methods of treatment are not especially effective in ridding a furnish of grit, the washing action of the Paprifer process is. A grit content of 1.69% in a full-tree softwood furnish was reduced to 0.09% through treatment in the pilot plant. The same treatment also reduced the content of bark and foliage from 16.7% in the feed to 2.5% in the upgraded chips. These results, based on trials with the batch-type laboratory pilot plant, suggest that the process is effective in significantly reducing the level of contaminants in a variety of chip furnishes.

Appendix

Definitions

The terms "wood loss" and "bark content" as used in this report are defined as follows:

Wood loss (%) = [(weight of wood in process residue) × 100] / [(weight of wood in process residue) + (weight of wood in upgraded chips)] (1)

Bark content (%) = [(weight of bark, foliage, and cones) × 100] / [(weight of bark, foliage, and cones) + (weight of wood)] (2)

Measurement of bark content

Bark content was based on the analysis of dried samples weighing not less than 500 g (o.d.). After drying, the samples were classified into seven fractions on a Williams classifier. Each fraction, with the exception of the "passing 3 mm," was sorted into its constituents, with bark being pared from wood as necessary. The sorted material was then weighed. For the passing-3-mm fraction, a visual estimate of bark content was made. Use of the term "bark content" in this report represents the overall percentage of all organic contaminants (bark, foliage, and cones) in the sample.

Paprifer prototype

In the summer of 1985, a batch-type prototype of the process was installed in the mill yard of Manfor Ltd., at The Pas, Manitoba (*27*). The plant was capable of producing 56 o.d. metric tons/day of upgraded, full-tree, softwood chips and consisted of the following principal components: (a) an 8-ft-diam. pulper, into which chips from a feed bin were fed by conveyor at intervals of 15 min, (b) a drainage bin, into which processed chips were discharged from the pulper after 10 min of processing, (c) a surge tank for receiving the contaminant-laden water discharged from the pulper as well as the water that drained off the processed chips in the drainage bin, (d) dewatering screens for removing solid entrained in the process water, (e) a screw press for dewatering the process residue deposited on the mesh of the screens (thus enhancing the value of this residue as hogged fuel), and (f) a surge tank for receiving the screened water before being recycled to the pulper. The prototype was designed and manufactured by Hymac Ltd., Paprican's licensee for the process. Other participants in these trials included Manfor Ltd., which provided the site, the furnish, as well as installation and handling services, and the Canadian government, which provided financial assistance under its Industrial and Regional Development Program.

The plant was in steady operation for 11 weeks, during which time 1000 o.d. metric tons of full-tree softwood chips (60% jack pine, 40% black spruce) were processed, yielding about 800 metric tons of upgraded chips for pulping and 200 metric tons of residue as hogged fuel. The level of contaminants (15.9% in the feed) was reduced to 3.2% in the upgraded material. The wood loss incurred in upgrading was 9.4%, of which 3.1% can be ascribed to fines generated during the chipping operation. The moisture contents of the feed chips, upgraded chips, and the hogged fuel were 35.4%, 54.5%, and 55.1%, respectively. Performance levels matched those established with Paprican's pilot plant in Pointe Claire, indicating that the pilot plant results presented here are representative of those that would be realized with a larger plant.

Sufficient tonnage was produced to operate the mill for 20 h solely on upgraded chips. No problems were encountered in mill operation, and unbleached paper of standard marketable quality was produced. The screened yield of pulp from upgraded chips was 43–44%, as determined in laboratory pulping trials. This was 1% less than the screened yield from regular mill chips. Differences between the Paprifer pulp and the regular mill pulp, as determined through PFI beating and handsheet testing runs, were negligible.

Economic implications

Paprican's kraft mill simulation model was used to assess the impact of substituting 200 o.d. metric tons/day of upgraded, full-tree chips in place of the Manfor mill's higher-cost chips. The preparation of such tonnage would entail the use of six 6-ft-diam. pulpers arranged in series, with the chips being processed in a steady and continuous manner (Fig. 2). The major items of equipment, as well as the projected inputs, outputs, and flows, are shown in **Fig. 11.**

The effects on mill operations would include (a) a slightly lower screened yield of pulp, leading to a higher consumption of wood to achieve a given daily production, (b) an increased load on the recovery system (evaporators and boilers), (c) an increase in the supply of hogged fuel and thus a lower consumption of fuel in the power boiler, and (d) a higher fuel demand in the lime kiln.

The economic advantage of using upgraded chips to meet 25% of the mill's fiber requirement would be substantial: $4,000/day in producing 358 o.d. metric tons of finished paper, i.e., $11/o.d. metric ton of paper. Much of this benefit is derived from the use of lower-cost fiber. The discounted cash flow rate of return on the investment required to realize this advantage could range from 38% to 44%, depending on the depreciation rate used for tax purposes and on other associated factors.

These estimates are specific to the Manfor mill and serve to illustrate a single situation where the process could be used to good effect. Presumably, other such situations exist and await evaluation.

Conclusions

Upgrading of wood chips is the enhancement of a chip furnish in ways that favor the operation of a mill, either by permitting the use of cheaper sources of fiber or by improving the quality of mill products. Upgrading of wood chips entails (a) decreasing the level of contaminants and (b) reduction of the variations that commonly occur in both chip-size distribution and chip moisture content.

For many years, flat screening was the only technique used for this purpose. However, technological advances are introducing changes in an area that has not seen much change in decades as the industry continues to search for alternative, cheaper sources of fiber. Extensive trials with a laboratory pilot plant and, more recently, with a mill-yard prototype have demonstrated that the Paprifer process for upgrading chips can enhance a variety of furnishes, including full-tree chips (with their high content of bark and foliage), sawmill chips (containing relatively small amounts of bark), chips from partially decayed trees (containing high levels of rot), chips from logging residues, and other sources of fiber.

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