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PAPRIFER PILOT PLANT TRIALS — UPGRADING A VARIETY OF CHIP FURNISHES

R.W. Berlyn and R.B. Simpson

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FOREWORD

The Paprifer process for upgrading wood chips is a joint development of PAPRICAN and FERIC. The method has been the subject of detailed study both with a one tonne (od)/day pilot plant, at PAPRICAN's laboratory in Pointe Claire, and more recently, with a 56 tonne (od)/ day millyard prototype, designed and fabricated by Hymac Ltd., PAPRICAN's licensee for the process. The performance of the prototype was found to match that of the pilot plant, as reported in PPR 642/SR-47.

Trials on a variety of furnishes have been run with the pilot plant. Some were carried out under contract for individual companies, while others were conducted as part of the research program. The data obtained under contract have now been released.

To acquaint industry with the process's potential to upgrade such diverse furnishes as full-tree chips, chipped logging residues, barky stemwood chips, sub-standard sawmill chips, and chips prepared from partly decayed wood, the results from pilot plant trials were reviewed in a paper presented at the TAPPI Pulping Conference, Washington, D.C., November 1987. This paper is now issued as a joint report of the two Institutes.

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ABSTRACT

The upgrading of wood chips entails the removal of contaminants (e.g., bark, foliage, rot and grit) and the modification of chip size. The Paprifer process, developed in a joint project between PAPRICAN and FERIC, achieves this through the use of industry-proven equipment. The method has been the subject of trials with a variety of furnishes using a one tonne (od)/day laboratory pilot plant and, more recently, a 56 tonne (od)/day millyard prototype manufactured by Hymac Ltd. In service, the process stands to enhance existing sources of fibre, and permit the wider use of cheaper furnish, such as full-tree chips. Experimental findings are reviewed.

KEYWORDS

WHOLE TREES, CHIPS, UPGRADING, FURNISH, AGITATION, SEPARATION, PILOT PLANTS, PULPERS, BARKING, REJECTS, SCREENING, WASHING, ECONOMIC ANALYSIS.

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RESUME

L'amélioration des copeaux comprend l'élimination d'impuretés (i.e., écorce, feuillage, pourriture et sable). Le procédé Paprifer, mis au point dans le cadre d'un projet conjoint entre PAPRICAN et FERIC, accomplit cette tâche en utilisant de l'équipement qui a fait ses preuves dans l'industrie. Cette méthode a fait l'objet d'essais avec une diversité de compositions en utilisant une usine pilote de laboratoire d'une capacité d'une tonne (sec absolu)/jour et, récemment un prototype d'une capacité de 56 tonnes (sec absolu)/jour fabriqué par Hymac Ltée et situé dans la cour d'une usine. Une fois installé, le procédé pourrait accroître les sources existantes de fibres, et permettrait l'usage plus répandu d'une composition moins chère telle que les copeaux d'arbres entiers. Dans cette communication, les résultats d'expériences sont présentés.

INTRODUCTION

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 fibre 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 sound enough to withstand the effects of handling. Further, they should be of uniform moisture content, and free of contaminants, e.g., 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 dictates of its products.

When the quality of a given source of chips deteriorates, attention generally focusses on the tuning and maintenance of the associated chip making and chip handling equipment. In the event that such equipment is already in good adjustment, further improvements in chip quality are possible only through the use of methodology developed expressly for upgrading wood chips.

REQUIREMENTS OF A CHIP UPGRADING SYSTEM

A high level of chip quality requires that the chipper itself is in good operating trim, so that the amount of sub-standard material produced is minimal [2]. Even then, a certain percentage of a chipper's output will inevitably fall into the "oversized" and "undersized" categories. Accordingly, the segregation of poorly sized material from acceptably sized 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 vs. thawed, seasoned vs. 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 of the year, etc. Yet another feature of a chip upgrading system should therefore be the capability to remove 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 constituents of the feed being present in a discrete form, it is also important that the system provide for the detaching of one material from another (e.g., the severing of bark from wood, and the reduction of conglomerates). Methods for upgrading chips have been developed, are commercially available, and, as industry reliance on alternate and often inferior sources of fibre increases, stand to find wider use.

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 i) careful selection of screen aperture size, ii) ensuring that the flow onto the screen deck is uniform and within the design capacity of the unit, and iii) due attention being given 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, so the trend seems likely to continue. Screening is effective in removing oversized and undersized material from a chip furnish, and to the extent that 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 which are too large to be screened away as fines and too small to be scalped off with the oversized material carry through with the screened chips. With regard to bark, a significant percentage of it 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 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 focussed 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 plates of the refiner. Although designs differ, all washers employ a water bath through which the chips are passed, and all rely on the sinkage of the contaminants to effect the segregation of stones etc. 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, but tend to carry through the bath with the chips.

Miscellaneous Methods for Segregating Bark and Other Contaminants from Wood Chips

In the past twenty years, several attempts have been made to develop a method for removing bark from wood chips [6], the principal impetus stemming 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: i) increased utilization of the forest resource, through the use of tops and branches that are otherwise left on the forest floor and which act as an impediment to regeneration (natural or managed), ii) the use of stands currently considered unmerchantable by virtue of small tree size, high contents of decay, etc., iii) less in-woods labour, iv) simplified in-woods handling, and most important of all v) the provision of low-cost fibre to the mill in many situations [7,8,9,10]. Notwithstanding such 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 which could substantially reduce the high percentage of bark, foliage, etc. in these chips would greatly augment the industry's fibre supply.

The effectiveness of any given sorting process depends on the existence of some property or combination of properties that allows one material to be distinguished from another. Properties that are commonly used to purify or otherwise enhance a given commodity include size (e.g., screening), shape, weight, colour, 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 which can then be exploited, and it is this approach which 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 which were somewhat dry absorbed water less readily, tended to float, and were lost to the reject fraction. The one commercial application is no longer operational.

In yet another method, compression debarking, chips and bark are fed in a monolayer into the nip between one or more pairs of rolls, the action of the rolls serving to promote i) the breaking free of bark which is attached to wood, ii) the adhesion of some of the bark to the surface of the rolls (subsequently doctored off as "rejects"), and iii) the comminution of the friable (non-adhering) fragments of bark [13,14, 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 [16,17,18] and led to the installation of a mill prototype which was operated for several years [19]. Good performance reputedly depended on the surface of the rolls being smooth, a condition that was difficult to maintain.

Mechanical attrition has also featured 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 it 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 i) the detachment of bark from wood, and ii) the comminution of the contaminants. Steaming in advance of the attrition stage favours both. An unwelcome side effect is the tendency of mechanical attrition to promote chip breakage, displacing the chip-size distribution curve towards the smaller size fractions and promoting significant loss of wood as fines during subsequent screening.

The 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 and the Forest Engineering Research Institute of Canada, also exploits the fact that most of the organic contaminants in a chip furnish tend to be weaker than the wood chips and therefore, are susceptible to being broken down into small-sized particles, readily segregable from the large ones, the wood chips [23]. The method entails three stages of treatment:

i) conditioning, through either several weeks of pile storage or several minutes of atmospheric steaming, to weaken the bark and the other contaminants and make them easier to comminute [24,25].

ii) 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.

iii) washing, through suitably-sized holes, to segregate the comminuted material from the wood chips.

The use of water is important to process performance, serving not only as a washing agent, but also to further weaken the bark and make it easier to comminute.

PROCESS CONFIGURATION

The method can be set up in a number of ways, but in its simplest configuration could consist of a single pulper operated on a batch basis, the action of the impeller serving to break free and comminute the weaker constituents of the slurry, the perforated extraction plate allowing small-sized material to be continuously removed from the tub (Fig. 1). The process effluent is treated, to remove entrained solids, and 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 for modest outputs, up to 100 tonnes (od) of treated chips per day. Continuous processing is preferred for larger tonnages, where it offers savings in both capital and operating costs. It is effected by arranging several pulpers in series, with the flow out of the first unit passing to the second, and so on. In such applications, counter-current washing, as indicated in Figure 2, is favoured, 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 one tonne (od)/day batch-type pilot plant [26]. Its principal components are a two-foot diameter pulper, a four-foot wide Bauer Hydrasieve, two three-inch Bauer centricleaners, two pumps and the necessary tanks and bins. Ten minutes of treatment in the pulper is the norm. While the plant is in operation, the water which flows out of the pulper through its extraction plate is fed over the Hydrasieve and then through the cleaners, to remove the entrained solids. It is then recycled to the pulper. No water is bled from the system but rather, a small flow of make-up is required to compensate for that absorbed by the chips during their treatment in the plant.

PROCESS PERFORMANCE

The laboratory pilot plant has been used to process more than 1000 batches of chips, and in one instance was operated for five days non-stop 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. For any given combination of these operating factors it is possible to establish the upgrading characteristics of a furnish in terms of the bark content attained and the wood loss incurred at any given stage during the course of a trial. The results suggest that the process stands to both broaden the use of alternate and cheaper sources of fibre, and enhance existing sources of supply. (Note: The terms "bark content" and "wood loss", as employed in the balance of this report, are defined in the Appendix.)

Full-Tree Softwood Chips

Much of the experimental work has centred on the upgrading of Eastern Canadian full-tree softwood chips. Such furnish usually contains 15 to 20 percent contaminants in the form of bark and foliage.

If it is processed in a fresh state (i.e., without any conditioning) half the bark and foliage is removed. However, when it is processed after conditioning (i.e., after either several weeks of storage or approx. 15 minutes of atmospheric steaming), bark contents of 2 to 3 percent are realized in the processed chips. Wood loss amounts to about 10 percent, three percent of which is ascribable to the fines generated by the chipper while the balance, seven percent, is process induced. Typical performance curves are shown in Figure 3. The marked reduction in the overall content of bark and foliage which occurs during the early minutes of processing testify to the rapid removal of certain of the contaminants, e.g., 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. By contrast, bark which is tough breaks less readily, and in this regard thick, well-developed outer bark is particularly resistant to comminution. Cones also resist breakdown, and are best removed with a disc-type scalping screen in advance of processing. As processing proceeds, wood losses increase, with each incremental reduction in bark content taking longer to effect and incurring a correspondingly larger loss of wood. Chip-size distribution is altered as a consequence of Paprifer treatment, the chips tending to be smaller and more uniform after processing than before (Table 1).

Full-Tree Hardwood Chips

The combined content of bark and foliage in full-tree hardwood chips also ranges between 15 to 20 percent. 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 furnish falls between 4 to 5 percent, as seen in the results shown in Figure 4 obtained in trials with mixed hardwood furnish (oak, maple, hickory, poplar, ash and beech).

Mixed Hardwood Chips from Unbarked Boles

Chips prepared from the unbarked boles of mixed hardwoods benefited from treatment in the pilot plant. The data shown in Figure 5 indicate that an input bark content of 7.7 percent (after screening) was reduced to 3.9 percent following only 4 minutes of treatment during which a wood loss of 2.4 percent was incurred. Extending the treatment time to 12 minutes reduced the bark content even further, to 1.7 percent, while increasing the overall wood loss to 6.7 percent.

Softwood Chips from Unbarked Logs and Slabs

The two sets of results presented in Figure 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 liable 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 ones.

Poplar Chips from Unbarked Boles

Chips prepared from unbarked poplar bolewood contained substantial amounts of thick (intractable) bark, difficult to break down but subject to removal nonetheless, through thickness screening in advance of treatment in the Paprifer 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. The chips produced from such material contain large amounts of bark and foliage, but for all that, can be upgraded with good results in the Paprifer process. The data plotted in Figure 8 were obtained in trials with a furnish prepared from lodgepole pine tops. The very high content of bark and foliage in the feed, 30.7 percent, presented no problems and was reduced to 0.3 percent, while incurring a process-induced wood loss of only 3.7 percent.

Sub-Standard Sawmill Chips

Approximately one 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. The results from pilot plant trials suggest that the Paprifer process offers a means by which modest-to-low levels of bark can be reduced even further. The data shown in Figures 9 and 10 were obtained in trials with hardwood sawmill chips that contained 3.9 percent bark.

The curves in Figure 10 illustrate the limitations of both flat and disc screening in reducing bark content.

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

Rot Removal

Some furnishes contain a substantial percentage of rot, e.g., much of the poplar resource in Canada is overaged 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 Paprifer process can effect their removal. The data shown in Table 2 compare three kraft pulps made from a mix of Coastal hemlock and fir chips. One pulp was prepared from 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 (one percent) were improved upon by a further two percent in subsequent treatment in the Paprifer 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, e.g., 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 percent in a full-tree softwood furnish was reduced to 0.09 percent through treatment in the pilot plant — a treatment which also reduced the content of bark and foliage from 16.7 percent in the feed to 2.5 percent in the upgraded chips.

These results, based on trials with the batch-type laboratory pilot plant, suggest that the Paprifer process is effective in significantly reducing the level of contaminants in a variety of chip furnishes and as such, could serve a number of industry needs.

PAPRIFER PROTOTYPE

In the summer of 1985, a batch-type prototype of the Paprifer process was installed in the millyard of Manfor Ltd., at The Pas, Manitoba [27]. The plant was capable of producing 56 tonnes (od)/day of upgraded, full-tree softwood chips, and consisted of the following principal components: i) an 8-foot diameter pulper, into which chips were fed by conveyor, every 15 minutes, from a feed bin, ii) a drainage bin into which processed chips were discharged from the pulper after 10 minutes of processing, iii) a surge tank for receiving the contaminant-laden water discharged from the pulper, as well as the water which drained off the processed chips in the drainage bin, iv) dewatering screens for removing solids entrained in the process water, v) a screw press for dewatering the process residue deposited on the mesh of the screens (thereby enhancing the value of such residue as hog fuel), and vi) a surge tank for receiving the screened water prior to its 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 Government of Canada, which provided financial assistance under its Industrial and Regional Development Program.

The plant was in steady operation for 11 weeks, during which time 1000 tonnes (od) of full-tree softwood chips (60 percent jack pine, 40 percent black spruce) were processed, yielding about 800 tonnes of upgraded chips for pulping and 200 tonnes of residue as hog fuel. The level of contaminants (15.9 percent in the feed) was reduced to 3.2 percent in the upgraded material. The wood loss incurred in upgrading was 9.4 percent, of which 3.1 percent can be ascribed to fines generated during the chipping operation. The moisture contents of the feed chips, upgraded chips, and the hog fuel were 35.4, 54.5, and 55.1 percent, respectively.

Performance levels matched those established with PAPRICAN's pilot plant in Pointe Claire, indicating that results obtained with the pilot plant, as reviewed above, are representative of those which would be realized with a larger plant.

Sufficient tonnage was produced to operate the mill for 20 hours 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, 43 to 44 percent, as determined in laboratory pulping trials, was one percent less than that from regular mill chips. Differences between the Paprifer and the regular mill pulps, as determined through PFI beating and handsheet testing runs, were negligible.

ECONOMIC IMPLICATIONS

PAPRICAN's kraft mill simulation model was employed to assess the use of 200 tonnes (od)/day of upgraded, full-tree chips at Manfor Ltd's mill, as a replacement for the mill's higher cost chips. The preparation of such tonnage would entail the use of six six-foot diameter pulpers arranged in series, the chips being processed in a steady and continuous manner (see Fig. 2). The major items of equipment, as well as the projected inputs, outputs, and flows are shown in Figure 11.

Mill operating effects would include i) a slightly lower screened yield of pulp, leading to a higher consumption of wood to achieve a given daily production, ii) an increased load on the recovery system (evaporators and boiler), iii) an increase in the supply of hog fuel and thus a lower consumption of fuel in the power boiler, and iv) a higher fuel demand in the lime kiln. The economic advantage of using upgraded chips to meet one quarter of the mill's fibre requirement would be substantial: $5,400 per day in producing 358 tonnes (od) of finished paper, i.e. $15 per tonne (od) of paper. Much of this benefit stems from the use of lower-cost fibre. The DCF rate of return on the investment required to realize this advantage could range from 38 to 44 percent, depending on the depreciation rate used for tax purposes and on other associated factors.

The estimates summarized above are specific to Manfor Ltd's mill, serving to illustrate a single situation where the Paprifer process could be used to good effect. Presumably, other such situations exist, and await evaluation.

CONCLUSIONS

The upgrading of wood chips is concerned with enhancing a chip furnish in ways that will favour the operation of a mill either by permitting the use of cheaper sources of fibre or by improving the quality of its product(s). It entails each of the following: i) decreasing the level of contaminants, and ii) reducing the variations that commonly occur both in chip-size distribution and in chip moisture content.

For many years flat screening was the only technique employed for the purpose. However, technological advances in conjunction with the search for alternate and cheaper sources of fibre are fostering change in an area where little has occurred for decades. The Paprifer process for upgrading chips is one such development which, after extensive trials with a laboratory pilot plant and more recently with a millyard prototype, offers a means of enhancing a variety of furnishes: 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 undue amounts of rot), chips from logging residues, and other sources of fibre.

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REFERENCES

1. Hartler, N. and Stade, Y., Chip Quality Monograph (J.V. Hatton, Ed.), No. 5 in Pulp and Paper Tech. Series, Jt. Textbook Comm. of Pap. Ind., 1979, 29 p.

2. McLauchlan, T.A. and Lapointe, J.A., Chip Quality Monograph (J.V. Hatton, Ed.), No. 5 in Pulp and Paper Tech. Series, Jt. Textbook Comm. of Pap. Ind., 1979, 18 p.

3. Barnes, E.T., Chip Quality Monograph (J.V. Hatton, Ed), No. 5 in Pulp and Paper Tech. Series, Jt. Textbook Comm. of Pap. Ind., 1979, 20 p.

4. Erickson, J.R., Chip Quality Monograph (J.V. Hatton, Ed), No. 5 in Pulp and Paper Tech. Series, Jt. Textbook Comm. of Pap. Ind., 1979, 26 p.

5. Christie, D., Tappi, 70(4):113 (1987).

6. Sturos, J.A., Genl. Tech. Rep. INT-110, USDA For. Serv., Ogden, Utah. 1981. 12 p.

7. Fleming, A.S., In Preprints, CPPA Woodlands Sec. Ann. Mtg., Montreal, Que., January 1982, p. B223.

8. Johnson, R.E., In Preprints, CPPA Woodlands Sec. Ann. Mtg., Montreal, Que., January 1975, p. B79.

9. Deal, E.L., Pulpwood Production, 20(7): 14 (1972).

10. Keays, J.L., For. Prod. Jnl., 24(11):13 (1974).

11. Wesner, A.L., Pulp & Paper, 36(17):61 (1962).

12. Wesner, A.L., Pulp & Paper, 36(18):59 (1962).

13. Blackford, J.M., For. Prod. Jnl., 11 (11):515 (1961).

14. Blackford, J.M., Pulpwood Production, 13(5):6 (1965).

15. Arola, R.A., and Erickson, J.R., Res. Pap. NC-85, USDA For. Serv., St. Paul, Minn. 1973, 11 p.

16. Arola, R.A., Res. Note NC-147, USDA For. Serv., St. Paul, Minn. 1973. 4 p.

17. Arola, R.A., and Erickson,J.R., FPRS Separate No. MS-73-S5, For. Prod. Res. Soc., Madison, Wis. 1975. 10 p.

18. Erickson, J.R., For. Prod. Jnl., 26(2):45 (1976).

REFERENCES (Cont'd)

19. Wawer, A.,and Misra, M.N., Pulp & Pap. Can., 78(11):T264 (1977).

20. Eberhardt, L., Paper Trade Jnl., 135(25):23 (1952).

21. Anon., Papier, Carton et Cellulose, 28(10):50 (1979).

22. Altman, J., Tech. Release 82-R-55, Amer. Pulpwood Assoc., June 10, 1982, 3 p.

23. Berlyn, R.W., and Hutchinson, J.D., For. Eng. Res. Inst. of Can., SR-5, Montreal, Que., July 1979, 18 p.

24. Hutchinson, J.D.and Berlyn, R.W., For. Eng. Res. Inst. of Can., SR-8, Montreal, Que., July 1979, 23 p.

25. Hutchinson, J.D., and Berlyn, R.W., For. Eng. Res. Inst. of Can., SR-6, Montreal, Que., July 1979, 67 p.

26. Berlyn, R.W., Hutchinson, J.D., and Gooding, R.W., Pulp & Pap. Can., 80(8):56 (1979).

27. Berlyn, R.W., Gooding, R.W., Skerry, R., Morrison, J.S. and Simpson, R.B., Pulp & Pap. Can., 87(12):T440 (1986).

APPENDIX

Definitions

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

Wood loss (expressed as a percent) =

$$\frac{(\text{Weight of wood in process residue}) \times 100}{(\text{Weight of wood in process residue}) + (\text{Weight of wood in upgraded chips})}$$

Bark content (expressed as a percent) =

$$\frac{(\text{Weight of bark, foliage, and cones}) \times 100}{(\text{Weight of bark, foliage and cones}) + (\text{Weight of wood})}$$

Measurement of Bark Content

Bark content was based on the analysis of a dried sample weighing not less than 500 gm (od). After drying, the sample was classified into seven fractions on a Williams Classifier. Each fraction, except the "Passing 3 mm", was sorted into its constituents, with bark being pared from wood as necessary. The sorted material was then weighed. With regard to the Passing 3 mm fraction, a visual estimate was made of its bark content. For the purposes of this report, the term "bark content" represents the overall percentage in the sample of all organic contaminants (bark, foliage, and cones).

Table 1. Effect of Paprifer Treatment on Chip-Size Distribution

		Before Treatment	After Treatment
Williams Classification			
Percent Retained on:			
	32 mm	10.9	5.4
	19 mm	28.6	18.8
	13 mm	27.8	29.9
	10 mm	17.2	23.5
	5 mm	13.0	21.8
	3 mm	0.4	0.2
Passing:	3 mm	2.1	0.4

Table 2. Effect of Rot Removal Treatments on Kraft Pulping Yields

Treatment	Total Pulp Yield (%)
None	36.5
Dry Screening	37.5
Paprifer	39.4

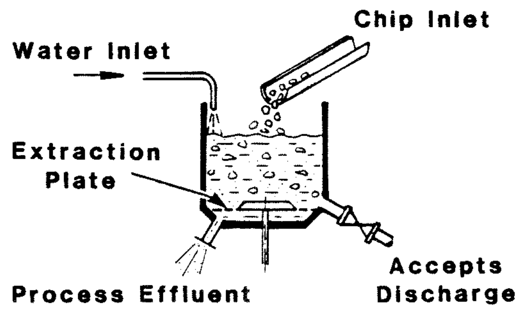

Figure 1. Sectional view of a pulper. When used to upgrade chips on a batch basis, water is added continuously to replace that drawn off with the comminuted bark and foliage through the extraction plate.

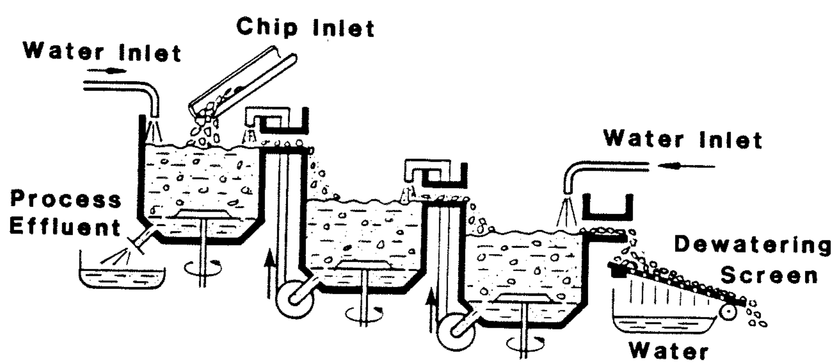

Figure 2. Pulpers arranged in series, to permit the processing of chips on a continuous basis. The process effluent is treated to remove the comminuted material and recycled to the pulpers with the addition of fresh make-up water.

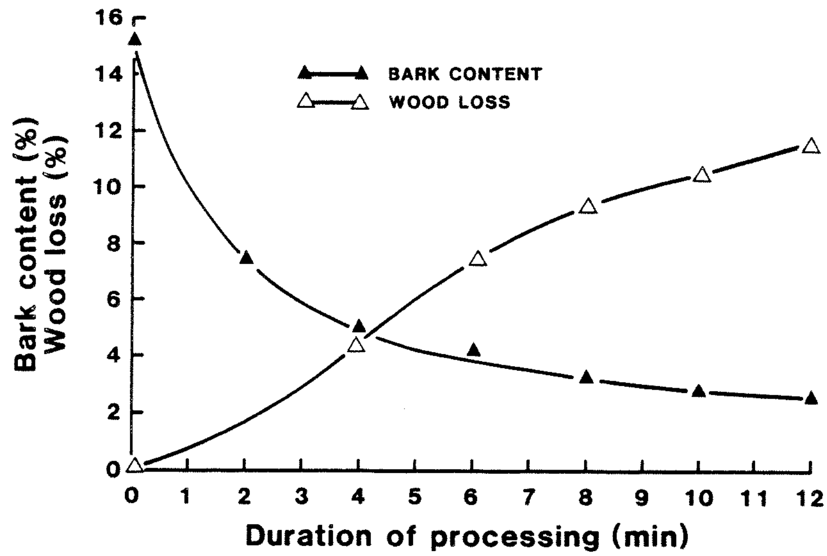

Figure 3. Full-tree softwood chips. The bark content of processed chips decreases with the duration of processing. Concurrently, the wood loss (fibre) increases. The chips were prepared from full trees, a 60/40 mixture of jack pine and black spruce. The curves are based on data obtained with the laboratory pilot plant.

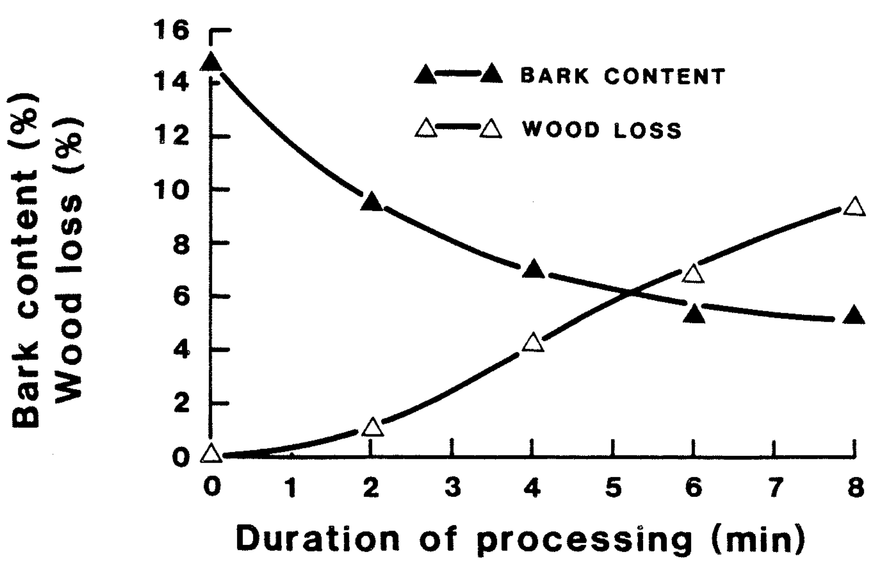

Figure 4. Full-tree hardwood chips (mixed species). Compared to softwood (Fig. 3), bark content and wood loss change more slowly.

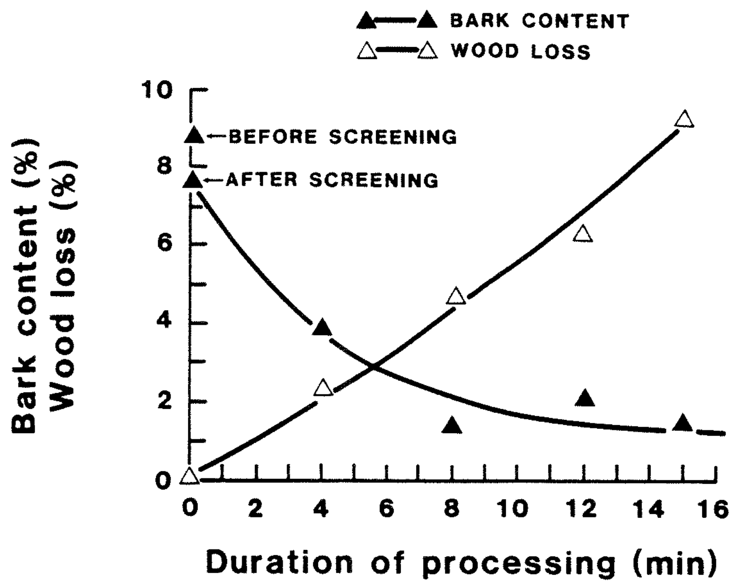

Figure 5. Chips from unbarked hardwood boles. Screening the chips in advance of treatment in the Paprifer plant had little effect on bark content or on the observed relationships between bark content, wood loss, and the duration of processing.

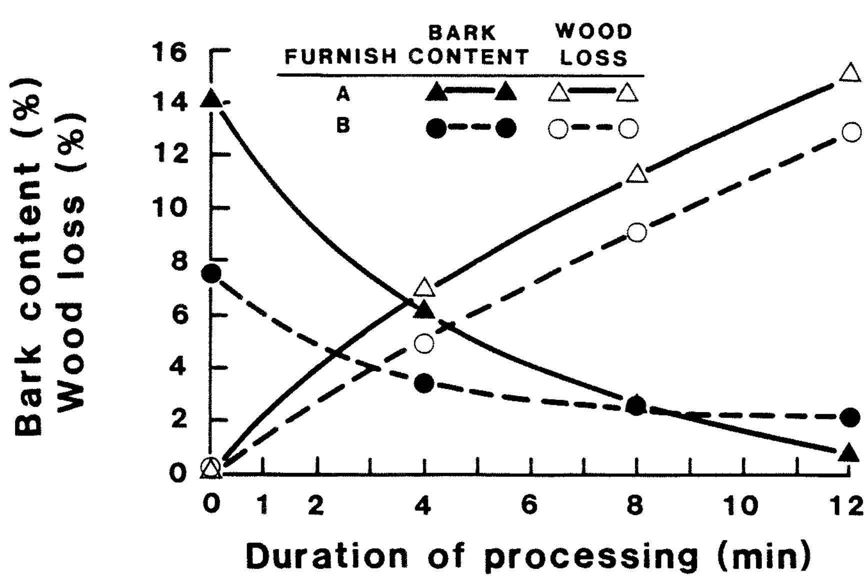

Figure 6. Two different softwood furnishes, both prepared from mixtures of logs and slabs. A high content of bark in the feed does not preclude the attainment of a low one in the processed chips. Similarly, a low level of bark in the feed does not guarantee an equivalent degree of upgrading.

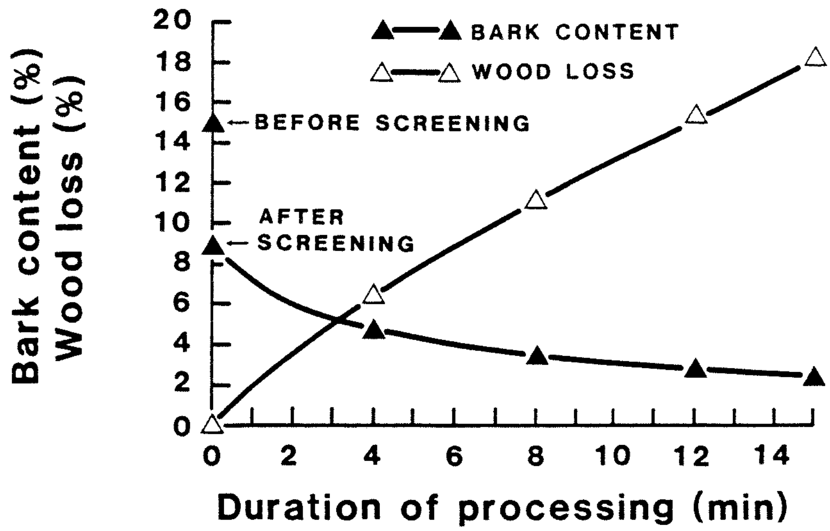

Figure 7. Chips from unbarked poplar logs. The chips used in this trial were derived from large-diameter logs (>40 cm). In this case, thickness screening in advance of Paprifer treatment was effective in removing large fragments of bark, reducing the bark content of the feed from 15.0 percent to 8.8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

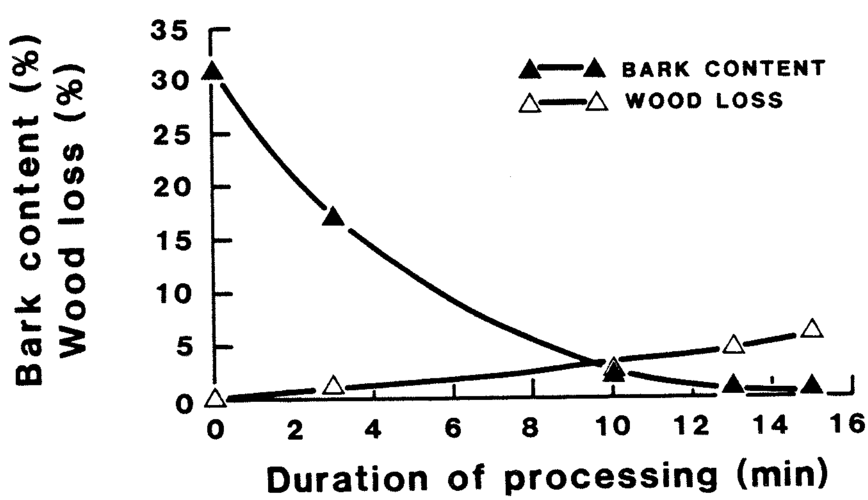

Figure 8. Chips prepared from logging residue. The high content of bark and foliage in unscreened chips prepared from lodgepole pine tops posed no problems to upgrading. Very low bark contents were realized with only a small loss of wood.

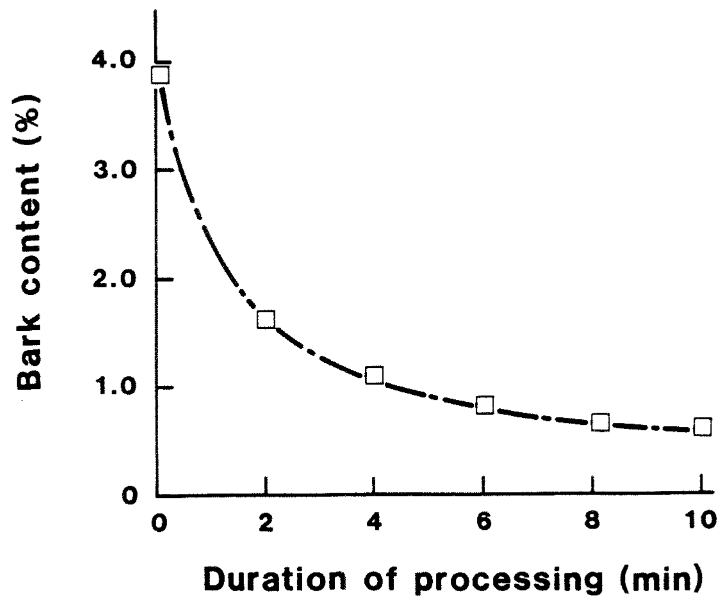

Figure 9. Barky hardwood sawmill chips. Notwithstanding the low bark content of the feed, the shape of the curve relating bark content to duration of processing is identical to that obtained with much barkier furnishes, i.e., a marked reduction in bark content during the first minutes of processing followed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

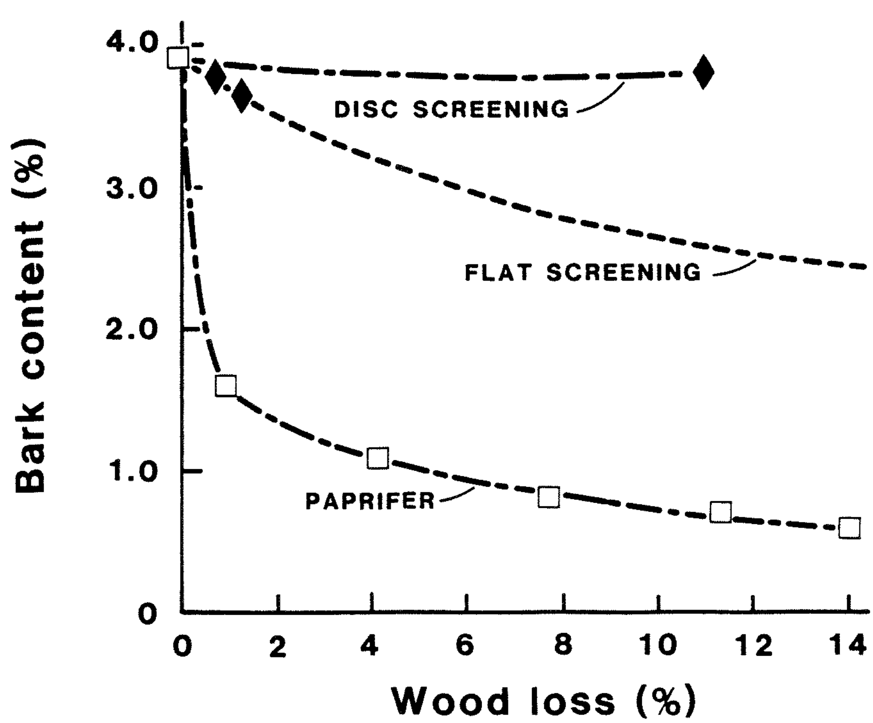

Figure 10. Barky hardwood sawmill chips. The relationship of bark content to wood loss as determined for the Paprifer process and for two methods of screening. The Paprifer process offered a substantial reduction in bark content for a modest loss of wood.

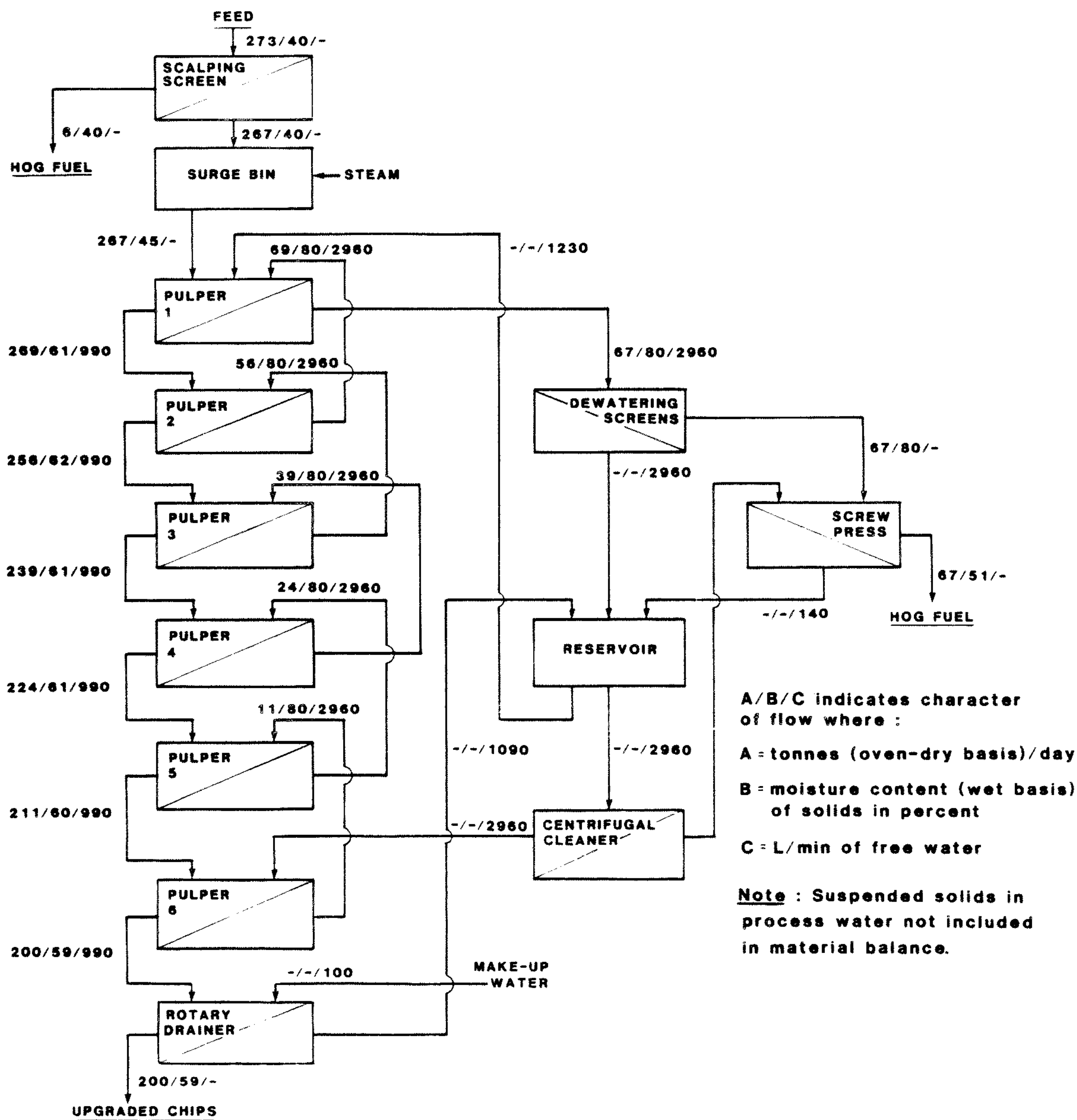

Figure 11. Flow diagram of a Paprifer installation for the continuous processing of chips. Six pulpers are arranged in series, with counter-current washing serving to remove the comminuted material. The projected output of the plant is 200 tonnes (od) of upgraded full-tree softwood chips per day and 73 tonnes (od) of hog fuel.