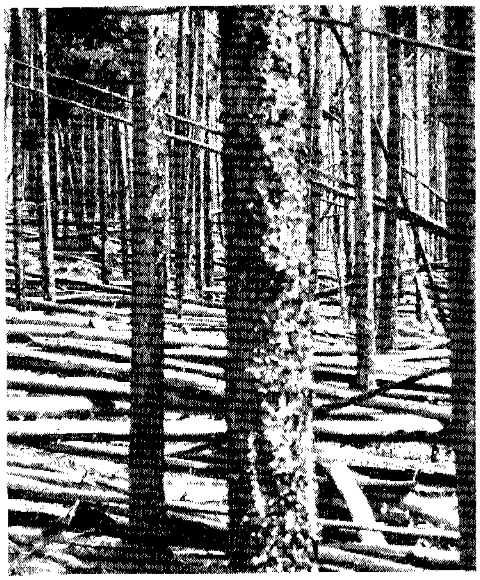
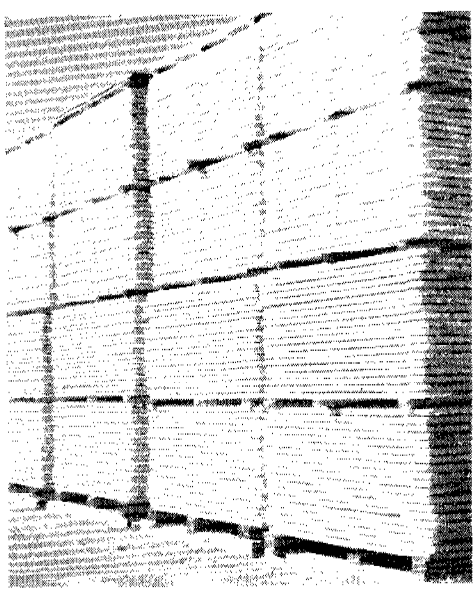
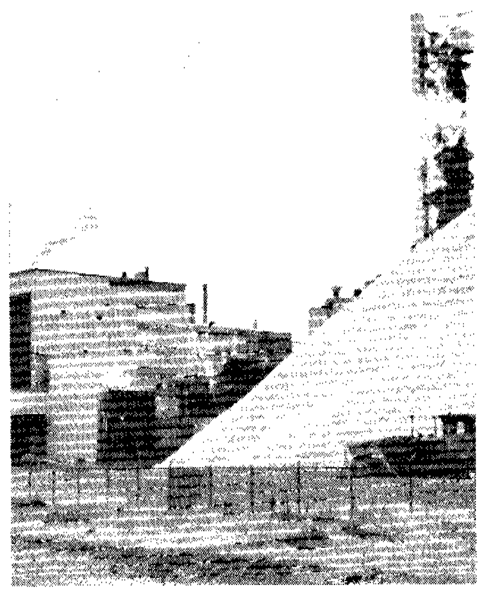
HARVESTING AND UTILIZATION OPPORTUNITIES FOR FOREST RESIDUES in the northern rocky mountains







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OUTLOOK AND OPPORTUNITY FOR WHOLE-TREE CHIP QUALITY IMPROVEMENT

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ABSTRACT

Three processes have been developed in the United States, one in Canada, and one in Finland for improving the quality of whole-tree and forest residue chips. They have potential application individually or in combination. Two of them have been applied commercially by the pulp and paper industry. Application of these processes coupled with integrated utilization of the various output wood, bark, and foliage fractions for fiber and energy products should promote the recovery of more forest residues.

KEYWORDS: bark removal, residues, biomass, utilization, foliage removal

INTRODUCTION

The demand for wood and fiber products is projected to increase due to high energy costs and a decreasing forest land base. The forest industry can help meet the projected increase by improving the recovery and utilization of forest residues.

Enormous quantities of forest residues are generated annually throughout the country. In the Eastern United States, there is an estimated potential annual supply of slightly over 200 million dry tons (USDA Forest Service 1978). National forests in the Pacific Northwest, California, and Northern Rocky Mountains annually generate 24 million, 15 million, and 5.5 million tons respectively of residue (Lowery and Host 1978). The cost of extracting and processing these residues for wood fiber products or other uses exceeds that of using available standing round wood or sawmill residues.

Whole-tree harvesting could recover a large portion of these unutilized materials economically. By this method entire trees are skidded to the landing, the more valuable saw logs are bucked out, then the tops and limbs are chipped. Non-saw-log trees, including culls, are chipped on the spot. Whole-tree harvesting should result in lower residue recovery costs for the following reasons:

- The available fiber is more completely utilized by chipping of tops, limbs, small trees, and other material currently abandoned as residues. Yield increases in tons per acre over conventional harvesting can reach 150 percent.
- Slash treatment, site preparation, and regeneration costs are reduced by removal of all the material from the stand.
- Chips can be handled easier than round wood. Chips are small and can be transported continuously as a bulk commodity over long or short distances using belts, conveyors, or pneumatic pipelines.
- Since several trees can be chipped at a time if the stems are small, chipping productivity is unaffected by tree size.
- Delimbing and bucking are reduced considerably. Only the saw log portion of trees requires delimbing and bucking.

Four factors that have promoted the great activity in research, development, and utilization of whole-tree chips are the steady growth of pulp markets, the abrupt increases in the cost of energy, the increasing public and environmental pressure to more fully utilize the forest biomass, and the development of mechanized harvesting.

The amount of whole-tree or unbarked chips acceptable in a specific mill depends upon its pulping process, cleaning facilities, and end product specifications. A number of pulp mills are using whole-tree or forest residual chips by blending small percentages of them with other "clean" chips. Although some mills have used over 30 percent barky chips, most mills have limited their use to less than 20 percent. The number of mills using whole-tree chips has decreased in recent years due to an adequate supply of clean chips and/or problems that were encountered in their initial trials with whole-tree chips. Widespread use of forest residues for pulp and paper will depend on methods for improving the quality of forest residual chips.

To increase utilization, field chipping of residues--including whole trees--must be coupled with an effective system for removing the bark from the chip mass. This paper reviews significant progress made in bark segregation in the United States, Canada, and Finland. The segregation processes developed have the potential of not only upgrading residue chips but also producing a valuable fuel. The processes could be the key to an integrated fiber and fuel raw material supply system for the future.

RESEARCH BY THE USDA FOREST SERVICE

Research in improving whole-tree chip quality has been conducted by the North Central Forest Experiment Station's Forestry Sciences Laboratory at Houghton, Michigan. The research has resulted in three promising processes--steaming-compression debarking, vacuum-airlift segregation, and photosorting (Arola and Erickson 1973; Mattson 1975; Sturos 1978; Sturos and Brumm 1978). Combinations of the above processes are also possible.

The patented steaming-compression debarking process (Erickson and Hillstrom 1974) basically consists of three steps: (1) presteaming the unbarked chip mass, (2) passing the chips through a compression debarker, and (3) screening the compression debarker output to remove fines (fig. 1). Additional (optional) steps include mechanical attrition of the smaller chip output fractions followed by screening to remove additional fines.

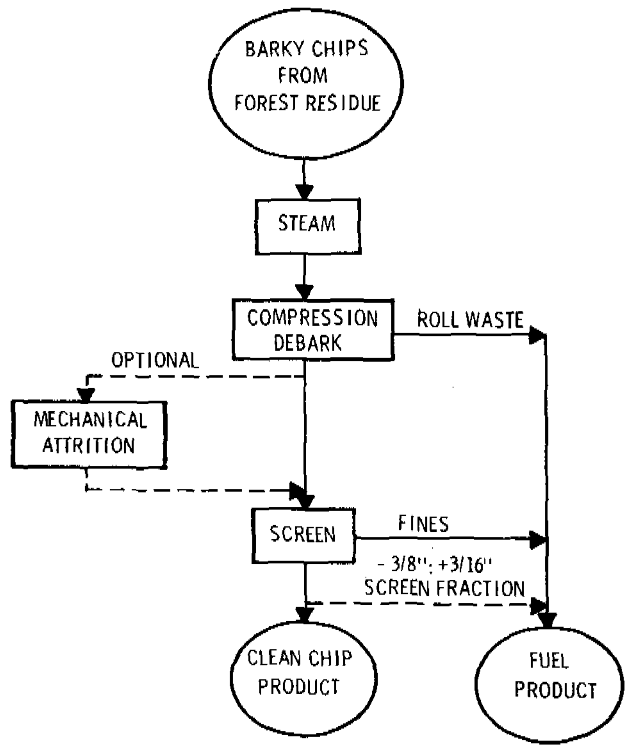

Figure 1.--Flow chart of the steaming-compression system for upgrading forest residue chips.

Bark removal tests have been conducted with western forest residues using the steaming-compression debarking process (Arola and Host 1976). Bark removal ranged from 60 to 85 percent and wood recovery from 87 to 92 percent with the lodgepole pine, ponderosa pine, Douglas-fir, and western larch residue chips. The output bark content ranged from 1 percent for lodgepole pine to 7 percent for western larch. However, by rejecting the 3/16-inch screen fraction from the output, bark content in the output was reduced to less than 4 percent for all four species. This, however, decreased the wood recovery to a range of 72 to 84 percent.

Successful chip debarking trials have also been conducted with three additional western species, namely, western hemlock, red alder, and bigleaf maple (Hillstrom 1974). Best results were obtained with red alder; more than 92 percent of the input bark was removed and 92 percent of the input wood fiber was recovered (table 1). The clean output chips had a bark content of 1.7 percent compared to 20.4 percent in the input.

The Forest Service steaming-compression debarking process has been put into practice commercially by Parsons & Whittemore, Inc. who designed and built a debarking plant at their St. Anne Nackawic pulp mill in New Brunswick, Canada. The plant has been operating since April 1975 processing all of their hardwood whole-tree chips. The plant capacity is rated at 10 oven-dry tons per hour. The bark content of their whole-tree chips has been reduced from 12 to 3.6 percent with a wood loss of 9 percent (Wawer and Misra 1977). One major advantage of the compressed chips is that the cooking time in the digester decreased by 9 percent.

Table 1.--Compression debarking of whole-tree chips of four western species (Hillstrom 1974)

(In percent)

Species	Treatment[1]	Input bark	Output bark	Bark removed	Wood recovered
Western hemlock	SCD	16.0	4.1	74	92
Douglas-fir	CD	15.5	7.9	49	91
Red alder	SCD	20.4	1.7	92	92
Bigleaf maple[2]	CD	15.8	5.8	64	92

[1]SCD - Presteaming, compression debarking, and mechanical attrition
CD - Compression debarking and mechanical attrition.
[2]Chips produced from stem only.

A second steaming-compression debarking pilot plant has been erected and operated at Saint-Gaudens, France, by Groupement Européen de la Cellulose (GEC) (Tyrode et al. 1977). The process consists of four stages as follows: prescreening, steaming, compression debarking, and postscreening. After 1 year of operation the bark level of a mixture of French hardwoods has been reduced from 18.8 percent to 7.8 percent with 5 percent or less wood loss. The compressed hardwood chips have not modified the physical properties of the pulp made with their kraft process. A better liquor penetration has been obtained, thereby requiring less alkali and a reduction in pulp screenings. Promising results have also been obtained with softwoods.

A 60 green ton per hour debarking plant using presteaming, compression debarking, and screening should process whole-tree chips for an estimated $7.58 per dry output ton, exclusive of raw materials costs (Biltonen et al. 1979). The total physical plant cost is estimated to be about $4 million, including about $1.6 million for the process equipment.

A vacuum-airlift segregator has also received laboratory scale testing both by the USDA Forest Service and by industry (Sturos and Marvin 1978). This consists of a wire mesh conveyor belt with vacuum hoods placed above the belt at various stations (fig. 2). Whole-tree chips are spread over a continuously moving conveyor belt passing through fields of air currents that subject the chips to vacuum forces from above the belt. The material is then segregated on the basis of differences in terminal settling velocities caused by density and geometric differences. Typically in a multiple-stage system, foliage, clean wood chips, and middlings are removed at different locations along the belt. Bark, knots, and twigs remain on the belt to discharge to a hog fuel product area. Fines, including bark, foliage, dirt, and grit, fall through the mesh belting and discharge to the hog fuel pile.

The "middlings" fraction contains from 30 to 50 percent of the total input material, depending on species, and has a bark content equal to or greater than the as-received whole-tree chips. This fraction can be used for pulp, particleboard, fuel, or chemicals. If the middlings are to be used for pulp, further beneficiation by the compression debarking process is recommended.

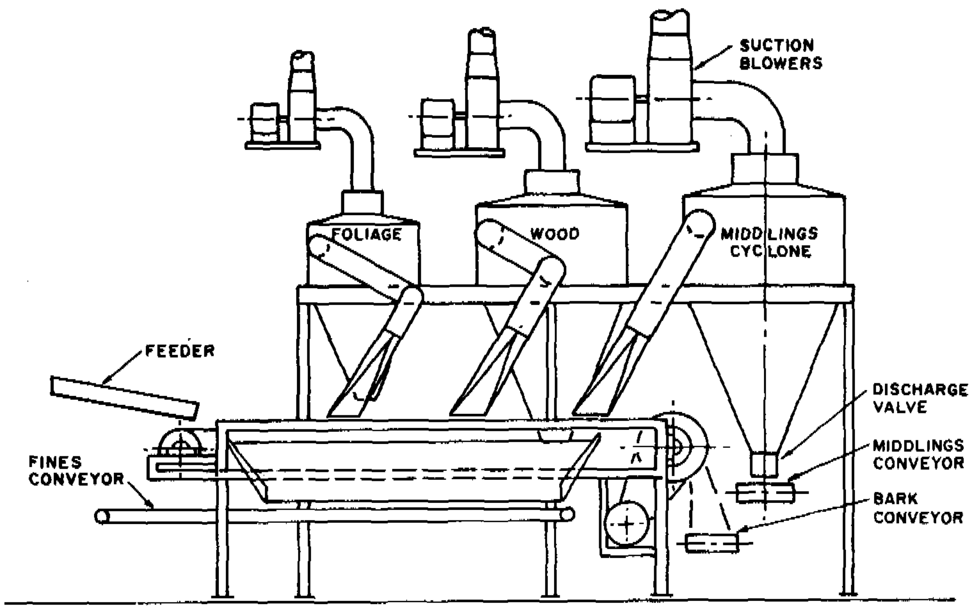

Figure 2.--Multiple-stage vacuum-airlift segregator. Fines fall through the wire mesh conveyor.

For maximum recovery of "clean" fiber, a combined system is recommended (fig. 3). It consists of vacuum-airlift segregation followed by steaming-compression debarking of the middlings. Typical results for Lake States aspen is as follows: By means of the vacuum-airlift stage, 4 percent of the input is removed as commercial foliage, 4 percent falls through the wire mesh conveyor as fines, 42 percent is recovered as clean wood chips acceptable for pulping, 36 percent is recovered as middlings, and 14 percent is left on the conveyor primarily as bark (fuel). Passing the middlings through the compression debarker results in an additional 29 percent clean wood chips and 7 percent bark. The combined product recovery results are 71 percent fiber, 25 percent fuel, and 4 percent foliage.

A limited amount of testing was conducted on western forest residues with vacuum-airlift segregation alone and in combination with compression debarking (Lowery et al. 1977). The vacuum-airlift stage recovered 38 to 85 percent of the input wood with bark levels of 1.5 to 3.6 percent (table 2). Processing the middlings from the vacuum-airlift segregator through the steaming-compression debarking process increased the wood recovery to 95 to 99 percent with bark levels of 1.9 to 5.1 percent in the combined output.

Several cost analyses of the steaming-compression debarking system, the vacuum-airlift system, and combinations of these two systems have revealed that the combined system is the most cost efficient. One of the primary advantages of coupling the vacuum-airlift segregator and the compression debarker is to decrease the amount of material the compression debarker has to process, which in turn reduced steam requirements and the size of the press. Therefore both capital equipment and beneficiation costs are reduced. The beneficiation costs (excluding raw material costs) are estimated to range from $7.85 per dry ton of debarked chips for a steaming-compression debarking system, to $5.60 for a combined system in which only 34 percent of the material is compression debarked. Total capital investment for a 60 ton per hour debarking plant ranges from about $4 million for a steaming-compression debarking plant to $2 million for a combined vacuum-airlift and steaming-compression system.

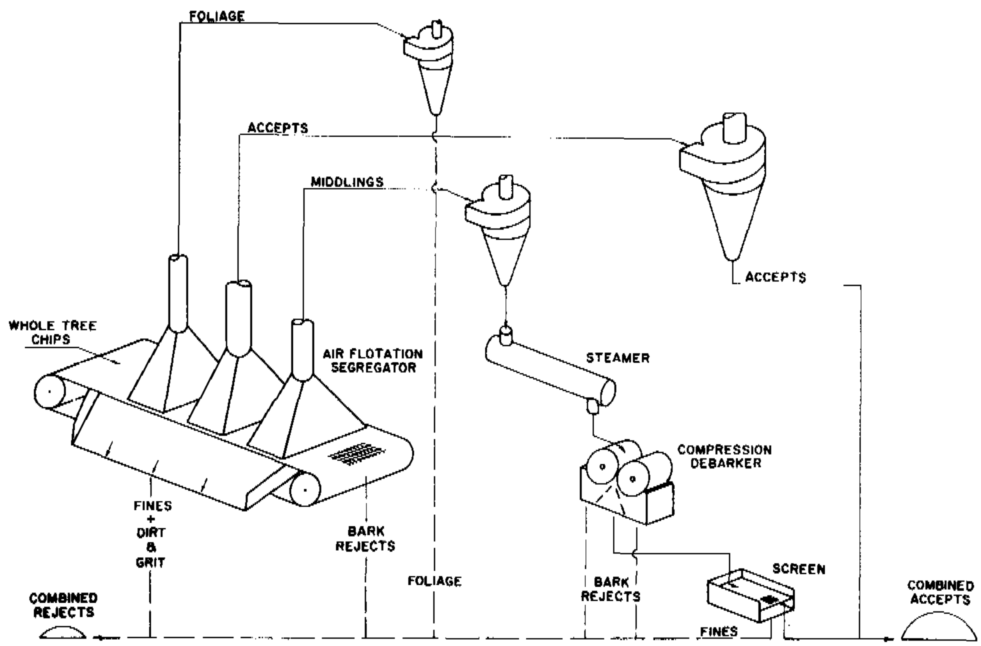

Figure 3.--Combined vacuum-airlift and steaming-compression debarking process for upgrading whole-tree and forest residual chips.

Table 2.--Bark removal results obtained with the vacuum-airlift system alone and in combination with the compression debarking system (Lowery et al. 1977)

(In percent, dry weight)

Species	Condition	Input bark	Vacuum-airlift segregation		Vacuum-airlift and compression debarking		
			Output bark	Wood recovered	Output bark	Bark removed	Wood recovered
Engelmann spruce	Green	13.4	3.0	79	4.1	73	99
Engelmann spruce	Dead standing	12.3	1.5	38	1.9	87	96
Western larch	Dead down	8.6	3.6	85	5.1	45	95

As mentioned earlier, the combined system is recommended for pulp mills needing a fiber supply where maximum "clean" wood recovery is the prime objective. In the near future many powerplants, both at forest industrial sites and others, will likely be fueled with whole-tree and/or forest residue chips. To help cover the potentially higher costs of recovering forest residues, an effort should be made to "scalp off" some clean pulp chips from the incoming wood because of the high value of pulp chips compared to fuel chips. As indicated in table 2, 38 to 85 percent of the input wood can be recovered with acceptable bark levels from western residue chips through the use of the vacuum-airlift segregator alone. Cost to install a 20 ton per hour vacuum-airlift system into an already existing plant has been estimated to be $175,000. The processing cost would be about $1 per input ton with a total connected horsepower of 205.

Photosorting has also been investigated at the laboratory scale by the USDA Forest Service. Wood and bark chips differ sufficiently in their optical transmittance to be sortable (Sturos and Brumm 1978). During photosorting, the chips are fed by a conveyor over a linear array of optical detectors (fig. 4). Light from an incandescent source is incident on the chips from above. The light intensity is adjusted so that most wood chips transmit sufficient light to be sensed by the detector array. When a bark chip passes over the detectors, the transmitted light falls below a preset detection threshold and the detector photo current decreases. The resulting signal is amplified to energize an air valve, which deflects the bark chips with a blast of air (fig. 5). Promising results have been obtained with three Lake States species, namely, balsam fir, white spruce, and aspen (table 3): 84 to 92 percent of the bark has been removed while recovering 58 to 65 percent of the wood. Photosorting should be considered as only a part of a total chip debarking system. It could be used ahead of the steaming-compression debarking process similar to the vacuum-airlift segregator, to "scalp off" a clean chip fraction. A modular 8 green ton per hour capacity photosorter is estimated to cost less than $40,000.

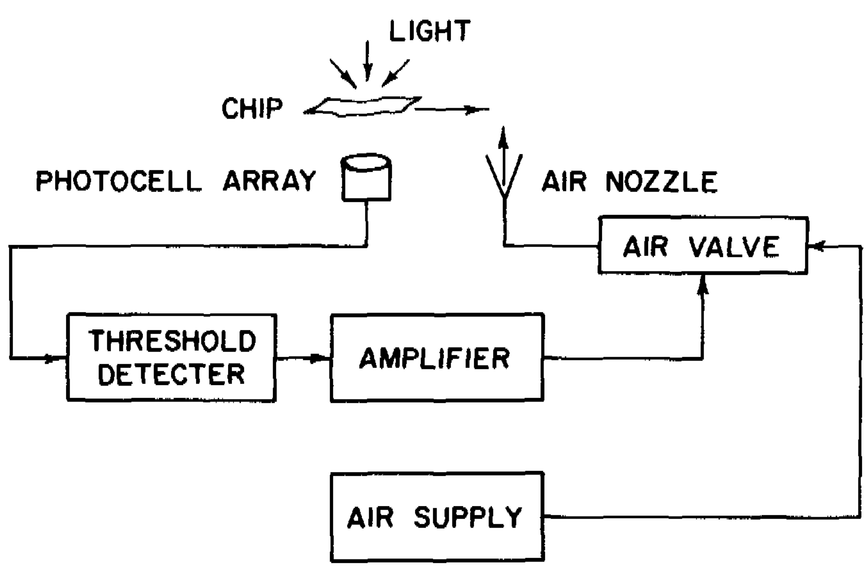

Figure 4.--Photosorting system diagram.

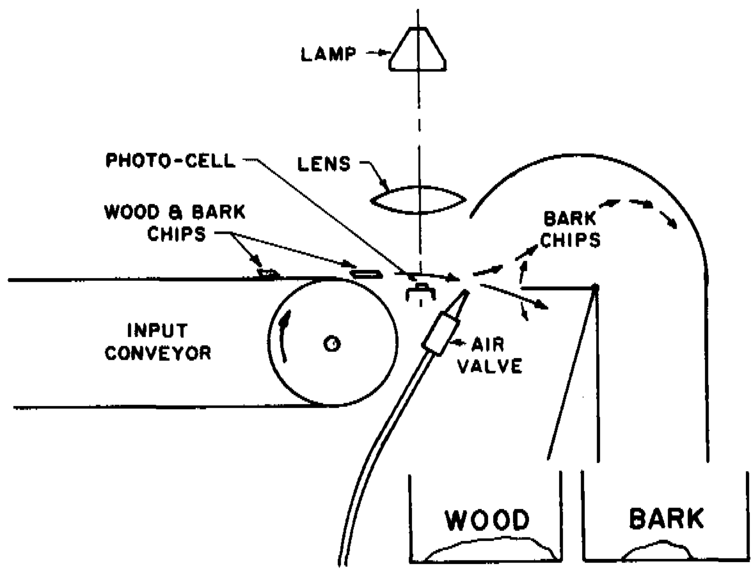

Figure 5.--Mechanical configuration of the photosorting system.

Table 3.--Typical photosorting results with the 5/8-inch size chips of three Lake States species

(In percent)

Species	Input bark	Output bark	Wood recovered	Bark removed
Balsam fir	10.2	1.3	64	92
White spruce	5.9	1.4	58	87
Aspen	10.3	2.7	65	84

RESEARCH BY PPRIC AND FERIC[1]

The Pulp and Paper Research Institute and the Forest Engineering Research Institute of Canada have developed a patented process for upgrading whole-tree chips (Berlyn et al. 1979). The method consists of three stages:

[1]PPRIC - Pulp and Paper Research Institute of Canada

FERIC - Forest Engineering Research Institute of Canada

- Conditioning by storing the chips in a pile or by steaming to increase the difference in strength between wood, bark, and foliage.
- Agitating in water to separate the bark and foliage from the wood and then breaking the bark and foliage down into small fragments.
- Segregating the fragmented bark and foliage from the wood chips by washing them over a screen plate.

Six weeks of storage in a chip pile or six to ten minutes of steaming at atmospheric pressure is generally required as a conditioning pretreatment. The process is designed to be set up as either a batch or continuous process. The Canadian researchers have experienced some problem with the thick outer bark on some species. However they do report good bark removal even from bark/wood chips (tight bark) and twigs, so as to reduce the bark/foliage content of whole-tree softwood chips from 20 percent to 2 percent with 91 to 96 percent wood recovery. They estimate the capital cost of a 220 O.D. ton per day batch process to be about $1 million with operating costs ranging between $3.70 and $7.40 per ton of whole-tree chips. The batch process would consist of a 15-minute processing cycle in a 12-foot diameter pulper (agitation chamber). Advantages noted are that the process has application to both softwood and hardwood and that the process uses no specialized or new equipment. Two disadvantages are the recycling and treatment of the waste water required and the low solid content of the bark/foliage fraction removed, thereby lowering the fuel value.

METHOD DEVELOPED IN FINLAND

A ballmilling process for beneficiating whole-tree and forest residual chips has been developed cooperatively in Finland by Kone Osakeyhtio and Enso-Gutzeit Oy (Hakkila et al. 1979). The process begins by removing oversized material, including stones, with a disc screen (fig. 6). This is followed by removal of iron tramp metal with a magnet. From this point the whole-tree chips are fed into a revolving ballmilling drum where the bark and foliage are fragmented and subsequently segregated from the wood by two stages of screening. The first screening stage is a thickness sort on a disc screen. Overthick chips are rechipped and fed back through the disc screen. The material which passes through the disc screen is then conveyed to a flat screen where long slivers (over-long particles) are removed. They are rechipped and screened again. The fines removed are collected as hog fuel.

Experimental results with pine, birch, and alder whole-tree chips indicate that 15.9 to 21.3 percent input bark can be reduced to 3.4 to 5.4 percent bark in the output material with a range of wood recovery of 87.6 to 92.5 percent. The hog fuel rejects represent 23-25 percent of the input. The experimental trials were conducted with a pilot scale chip debarking plant built at the Enso-Gutzeit Oy site in Imatra, Finland. The capacity of the plant is 8 to 12 solid cubic meters (20 to 30 loose cubic meters) per hour. The manufacturer, Kone Osakeyhtio, estimates that the capacity of the plant can be increased to the 40-120 solid cubic meters per hour level. The power requirements of the process range from 12 to 25 kilowatt-hours per solid cubic meter.

The developers of the process consider the debarked chips acceptable for sulphate pulping. In addition they claim the following advantages:

- Neither water nor chemicals are used.
- The fuel value of the reject material is high and waste water problems are avoided.
- The labor requirement is small.

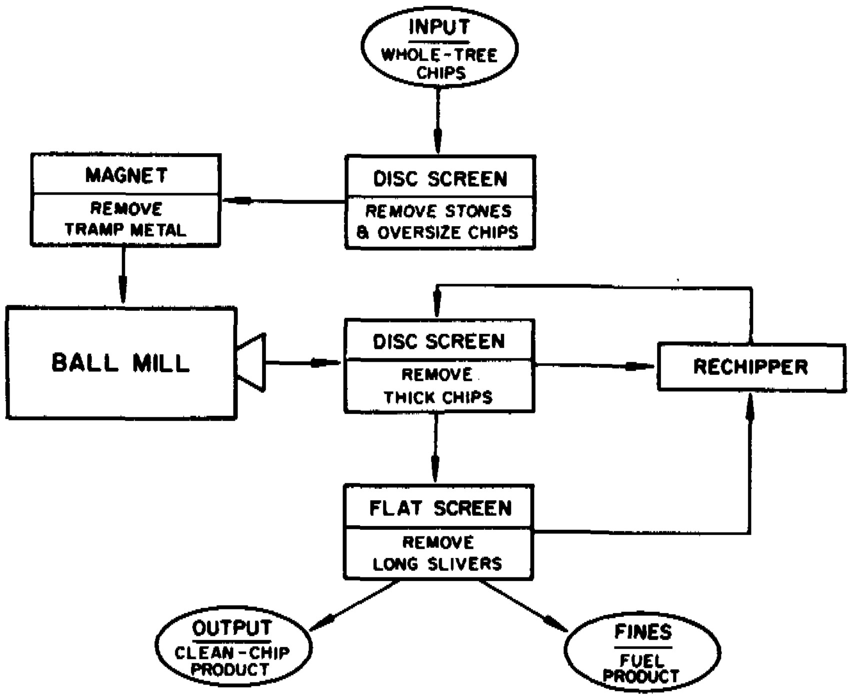

Figure 6.--Schematic of the Finnish ballmilling process for upgrading whole-tree chips.

SUMMARY

Significant progress has been made in developing the technology to improve the quality of whole-tree and forest residue chips. The USDA Forest Service has developed three methods: steaming-compression debarking followed by an optional ballmilling process, vacuum-airlift segregation, and photosorting. They have potential both individually and in combination. The steaming-compression debarking process has been scaled up to commercial pilot plants by St. Anne Nackawic Pulp and Paper Company, New Brunswick, Canada, and by Groupement Européen de la Cellulose (GEC), Saint-Gaudens, France. The Pulp and Paper Research Institute and the Forest Engineering Research Institute of Canada, Point Claire, Quebec, have developed a method for separating and breaking off bark. Whole-tree chips are exposed to microbial action during 6 weeks of storage and then subjected to heavy attrition motion in water in a device resembling a pulper. In Finland, Kone Osakeyhtio in cooperation with Enso-Gutzeil Oy has developed a whole-tree chip upgrading process based on ballmilling.

Certainly more and more residuals are going to be used in the future. Even though the major obstacle preventing widescale use of forest residues is the high harvesting and transporting costs, a considerable amount of tops and cull trees and logs can be recovered from ongoing logging operations by employing integrated harvesting techniques. The use of whole-tree chippers at the landing simultaneously with the saw log recovery system is usually the most economical way to recover residues for fiber and fuel.

To help pay for the high residue recovery costs, attention should be given to processing the residue chips so that they are allocated to the highest end value. The new chip upgrading processes presented in this paper can fractionate forest residue chips into clean wood chips for the pulp mill and bark, twigs, and poor quality wood chips for the boiler as hog fuel. The fuel value of the bark more than covers the operating cost of the chip debarking process.

Processes to improve whole-tree and residue chips will become a part of the total residue recovery system because they can provide both fiber and energy for the future. Fuller utilization of the forest biomass is rapidly becoming a necessity for the pulp and paper industry. Companies that do not provide close utilization for a sizable portion of their fiber and energy will find it more and more difficult to compete.

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