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Frank E. Biltonen, James A. Mattson, and Edsel D. Matson

North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture

North Central Forest Experiment Station
Robert A. Hann, Director
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota
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THE COST OF DEBARKED WHOLE-TREE CHIPS: STUMP TO DIGESTOR

Frank E. Biltonen, *Principal Research Engineer, (currently with the Forest Products and Engineering Staff, Washington, D.C.)*
James A. Mattson, *Research Mechanical Engineer, and* **Edsel D. Matson,** *Mechanical Engineer, Houghton, Michigan*

BACKGROUND

The need to increase the productivity of our forest land has been well documented by numerous investigators (Cliff 1973, USDA Forest Service 1973). With the price of timber products relative to other materials at 1970 levels, a medium projection of United States demand for roundwood indicates an increase from the 1970 level of 11.6 billion cubic feet to more than 22 billion cubic feet by the year 2000. At the same time, the commercial timber land available for growing timber products is projected to decrease by as much as 15 million acres. This situation presents a major challenge to woodland managers as well as researchers. They must consider all possible ways of producing more material from fewer acres.

One untapped source of potentially usable resources are "forest residues"—logging waste, cull trees, wind falls, thinnings, or stands considered unprofitable to harvest by current standards. If these materials were utilized, they could contribute substantially to meeting future needs. However, these residues are not usually in the form that current harvesting and processing equipment can efficiently handle—it is either crooked, small, large, or dirty. Despite the problems involved, it is inevitable that much of this residue must be utilized to meet future demand.

Logging residue is the largest single source of potential timber supplies. At least 100 million oven dry tons of wood are discarded annually in harvesting operations in the form of limbs, tree tops, and defective or broken logs (USDA Forest Service 1976) (table 1). These harvesting residues have commonly been burned in the woods or left to decay and return to the soil. Burning the debris has provoked questions about air pollution. Leaving it untreated creates fire hazards and is an aesthetic liability.

Table 1.—*Sources of forest residues by regions in the United States (USDA, Forest Service 1976)*
(In millions of tons oven dry)

Region	Yearly harvesting residues	Yearly other removals	Inventory of noncommercial timber
Pacific Coast	26	1.6	148
Rocky Mountain	6	0.2	180
South	52	11.8	375
North	26	6.0	281
Total	110	19.6	984

Vast quantities of wood are removed from the timber inventory by such operations as timber stand improvement and land clearing that are not utilized for timber products. These removals also represent a large potential supply of fiber if the technology to utilize them can be developed. Annually, 20 million oven dry tons of wood are estimated to be lost through these removals.

Another source of usable fiber are the rough, rotten, and salvageable dead trees, or "noncommercial" timber currently in our forests. Estimates of this resource are close to 1 billion tons of oven dry material or 66 billion cubic feet. The magnitude of this resource is realized when it is compared to the 13 to 15 billion cubic feet of timber being consumed annually.

The introduction of portable chippers, which operate in the woods to reduce whole-trees or tops and limbs remaining after logging to chips, has opened the door to increased use of residue materials by the paper and board industries. Reduction of the residue material to chips facilitates the handling and processing of the initially bulky and irregular material by putting it in a form that standard materials handling equipment can accommodate and the pulpwood industry requires.

The basic whole-tree harvesting system consists of: (1) feller-bunchers that sever the trees and accumulate them into bunches for subsequent forwarding to the chipper site, (2) grapple skidders to move the bunches to the chipper, (3) portable chippers that operate at a woods landing to reduce the whole trees to chips, and (4) chip vans that transport the chips to the mill (fig. 1).

Because the tops, limbs, and boles have been chipped with the bark on, the increased levels of bark and associated dirt and grit reduce product quality and increase wear on processing equipment. Most pulp mills have found that they are only able to blend a small amount of whole-tree chips with their normal pulp furnish and still maintain quality control. However, if use of whole-trees are to increase, the quality of the chip material must be upgraded.

A technically sound chip debarking system has been developed at the laboratory level (Erickson and Hillstrom 1974). A vacuum-airlift system has also been developed that, when used in conjunction with the compression debarking system, can reduce the capital cost of the debarking plant and thus lower the processing cost per ton of chips (Sturos 1978).

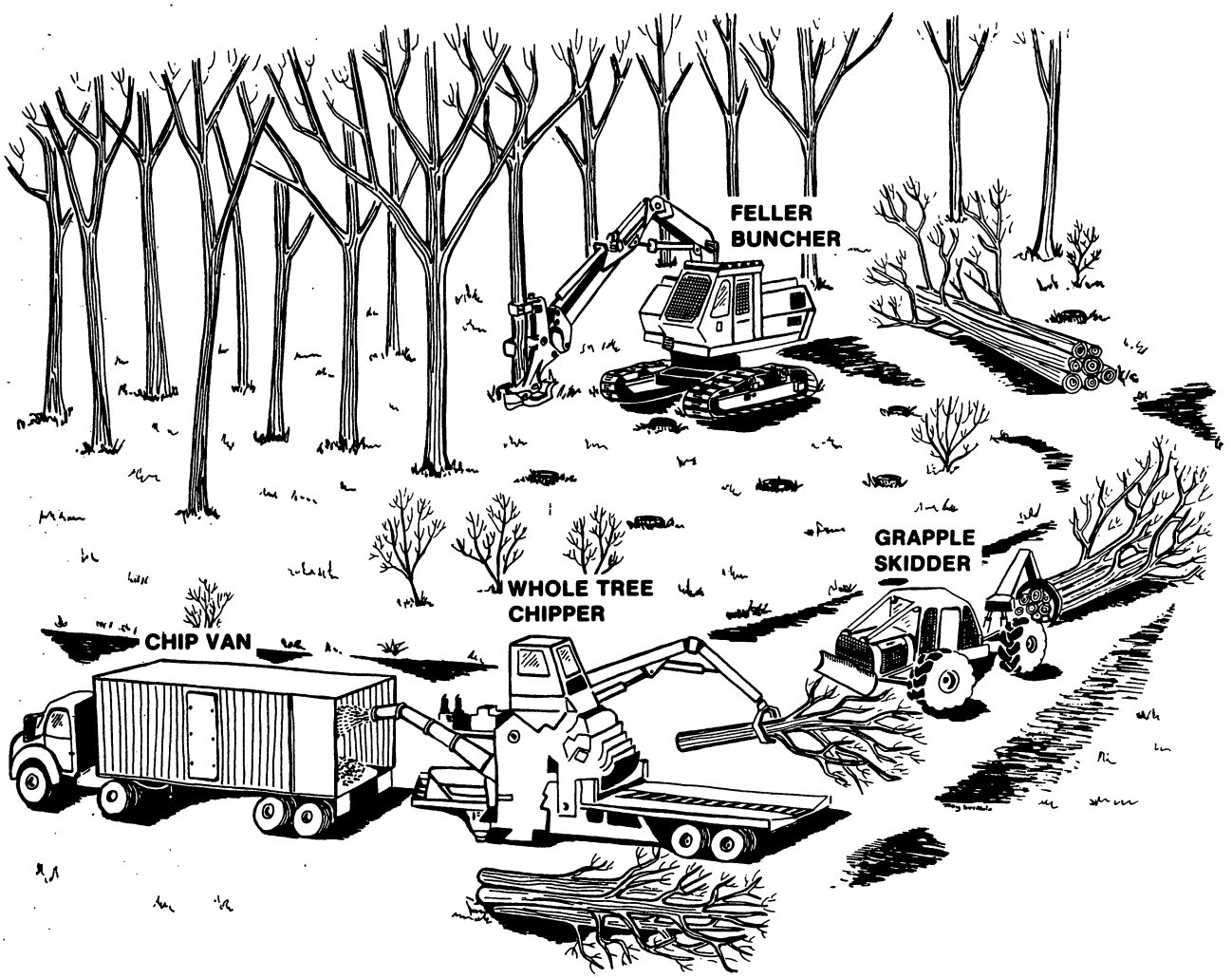

Figure 1.—*Typical whole-tree chipping equipment.*

This paper presents a cost estimate of the physical plant and machinery of a commercial-sized compression debarking plant capable of processing 60 green tons per hour. It also offers an estimate of the cost per unit of harvesting and processing unbarked chips to an acceptable level of bark content.

THE BARK-CHIP SEPARATION-SEGREGATION (BCSS) SYSTEM

The elements of this chip debarking system are presteaming, compression debarking, mechanical attrition (optional), and screening. The principal element is the compression debarker (Blanchard 1962) which consists of two oppositely rotating steel cylinders with a nip spacing smaller than the thickness of bark and wood chips (fig. 2).

A continuous single-layered flow of unbarked chips are compressed through the nip. The compression will break the bark-wood bond, cause the bark to adhere to the rolls, or fragment the bark into finer particles. Bark adhering to the rolls can be scraped from the rolls into the waste area. The fragmented material can be screened out (the optional mechanical attrition treatment increases the amount of fragmented bark). The effectiveness of the compression is dependent upon the condition of the raw material. If it is green and chipped during the growing season, the bark will readily adhere to the rolls. Up to 50 percent of the input bark in whole-tree chips can be removed by compression debarking alone (Mattson 1975). If the chips are steamed prior to compression, bark removal is greatly improved and most of the seasonal effect is eliminated. This steaming treatment can increase compression debarking efficiency up to 85 percent bark removal (Erickson 1976, Mattson 1975).

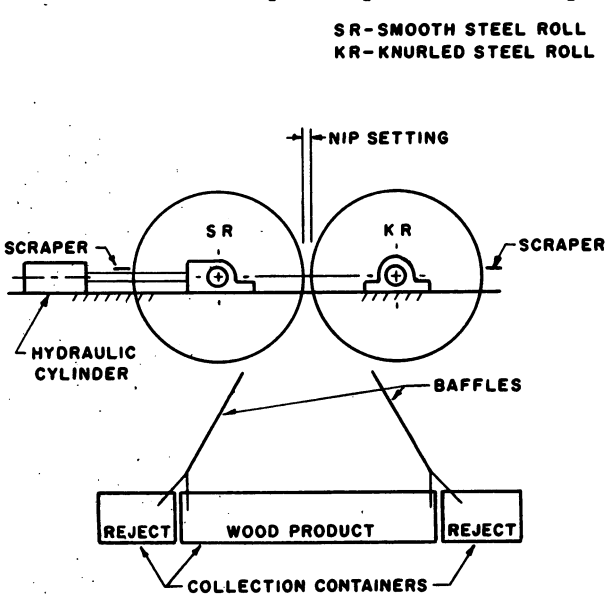

Figure 2.—*Simplified schematic diagram of the compression debarker.*

Most of the residual bark in the "clean" chip mass after steaming and compression is concentrated in the smaller size classes. If a minimal level of bark is desired in the compression debarker output, the minus ⅜-inch size class can be screened out. This screening will reduce the bark content of whole-tree chips of the major Lake States pulpwood species to an average level of 5 percent or less with total bark removal more than 80 percent (table 2). To illustrate, 100 pounds of as-received aspen input material contained 20.6

Table 2.—*Compression debarking results for whole-tree chips*[1]

(In percent)

Month	Input bark	Output bark	Input bark removed	Input foliage	Output foliage	Input foliage removed	Input wood recovered	Total material removed
ASPEN								
Jan.	22	3	89				91	27
Mar.	19	2	90				92	24
May	21	2	94				93	25
July	20	2	92	1	1	43	92	25
Sept.	21	2	92	1	1	34	92	26
Nov.	20	3	89				93	24
Average	21	2	91	1	1	39	92	25
SUGAR MAPLE								
Jan.	14	2	91				84	26
Mar.	13	2	87				90	20
May	14	4	79				88	22
July	14	4	82	2	2	40	80	29
Sept.	14	3	82	2	1	54	82	28
Nov.	14	3	83				89	21
Average	14	3	84	2	1	47	86	24
JACK PINE								
Jan.	10	1	89	3		91	79	30
Mar.	9	2	87	3	1	88	85	24
May	12	2	88	5		95	88	26
July	10	2	85	4		96	87	24
Sept.	11	2	87	4		95	81	26
Nov.	10	3	80	5		94	85	25
Average	10	2	86	4		93	84	26

[1]Presteamed for 5 min. at 30 PSI, compression debarked, minus ⅜-inch size fraction screened off. All results on oven dry basis.

pounds of bark, 1 pound of foliage on an oven dry basis, and 78.4 pounds of clean wood. After steaming, compression, and screening off all material under ⅜-inch, 25.2 pounds of material has been removed, leaving 74.8 of the original 100 pounds. Of this 74.8 pounds, 1.8 pounds is bark, 0.6 pound is foliage, and 72.4 pounds is wood. The amount of removal has been 91 percent of the original bark and 39 percent of the original foliage.

HARVEST AND TRANSPORT COSTS OF WHOLE-TREE CHIPS

The harvest and transport costs of whole-tree chipping operations vary with equipment, stand, terrain, and distance to the mill. For this paper we will assume a typical harvesting situation and project a reasonable cost of supplying whole-tree chips to a mill.

To estimate the cost of whole-tree chips, we will assume: clearcut material is of average quality from aspen stands, distance from stump to mill is 50 miles, the operator has enough equipment to provide a constant flow of chips, and stumpage charge is based on total removal of chips.

Typical equipment an operator might have are: accumulating head feller-buncher(s), grapple skidder(s), whole-tree chipper, chain saws, fuel truck, maintenance truck, chip vans, highway tractors, and landing tractor.

The crew size required to support this equipment ranges from 5 to 10 and the purchase cost of the equipment exceeds $300,000.

The following tablulation presents estimated costs of supplying aspen whole-tree chips to the mill under the above assumptions.

Green Aspen Whole-tree Chips Delivered to Mill:

	$/Green Ton
Chips to van	6.25
Harvest equipment &labor—$5.00	
Misc. (Insurance, Roads, etc.)—$1.25	
Transport to mill (Approx. 50 mi.)	3.00
Stumpage	2.00
TOTAL TO MILL	11.25
Mill yard handling	1.00
TOTAL TO BCSS PLANT	12.25

BCSS PLANT COST ANALYSIS

The cost to process unbarked whole-tree chips through the BCSS plant was developed from the basic engineering data concerning the process flow obtained by laboratory testing, manufacturers cost estimates of equipment, and standard estimating factors for other physical plant costs based on the installed cost of process equipment (Cooldge and Pfeiffer 1956). The estimate is at a preblueprint stage and is only intended to give an initial indication of economic factors affecting the feasibility of compression debarking of whole-tree chips. Real proposed installations are unique cases and must be considered individually.

The following basic assumptions were made to arrive at the estimate:

- The scale of operation is mid-range, neither unusually large or small.
- The plant is independent of other operations for facilities and materials.
- All plant facilities are owned and not leased.
- All construction costs are included and there are no zero cost contributions of labor or other items.
- All materials and equipment are purchased new at normal prices with no extraordinary features.
- Construction costs will not be affected by excessive delays in plans or unusual time restraints.

Based on the laboratory results for a process of presteaming, compression debarking, and screening, the material balance for a production scale plant of 60 tons per hour (green weight basis) is tabulated for three typical Lake States species (table 3). The material balance dictates the size of process equipment required to handle the maximum amount of material expected at each stage of the process.

Using the material balance (table 3), equipment requirements of the plant flow diagram (fig. 3), and manufacturers estimates of costs for the hardware, the capital and operating costs of the 60 ton per hour plant were calculated as follows:

Table 3.—*Production for 60 ton per hour compression debarking plant*

Item	Aspen	Sugar maple	Jack pine
Input (green tons)	60.0	60.0	60.0
Input (dry tons)	31.8	38.0	29.2
Input moisture content[1] (percent)	47.0	37.0	51.0
Output (green tons)	43.9	44.5	39.6
Output (dry tons)	23.8	28.9	21.8
Output moisture content[1] (percent)	46.0	35.0	45.0
Rejects (green tons)	16.1	15.5	20.4
Rejects (dry tons)	8.0	9.2	7.5
Rejects moisture content[1] (percent)	50.0	41.0	63.0
Rejects bark (percent)	62.0	51.0	36.0
Rejects foliage (percent)	[2]2.0	[2]3.0	15.0

[1]Green basis.

[2]Foliage season only.

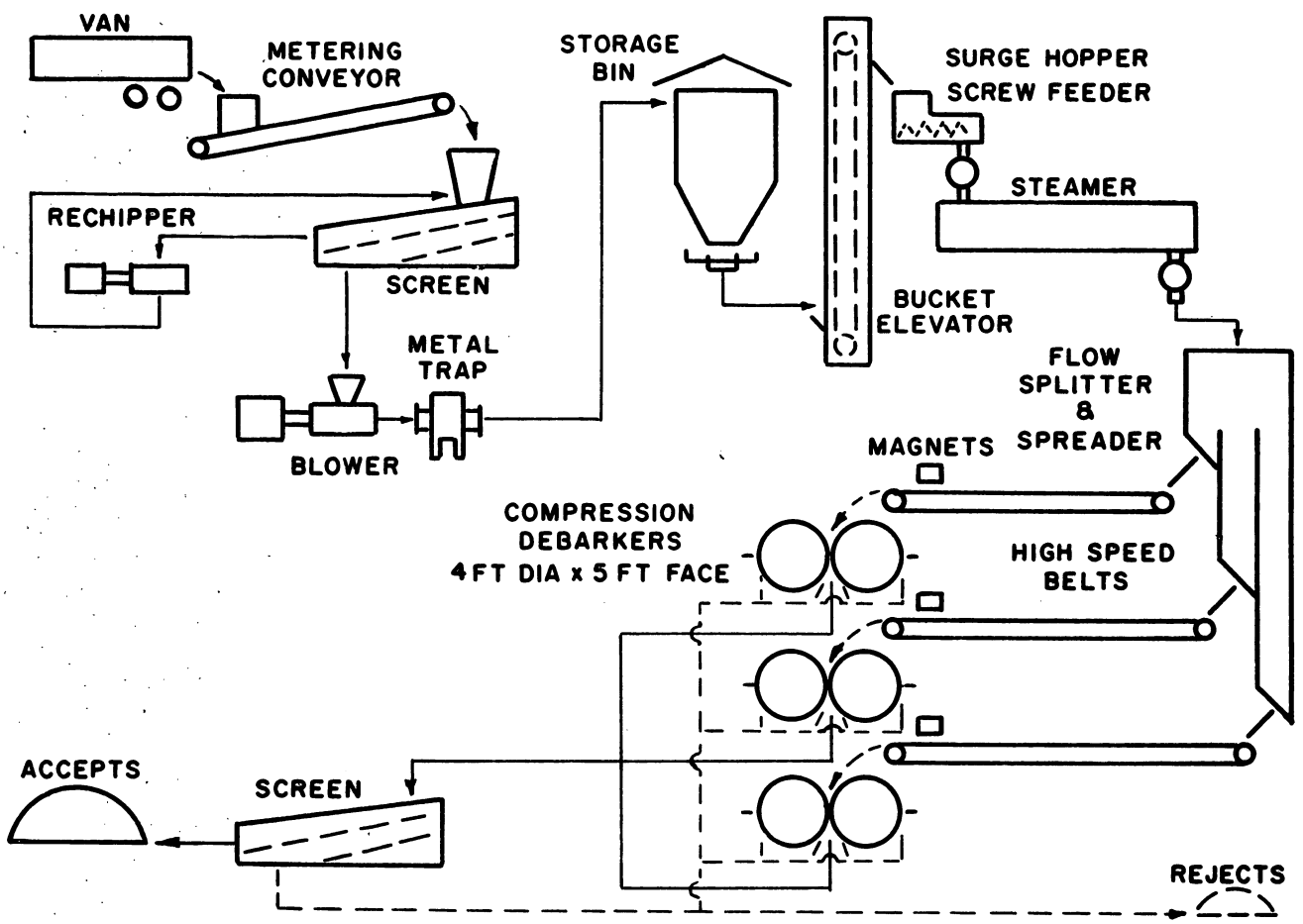

Figure 3.—*Schematic of 60 ton per hour compression debarking plant.*

COST ESTIMATE FOR 60 TON/HOUR BCSS PLANT

Equipment Cost Estimate

	Dollars
Presteamer	350,000
Compression debarker(s)[1]	857,000
Conveying Equipment	202,000
Supply hopper	56,000
Screens	92,000
Rechipper	29,000
Total delivered cost of equipment (to Green Bay, WI)	1,586,000
Installation (30%)	476,000
Total installed cost of equipment	2,062,000

Physical Plant Cost Estimate[2]

Item	Estimating factor (percent of installed cost)	Dollars
Installed equipment		2,062,000
Site preparation	5	113,000
Building & building services	20	412,000
Process piping	7	134,000
Electrical installations	9	186,000
Utilities and other services	9	186,000
Construction overhead	30	619,000
Contingencies	20	412,000
Total physical plant cost		4,124,000

Operating Cost Estimate

Estimated Annual Production: (8,000 hours/year) — 199,000 Oven dry debarked tons

	Annual cost	Cost/ output ton
Raw Material		
60 tons/hours × 8,000 hours/year × $12.25/ton =	$5,880,000	$29.55
Utilities		
Electricity: 789 hp × 0.7457 kw/hp × 8,000 hours/year × $.024/kwh =	112,965	.57
Steam: 60 tons/hour × 2,000 lbs./tons × 189Btu/lb. × MBtu/106 Btu × $2.50/MBtu × 8,000 hour/year =	453,600	2.28
Other Utilities:	79,600	.40
Total utilities	$ 646,165	$ 3.25
Labor		
Direct: 3 men/shift × 8,760 hours/year × $6.00/hour =	$ 157,680	$ .79
Direct Supervision Direct Labor × .10 =	15,768	.08
Payroll Overhead Direct Labor × .20 =	31,536	.16
Total labor	$ 204,984	$ 1.03

Investment Determined Cost

	Annual cost	Cost/ output ton
General Overhead		
Direct Labor × .55 = 157,680 × .55	$ 86,724	$ .44
Physical Plant Cost × .02 = 4,124,000 × .02	82,480	.41
Maintenance		
Physical Plant Cost × .04 = 4,124,000 × .04	164,960	.83
Operating Supplies		
Physical Plant Cost × .005 = 4,124,000 × .005	20,620	.10
Depreciation		
Process Equip. × .10 = 1,586,000 × .10	158,600	.80
Building × .05 = 412,000 × .05	20,600	.10
Taxes		
Physical Plant Cost × .02 = 4,124,000 × .02	82,480	.41
Insurance		
Physical Plant Cost × .01 = 4,124,000 × .01	41,240	.21
Total investment determined cost	657,704	3.31
TOTAL PRODUCTION COSTS	7,388,853	37.13
FUEL CREDIT (see below)	(2,432,500)	(12.22)
NET PRODUCTION COSTS	$4,956,353	$24.91

[1]*Based on 4 green tons per hour per foot of roll width, 3 units with 5-foot rolls are required.*

[2]*See Appendix for description of categories for physical plant costs.*

As a credit to the production cost of the BCSS plant, approximately 139,000 tons of reject material (50 percent of which is bark) at a moisture content of 50 percent is generated per year. This material is uniform in size and ideally suited for burning to generate process steam or power. With a fuel cost of $.35 per gallon for oil, the equivalent fuel value of this reject material would be $17.50 per ton (Arola 1975). This fuel value would give a credit of $2,432,500 per year or $12.22 per dry output ton to the production costs of the BCSS plant. Subtracting the fuel credit gives a net production cost of $4,956,353 per year or $24.91 per dry output ton. It is interesting to note that the fuel value of the reject material exceeds the production cost of the debarking plant, exclusive of raw material costs.

DISCUSSION

Any evaluation of the potential of whole-tree chips as a fiber source must consider the wood supply system in its entirety, i.e., from stump to digestor. Numerous factors not considered in this paper affect the overall economics of the system. Among the significant characteristics of whole-tree harvesting and utilization systems not considered here are the following:

- The increased yield of whole-tree chipping systems will reduce the size of the required woodshed of a mill and also reduce the average hauling distances for transport to the mill.
- The removal of all the material from the stand has positive benefits from the site preparation and regeneration aspects and also produces a site that is more aesthetically acceptable.
- The compression of the chips during the beneficiation process opens the chips along the fiber lines, which allows more rapid penetration of the cooking liquors and reduced cooking time.
- The opening of the chips reduces knot rejects and produces greater uniformity in the pulp.

The cost figures presented in this paper are only rough estimates of what might be found under actual conditions. Each pulp mill operator considering the installation of a compression debarking plant to beneficiate whole-tree chips will, of course, have to make his own analysis taking into account his individual circumstances. However, we feel the cost figures presented here indicate that whole-tree chipping and beneficiation of the chips by compression debarking is competitive with conventional fiber sources and is a feasible means of expanding wood supplies.

The costs presented are for one alternative chip quality improvement system. Another promising alternative approach is to combine the above system with air flotation.

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APPENDIX

Description of categories in physical plant costs

Site Preparation.—clearing; cleanup; grading and drainage; roads and walks; railroad and siding facilities; fencing.

Building and Building Services.—process building; warehouses; partitioning, doors and windows for offices and laboratory; lighting; plumbing for washrooms; drinking fountains; drains; ventilation; sprinkling system.

Process Piping (for materials handling).—installed costs of pipes to convey raw materials, intermediate products, finished products; steam; water; air; waste within process building.

Electrical Installations for Power Distribution.—transformers; yard distribution; wiring; power and instrument wiring within building; control centers; instrument panels; switchboards (does not include other outside costs, motor and motor starters, or building lighting).

Utilities and Other Service Facilities.—water; steam costs for generating plant (including pipes, valves, and meters); electrical costs from substation; fuel distribution air compressors and pipes; refuse disposal; fire protection; furniture; equipment.

Construction Overhead.—engineering, construction drawings; work planning and supervision; contractor's fee; home and field office expenses; insurance during construction; payroll overhead for permanent employees; property taxes; licenses and permits; interest charges on land and building during construction; depreciation of building and land during construction.

Contingencies.—Unforeseen outlays; uninsured losses; price increases.

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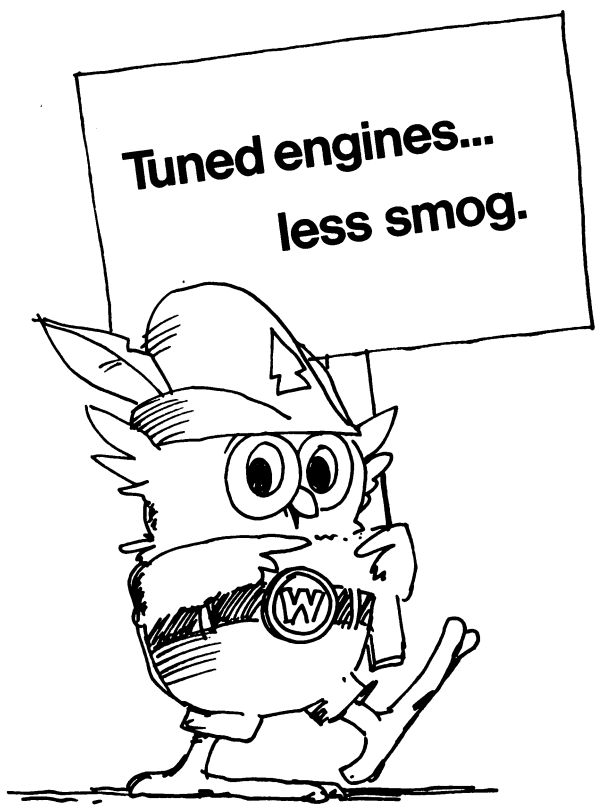
Tuned engines...
less smog.