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Rodger A. Arola,
John R. Erickson

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE • U.S. DEPARTMENT OF AGRICULTURE

**THE AUTHORS are Principal Mechanical Engineers for the Station. They are headquartered at the Station's Forest Engineering Laboratory in Houghton, Michigan. The Laboratory is maintained in cooperation with the Michigan Technological University.**

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**North Central Forest Experiment Station**
**John H. Ohman, Director**
**Forest Service — U.S. Department of Agriculture**
**Folwell Avenue**
**St. Paul, Minnesota 55101**
(Maintained in cooperation with the University of Minnesota)

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# COMPRESSION DEBARKING OF WOOD CHIPS

**Rodger A. Arola and John R. Erickson**

New timber harvesting methods are needed to improve the utilization of our forest resources, including logging residue. The gross volume of this material is estimated to be 2 billion cubic feet annually (excluding residual cull trees and thinnings) (Lassen and Hair 1970). This amount of wood fiber would fill more than 40 percent of our national pulpwood needs. Although economy is the major reason for leaving residue in the woods, the neglect of this material displays inefficient utilization standards.

In addition to the need for increased utilization, several environmental issues require attention. The Clean Air Act will impose restrictions on slash disposal by burning. We already have these restrictions in several areas of the country. Another environmental issue is "visual pollution." The public has voiced concern over the unsightly appearance of residue left after logging.

Before we can increase utilization standards and meet the impending environmental restrictions we must develop new technologies to remove sufficient levels of bark from residue wood. This is a major goal of the Forest Engineering Laboratory (F.E.L.) in Houghton, Michigan.

Bark removal after chipping is one promising approach that will help to improve the utilization standards of the forest industry. Bark removal after chipping is a two-stage problem: bark separation (the breaking of the bond between the bark and wood chip) and segregation (the removal of bark particles from the wood chips). We use the term bark removal to encompass both of these problems.

Compression debarking is a method that has shown considerable promise for removing bark from wood chips. The compression debarking principle involves passing a continuous single-layer flow of unbarked wood chips between two rotating steel rolls that have a nip spacing much smaller than the thickness of the wood chips. Due to the nip action, the bark particles either adhere to the surface of the rolls and are removed with roll scrapers into a waste area, or they fragment into smaller particles and are removed by screens.

The compression debarking process was initially developed by the Hosmer Machine Company (now HMC Corp.); however, the system was not developed commercially (Blackford 1961, 1965, 1966; Blanchard 1962). Because this concept showed promise, we decided that further work should be performed to evaluate the principle along with developing new methods to complement the process.[1] This paper discusses the results of an 18-month study of the compression debarking process as a single-pass system. Future publications will discuss complementary treatments.

## STUDY OBJECTIVES AND TEST VARIABLES

Our study objective was to investigate the effect of several natural and machine variables on the amount of bark removal and wood recovery possible with the HMC experimental unit (fig. 1). The ultimate goal was to reduce the chip bark content to a residual of 1½ to 3 percent by weight (green) and to hold the wood loss to less than 5 percent.

Natural variables included species, season of cut, presized chips versus random mix, and fresh versus roundwood storage prior to chipping. Duplicate runs were made with chips produced from bolewood and tops and limbs.

The prime machine variables investigated were nip setting between two steel compression rolls, nip pressure in the chip compression zone, and adjustable baffle location beneath the rolls (fig. 2). Because of the large

[1] *Arola, R. A. State-of-the-art and analysis of bark-chip separation-segregation. (Unpublished report on file at the North Cent. For. Exp. Stn., USDA For. Serv., St. Paul, Minn. 1966)*

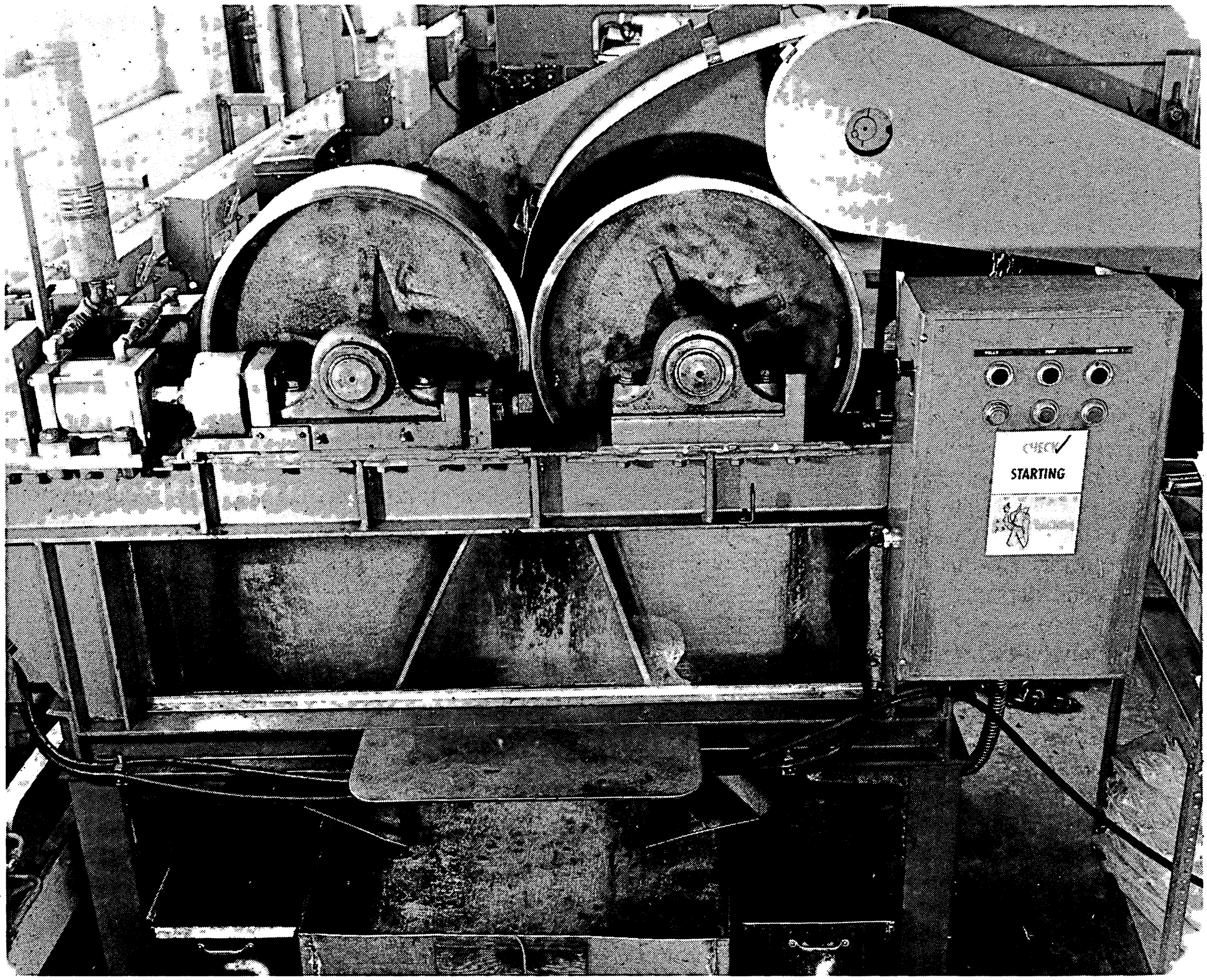


*Figure 1. – The experimental compression debarker used for debarking wood chips.*

number of tests required to complete the factorial experiments, roll speed and bulk feed rate (two additional prime variables) were kept constant for this study at respective values of 740 surface feet per minute and 1 cubic foot per minute.

## MATERIAL DESCRIPTION AND ANALYSIS

We included three important Lake States species in our test program — aspen, which commands over 50 percent of the pulpwood market; hard maple, from the northern hardwood type; and jack pine. Southern pine was also tested. The total number of cuttings tested was as follows: fresh jack pine and aspen, five each; fresh hard maple, four; stored aspen, three; and stored jack pine and hard maple, two each (table 1). Three cuttings of fresh southern pine were also tested.

Unbarked chip samples were obtained from fresh bolewood, fresh tops and limbs, and stored bolewood (table 1). Bolewood was topped at approximately a 4-inch diameter and the topwood diameters were limited to approximately 2 inches. Foliage was not present in topwood.

All chips were produced with a Morbark Chip-Pac[2] and delivered to the F.E.L. by the following day. Within 1 week of chip delivery all material was classified

[2] *Mention of trade names does not constitute endorsement by the USDA Forest Service.*

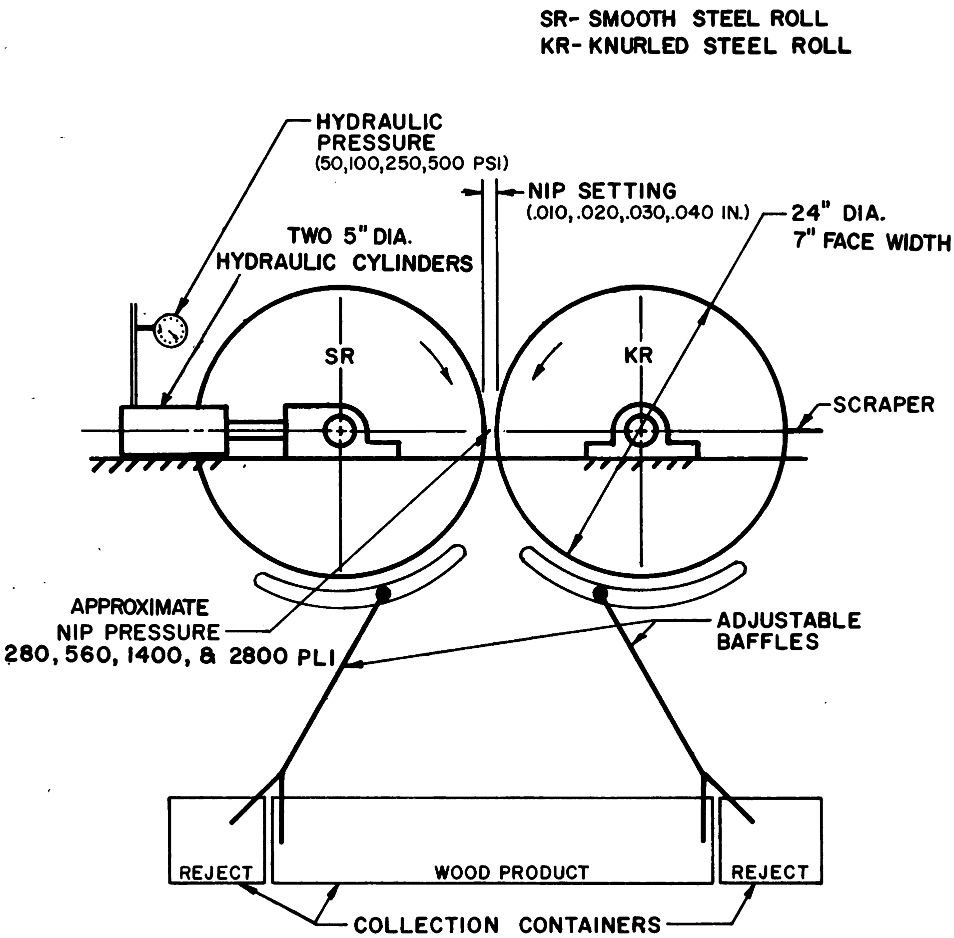


*Figure 2. – Simplified compression debarker and machine variables.*

and 25-pound charges were prepared and stored in plastic bags prior to compression debarking. During classification the chips were screened to remove those less than 3/16 inch and more than 1⅛ inches in size (round-hole screen), because we assumed fines would normally be discarded and oversize material rechipped and added to the input mix. The remaining chips were separated into three size classes with a SWECO[2] Classifier: 3⁄16 to ⅜ inch; ⅜ to ⅝ inch; and ⅝ to 1⅛ inches. Only the bark within these size classes was considered as input bark content in the compression debarking trials.

Two types of material were obtained for analysis from each debarking test — the residue removed from the compression rolls and the wood product output. The residue contained some wood fiber, which was considered as wood loss (methods to recover some of this wood are currently being studied). Conversely, the wood product output contained a residual bark content. Thus, both classes of material were sampled and analyzed to determine the amount of wood and bark in the output and in the residue material. The residual bark still adhering to the wood chips (called bark/wood) was also measured and compared with the input bark/wood fraction to evaluate the effectiveness of compression debarking in breaking the bark-to-wood bond. The output from the compression debarker was screened on a Williams Classifier[2] into the previously indicated size fractions and bark content determined within each chip size class.

## RESULTS

### Presized Chips Versus Random Mix

The chips were debarked both as a random mix and as separate presized fractions. In the latter, the best

Table 1. — *General information on species processed*

| Material | Date cut | Date chipped | Inclusive processing dates | Age | Approximate wood temperature at chipping | Bark content: Free bark | Bark content: Total bark | Bark content: Separation |
|---|---|---|---|---|---|---|---|---|
| | | | | Years | | Percent | Percent | Percent |
| **ASPEN** | | | | | | | | |
| Bolewood (fresh) | 17 Feb '70 | 19 Feb '70 | 3/3 -3/6 | 58 | Frozen | 13.1 | 15.8 | 86 |
| | 16 Apr '70 | 17 Apr '70 | 4/29-5/6 | 60 | Unfrozen | 13.4 | 20.1 | 67 |
| | 12 Aug '70 | 13 Aug '70 | 8/17-9/1 | 38 | Unfrozen | 14.5 | 15.3 | 95 |
| | 11 Dec '70 | 18 Dec '70 | 12/30-1/6 | 57 | 34° F | 12.8 | 15.3 | 84 |
| | 23 June '71 | 24 June '71 | 6/31-7/12 | 36 | 61° F | 18.2 | 18.2 | 100 |
| Topwood (fresh) | 16 Apr '70 | 17 Apr '70 | 4/29-5/6 | 32 | Unfrozen | 13.4 | 24.0 | 56 |
| | 12 Aug '70 | 13 Aug '70 | 8/17-9/1 | 21 | Unfrozen | 20.0 | 25.3 | 80 |
| | 11 Dec '70 | 18 Dec '70 | 12/30-1/6 | 32 | 34° F | 17.0 | 21.0 | 81 |
| | 23 June '71 | 24 June '71 | 6/31-7/12 | 14 | 61° F | 24.0 | 24.0 | 100 |
| Bolewood (stored) | 17 Feb '70 | 19 Nov '70 | 11/25-12/8 | 51 | — | 15.5 | 15.8 | 98 |
| | 16 Apr '70 | 20 June '71 | 1/25-2/2 | 46 | 24° F | 15.8 | 16.1 | 98 |
| | 12 Aug '70 | 6 May '71 | 5/11-5/25 | 37 | 50° F | 11.6 | 12.7 | 91 |
| **JACK PINE** | | | | | | | | |
| Bolewood (fresh) | 23 Dec '69 | 30 Dec '69 | 1/30-2/4 | 48 | Frozen | 4.6 | 6.4 | 72 |
| | 23 Mar '70 | 24 Mar '70 | 4/20-4/21 | 31 | Unfrozen | 4.8 | 8.5 | 57 |
| | 25 Aug '70 | 26 Aug '70 | 9/11-9/24 | 30 | Unfrozen | 8.6 | 8.9 | 97 |
| | 15 Feb '71 | 17 Feb '71 | 2/17-3/5 | 50 | 28° F | 3.9 | 7.8 | 50 |
| | 8 June '71 | 9 June '71 | 6/18-6/23 | 31 | 51° F | 8.8 | 8.8 | 100 |
| Topwood (fresh) | 23 Dec '69 | 30 Dec '69 | 1/30-2/4 | 22 | Frozen | 7.5 | | |
| | 23 Mar '70 | 24 Mar '70 | 4/20-4/21 | 14 | Unfrozen | 4.7 | 9.9 | 47 |
| | 25 Aug '70 | 26 Aug '70 | 9/11-9/24 | 13 | Unfrozen | 8.7 | 9.6 | 91 |
| | 15 Feb '71 | 17 Feb '71 | 2/17-3/5 | 23 | 28° F | 4.7 | 10.3 | 46 |
| | 8 June '71 | 9 June '71 | 6/18-6/23 | 13 | 51° F | 9.0 | 9.1 | 99 |
| Bolewood (stored) | 23 Dec '69 | 2 Nov '70 | 11/13-11/19 | 51 | — | 5.0 | 5.0 | 100 |
| | 23 Mar '70 | 6 June '71 | 1/11-1/20 | 29 | 8° F | 6.1 | 6.2 | 98 |
| **HARD MAPLE** | | | | | | | | |
| Bolewood (fresh) | 7 Mar '70 | 9 Mar '70 | 3/13-3/26 | 37 | Frozen | 10.9 | 11.6 | 94 |
| | 29 July '70 | 30 July '70 | 8/4 -8/14 | 54 | Unfrozen | 12.9 | 12.9 | 100 |
| | 21 Sept '70 | 2 Oct '70 | 10/19-10/28 | 63 | Unfrozen | 12.0 | 12.7 | 95 |
| | 17 May '71 | 20 May '71 | 6/2 -6/7 | 41 | 40° F | 12.6 | 12.6 | 100 |
| Topwood (fresh) | 7 Mar '70 | 9 Mar '70 | 3/13-3/26 | 37 | Frozen | 13.2 | 14.3 | 92 |
| | 29 July '70 | 30 July '70 | 8/4 -8/14 | 20 | Unfrozen | 13.5 | 13.6 | 99 |
| | 21 Sept '70 | 2 Oct '70 | 10/19-10/28 | 41 | Unfrozen | 14.6 | 17.6 | 83 |
| | 17 May '71 | 20 May '71 | 6/2 -6/7 | 24 | 40° F | 15.6 | 15.7 | 94 |
| Bolewood (stored) | 7 Mar '70 | 3 Dec '70 | 12/9 -12/21 | 88 | — | 10.7 | 10.7 | 100 |
| | 29 July '70 | 15 Apr '71 | 4/21-5/4 | 66 | 42° F | 13.4 | 13.4 | 100 |

results (in terms of bark removal) within each size fraction were mathematically weighted and combined into a "reconstituted" mix to give an overall bark removal and wood recovery. This permitted us to compare the results with presized chips with the best results for chips processed as a random mix. The hypothesis was that a "best" combination of machine parameters existed for processing each of the three chip sizes, which would be an improvement over processing random-sized chips.

The compression debarking results did not improve when presized chips were processed (table 2). For example, the mean input bark content of presized aspen bolewood was reduced to 8.5 percent while that of the random mix was reduced to 8.6 percent. The mean wood

Table 2. — *Compression debarking results for reconstituted and random-mix bolewood chips (fresh)*[1]
*(In percent)*

| Species | Input bark | Reconstituted mix | | | Random mix | | |
|---|---|---|---|---|---|---|---|
| | | Residual bark | Bark removed | Wood recovered | Residual bark | Bark removed | Wood recovered |
| Jack pine: | | | | | | | |
| Mean | 8.5 | 3.2 | 62.3 | 95.3 | 2.4 | 71.8 | 92.2 |
| Range | 7.8- 8.9 | 1.8- 4.4 | 43.6-79.5 | 93.7-96.7 | 1.3- 3.6 | 57.6-85.2 | 86.7-96.6 |
| Aspen: | | | | | | | |
| Mean | 16.9 | 8.5 | 49.2 | 97.0 | 8.6 | 49.4 | 96.3 |
| Range | 15.3-20.1 | 5.4-10.8 | 29.4-70.3 | 94.4-98.3 | 5.0-10.3 | 32.7-72.5 | 94.0-97.7 |
| Hard maple: | | | | | | | |
| Mean | 12.4 | 5.2 | 57.5 | 97.5 | 4.7 | 61.5 | 97.4 |
| Range | 11.6-12.9 | 3.3- 7.4 | 36.2-74.4 | 93.6-99.5 | 2.3- 7.9 | 31.9-82.2 | 93.6-99.2 |
| Loblolly: | | | | | | | |
| Mean | 10.3 | 4.9 | 52.4 | 96.9 | 4.8 | 53.6 | 96.2 |
| Range | 10.0-10.8 | 4.0-5.8 | 43.1-63.0 | 96.2-98.4 | 3.5- 5.6 | 45.1-67.6 | 94.9-97.6 |

1/ Nip pressure set at 560 Pli.

recovery for presized aspen chips was 97.0 percent, compared with 96.3 percent for chips processed as a random mix. The mean residual bark content of the other species was slightly less for the random mix than the presized material.

## Bolewood Versus Topwood

We found little difference between the compression debarking results of bolewood and topwood (table 3). The mean percent bark removal for aspen and loblolly topwood was slightly greater than for bolewood but was within the experimental seasonal range for bolewood. The percent of input bark content in topwood was 22 to 35 percent greater than for bolewood. Thus, the residual bark content in topwood was slightly greater than in bolewood. The wood recovery was about the same for both types of material — for bolewood it ranged from 92.2 to 97.4 percent, and for topwood from 92.4 to 98.1 percent.

## Fresh Versus Stored Bolewood

Although good bark separation resulted when bolewood was stored for approximately 9 months prior to chipping (table 1), no consistent improvement in segregation occurred (table 4). Roundwood storage had no

Table 3. — *Compression debarking results for random-mix bolewood and topwood chips (fresh)*[1]
*(In percent)*

| Species | Bolewood | | | | Topwood | | | |
|---|---|---|---|---|---|---|---|---|
| | Input bark | Residual bark | Bark removed | Wood recovered | Input bark | Residual bark | Bark removed | Wood recovered |
| Aspen: | | | | | | | | |
| Mean | 16.9 | 8.6 | 49.4 | 96.3 | 22.9 | 10.7 | 52.4 | 95.9 |
| Range | 15.3-20.1 | 5.0-10.3 | 32.7-72.5 | 94.0-97.7 | 20.2-25.3 | 6.1-15.8 | 34.2-74.6 | 93.4-97.9 |
| Hard maple: | | | | | | | | |
| Mean | 12.4 | 4.7 | 61.5 | 97.4 | 15.3 | 6.7 | 56.1 | 98.1 |
| Range | 11.6-12.9 | 2.3- 7.9 | 31.9-82.2 | 93.6-99.2 | 13.6-17.6 | 4.0- 9.9 | 30.8-72.4 | 97.1-98.8 |
| Jack pine: | | | | | | | | |
| Mean | 8.5 | 2.4 | 71.8 | 92.2 | 10.7 | 3.8 | 66.5 | 92.4 |
| Range | 7.8- 8.9 | 1.3- 3.6 | 57.6-85.2 | 86.7-96.6 | 9.1-14.7 | 0.5- 7.2 | 44.4-94.5 | 88.6-95.1 |
| Loblolly: | | | | | | | | |
| Mean | 10.3 | 4.8 | 53.6 | 96.2 | 12.6 | 5.1 | 59.7 | 95.8 |
| Range | 10.0-10.8 | 3.5- 5.6 | 45.1-67.6 | 94.9-97.6 | 11.9-13.3 | 4.4- 5.8 | 56.4-63.0 | 94.3-97.3 |

1/ Nip pressure set at 560 Pli.

Table 4. — *Compression debarking results for fresh and stored bolewood chips*[1]
*(In percent)*

| Species, bolewood condition | Input bark | Reconstituted mix | | | Random mix | | |
|---|---|---|---|---|---|---|---|
| | | Output bark | Bark removed | Wood recovered | Output bark | Bark removed | Wood recovered |
| Aspen: | | | | | | | |
| Fresh | 16.9 | 8.5 | 49.2 | 97.0 | 8.6 | 49.4 | 96.3 |
| Stored | 14.9 | 7.3 | 50.7 | 97.0 | 6.1 | 59.5 | 97.1 |
| Hard maple: | | | | | | | |
| Fresh | 12.4 | 5.2 | 57.5 | 97.5 | 4.7 | 61.5 | 97.4 |
| Stored | 12.1 | 5.2 | 57.8 | 92.5 | 6.5 | 46.1 | 96.4 |
| Jack pine: | | | | | | | |
| Fresh | 8.5 | 3.2 | 62.3 | 95.3 | 2.4 | 71.8 | 92.2 |
| Stored | 5.6 | 2.9 | 48.5 | 94.9 | 2.4 | 57.7 | 94.8 |

1/ Nip pressure set at 560 Pli.

effect on the average wood recovery. The aspen was cut in February and April, the hard maple in March and July, and the jack pine in December and March.

Long-term storage of wood chips in piles was not tested. However, we did observe a significant increase in bark removal when aspen chips were stored at room temperature in polyethylene bags for approximately 3 weeks. Regardless of the compression debarker nip and pressure settings we were able to remove approximately 90 percent of the input bark and recover 90 to 95 percent of the wood fiber. Because bark removal improved with bag storage, tests were run on aspen chips stored in a small pile in an unheated building during the winter and on chips stored in polyethylene bags at room temperature. Chips from each source were sampled for 2 months at 3- to 5-day intervals. The pile-stored chips did not yield an increase in bark removal over this period — the residual bark fluctuated between 57 and 73 percent of the input bark content with a mean value of 67 percent (fig. 3). The residual bark in bag-stored material showed a significant reduction with storage time — it decreased from 69 percent of the input at the start of storage to 11 percent after 55 days of storage. Wood recovery decreased slightly with prolonged bag storage.

The bag-stored aspen chips and bark were analyzed for moisture content at various intervals over a 43-day period. The wood chips started at about 53 percent moisture and decreased to 47 percent (wet basis) in that period while the bark started at 41 percent and increased to 53 percent. Thus, a transfer of moisture occurred between wood and bark stored in the plastic bags. The moisture content in wood and bark were equal in about 16 days, after which the cambial surface of the bark started to feel tacky. This explained why the bark readily adhered to the compression rolls.

The benefits of bag storage led to a search of "conditioning" treatments that would simulate the action in the polyethylene bags. One approach was to heat the chips with low-pressure steam. A study is now in progress to determine optimum steaming temperature, pressure, and time for aspen, hard maple, jack pine, and southern pine. Steaming prior to compression debarking to increase bark removal is definitely a beneficial treatment — particularly with aspen.

An interesting study that relates to the effect of bag storage on chips was conducted at the Forest Products Laboratory, where wood chips were covered with plastic membranes to limit chip deterioration by cutting down

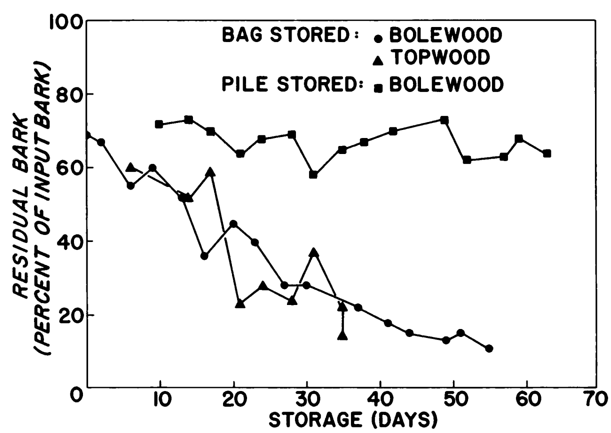


*Figure 3. – Effect of bag storage at room temperature on bark removal.*

the oxygen supply (Feist *et al.* 1971). Fresh aspen chips stored for 185 days under a 20-mil.-thick polyethylene sheet showed less deterioration and yielded a kraft pulp of comparable quality to fresh chips. The covered chips also showed slight staining and light mycelial growth. It is our opinion that this mycelial growth caused the tackiness of the cambial surface of the bark in our bag-stored chips, and we feel it desirable for improving the compression debarking process. Methods to artificially induce *controlled* mycelial growth in unbarked chip piles may be worthy of investigation.

## Nip Spacing and Pressure

The tests to evaluate the combined effect of nip spacing between the rolls and the pressure per lineal inch of roll width did not result in a true "optimum" combination of the two. Bark removal decreased with increased nip spacing within the range of 0.010 to 0.040 inch, whereas wood recovery increased. Conversely, bark removal increased with increased nip pressure in the range of 280 to 2,800 pounds per lineal inch (pli), and wood recovery decreased.

The greatest bark removal and least wood recovery occurred at the 0.010-inch nip spacing and 2,800 (pli) nip pressure. Ideally, both bark removal and wood recovery would be maximized. However, conditions that lead to improved wood recovery also lead to reduced bark removal. Thus, a compromise had to be made between bark removal and wood recovery. We looked for a combination of nip spacing and pressure that gave approximately 50 percent bark removal and 95 percent wood recovery for all seasons of the year. For bolewood, a combination of 0.020-inch nip spacing and 1,400 pli of nip pressure yielded results closest to the desired bark removal and wood recovery levels for all species tested. Topwood was tested only at the 560 pli level and four nip spacings. However, based on the similarity in results between bolewood and topwood at this pressure level, it is felt that the 1,400 pli nip pressure would also be a good compromise for topwood.

## Baffle Location

The original compression debarker employed stationary baffles under the compression rolls to segregate and collect bark and wood chips. Because the bark and wood chips of each species and season adhered to the compression roll with varying tenacity, we added adjustable baffles beneath the rolls of the compression debarker to control the bark removal or wood recovery for each species. As we moved the baffles closer to the mainstream of wood output more bark was removed, but at a sacrifice in wood recovery. As the baffles were moved away from the mainstream of wood output more wood was recovered, but the residual bark in the wood output also increased.

We were unable to determine the "best" baffle location because of mechanical limitations in the machine used in the original study. A more detailed study with a revised test setup is now underway to evaluate how much material adheres to each roll and the trajectory distribution of bark and wood particles that are thrown off the rolls. We plan to develop histograms of bark and wood trajectory from each roll and establish confidence limits for bark removal and wood recovery with varying baffle locations. These data will make it possible to recommend baffle locations in a production or pilot plant unit.

## Season of Cut

Cutting season affected the amount of bark that separated from the wood chips due to chipping. With wood cut during the growing season, nearly all of the bark separated from the wood due to the chipping action. However, with wood cut during the dormant season, less than 40 percent of the bark of some species separated from the chips. We also found that compression debarking segregated more bark from wood cut during the growing season:

| | *Bark removal* | |
|---|---|---|
| *Species* | *Growing season (Percent)* | *Dormant season (Percent)* |
| Aspen | 70 | 41 |
| Maple | 70 | 43 |
| Jack pine | 80 | 57 |

This is probably due to two factors: (1) better separation of the bark/wood bond, and (2) the cambial layer of the bark is tackier and adheres better to the compression rolls.

Because of the strong influence of season on bark removal we have sought a "conditioning" treatment to offset the seasonal effects. Preliminary test results show that steaming of the bark-chip mass prior to compression debarking helps to offset seasonal effects. As previously indicated, steaming of unbarked chips prior to compression debarking is now under investigation.

## Smooth Versus Knurled Roll

The compression debarker as tested was equipped with a smooth and a knurled compression roll (fig. 2). The amount of material that the smooth and knurled rolls removed from the mix varied by species (and, of course, by season as previously indicated) (table 5). For all cuttings the combined amount of material removed from both rolls was slightly over 10 percent of the input.

Table 5. — *Results of compression debarking with smooth and knurled rolls for random-mix aspen, hard maple, and jack pine*[1]

*(In percent)*

| Species | Material removed from: | | | | | |
|---|---|---|---|---|---|---|
| | Smooth roll | | | Knurled roll | | |
| | Percent of input | Wood | Bark | Percent of input | Wood | Bark |
| Aspen[2/] | 5.1 | 21.2 | 78.8 | 5.4 | 19.0 | 81.0 |
| Jack pine[2/] | 7.0 | 39.6 | 60.4 | 5.8 | 42.2 | 57.8 |
| Hard maple[3/] | 3.3 | 14.5 | 85.5 | 6.3 | 22.9 | 77.1 |

1/ Nip pressure set at 560 Pli.
2/ Mean test results for five separate cuttings.
3/ Mean test results for four separate cuttings.

For aspen, approximately 20 percent of the material removed was wood and 80 percent bark with both rolls. For jack pine there was a considerably greater proportion of wood fiber loss — approximately 40 percent wood and 60 percent bark. With hard maple the knurled roll residue had over 20 percent wood while the smooth roll residue had only 14 percent wood. The knurled roll contributed most to the wood loss in maple because it removed nearly twice as much material as the smooth roll.

These tests were run with fresh chips — thus the chips had a high moisture content. Later observations indicated that wood loss increases considerably as the wood chips become drier.

## Bark Analysis by Chip Size Before and After Compression Debarking

As mentioned earlier, bark removal after chipping requires both separation (breaking of the bark-to-wood bond) and segregation (the removal of bark chips from wood chips). Compression debarking partially accomplished both jobs. Because compression debarking is a fairly severe mechanical treatment, it is of interest to compare the bark and chip sieve sizes before and after treatment.

Thus, we determined the percentage of free wood, free bark, and bark/wood[3] within each chip size before and after the compression treatment in addition to the percentage of the total mix that each size represents (table 6).

After compression debarking the percent of mix in each size fraction did not change much; however, the free wood, free bark and bark/wood percentages within each size fraction did change. For example, with aspen we found the ⅝ to 1⅛ inches fraction exceptionally clean — it had only 0.3 percent residual free bark and 0.9 percent bark/wood. The ⅜- to ⅝-inch fraction still had 11.0 percent free bark and 1.0 percent bark/wood. Most of the residual bark was concentrated in the two smallest chip sizes. Hard maple, jack pine, and loblolly pine yielded similar patterns.

We believe that much of the residual bark after compression debarking is bark that was originally attached to the wood chips in the input mix. In other words, the nip action broke the bark-to-wood bond but did not remove this bark from the mix. The bark/wood content was reduced in each size fraction after compression debarking. For ⅝- to 1⅛-inch aspen chips we were able to reduce the bark/wood content from 7.5 percent to 0.9 percent; for ⅜- to ⅝-inch chips from 2.5 to 1.0 percent; and for ³⁄₁₆- to ⅜-inch chips from 0.5 to 0.4 percent.

The bark content in the input chips and the processed chips has been plotted by chip size for each species tested (fig. 4). Additionally, these figures illustrate the percentage that each size fraction represents in terms of total mix. The bark contents are illustrated in bar chart form, and the percent of material in each chip size is shown graphically.

## CONCLUSIONS

The single-pass compression debarking process tested did not consistently reduce residual bark content to the goal of 3 percent for the species tested and for wood cut during all seasons. Additional processing

[3] *Free wood = wood chips with no bark adhering; free bark = bark particles with no wood adhering; bark/wood = wood chips with bark still adhering.*

Table 6. —*Free wood, free bark, and bark/wood percentages before and after processing by chip-size class*[1]

| Chip-size class (inches) | Material | Total mix | | Free wood | | Free bark | | Bark/wood | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Range | Mean | Range | Mean | Range | Mean | Range |
| ASPEN | | | | | | | | | |
| 5/8 - 1-1/8 | Input | 64.3 | 53.7-71.1 | 86.3 | 76.3- 91.4 | 6.2 | 4.2- 9.0 | 7.5 | 0.0-19.4 |
| | Output | 63.5 | 49.9-74.6 | 98.8 | 96.1-100.0 | .3 | 0.0- .6 | .9 | 0.0- 3.3 |
| 3/8 - 5/8 | Input | 29.2 | 24.8-36.1 | 69.5 | 66.2- 78.8 | 28.0 | 18.4-33.5 | 2.5 | 0.0- 6.7 |
| | Output | 27.2 | 20.0-34.7 | 88.0 | 84.6- 91.5 | 11.0 | 8.4-14.5 | 1.0 | 0.0- 2.7 |
| 3/16 - 3/8 | Input | 6.7 | 4.1-10.2 | 54.9 | 46.7- 68.9 | 44.6 | 30.8-53.3 | .5 | 0.0- 1.7 |
| | Output | 9.3 | 5.4-15.4 | 64.7 | 56.3- 68.4 | 35.0 | 32.7-42.2 | .4 | 0.0- 1.5 |
| HARD MAPLE | | | | | | | | | |
| 5/8 - 1-1/8 | Input | 65.4 | 64.7-66.5 | 95.5 | 95.0- 96.0 | 3.8 | 2.9- 4.5 | .7 | 0.0- 2.1 |
| | Output | 67.1 | 65.6-69.0 | 99.2 | 98.9- 99.7 | .7 | .3- 1.2 | .1 | 0.0- .4 |
| 3/8 - 5/8 | Input | 27.9 | 27.1-28.4 | 75.4 | 74.5- 76.0 | 24.2 | 23.2-25.4 | .4 | 0.0- 1.0 |
| | Output | 25.2 | 24.0-26.3 | 93.8 | 92.4- 95.0 | 6.1 | 5.0- 7.4 | .1 | 0.0- .2 |
| 3/16 - 3/8 | Input | 6.7 | 6.4- 6.9 | 50.7 | 46.0- 53.4 | 49.2 | 46.6-53.7 | .1 | 0.0- .3 |
| | Output | 7.7 | 6.9- 9.2 | 70.4 | 58.6- 79.5 | 29.4 | 20.5-40.8 | .2 | 0.0- .6 |
| JACK PINE | | | | | | | | | |
| 5/8 - 1-1/8 | Input | 58.5 | 52.5-62.5 | 87.6 | 80.3- 93.8 | 3.2 | .8- 6.1 | 9.3 | .1-18.9 |
| | Output | 49.4 | 45.4-53.4 | 97.7 | 93.8- 99.8 | .4 | .2- .6 | 2.0 | 0.0- 5.6 |
| 3/8 - 5/8 | Input | 33.2 | 31.4-37.0 | 86.8 | 83.1- 90.4 | 8.1 | 4.6-12.0 | 5.1 | 0.0-10.7 |
| | Output | 37.6 | 35.1-40.1 | 94.3 | 89.2- 97.8 | 3.5 | 2.2- 5.4 | 2.3 | 0.0- 5.4 |
| 3/16 - 3/8 | Input | 8.3 | 5.7-10.4 | 74.5 | 68.9- 82.1 | 24.4 | 16.4-30.8 | 1.1 | 0.0- 2.6 |
| | Output | 13.0 | 11.5-14.5 | 84.7 | 81.8- 87.6 | 14.0 | 13.4-15.3 | 1.3 | 0.0- 3.4 |
| LOBLOLLY PINE | | | | | | | | | |
| 5/8 - 1-1/8 | Input | 56.3 | 51.6-61.7 | 90.0 | 87.4- 93.8 | 4.1 | 3.3- 5.4 | 5.9 | .8- 8.9 |
| | Output | 51.9 | 47.1-57.8 | 97.3 | 96.0- 98.1 | 1.5 | .4- 2.4 | 1.3 | .1- 1.9 |
| 3/8 - 5/8 | Input | 34.5 | 32.0-37.8 | 84.7 | 84.4- 85.3 | 12.7 | 11.9-14.1 | 2.6 | .6- 3.7 |
| | Output | 36.2 | 32.5-40.4 | 91.4 | 88.7- 96.1 | 7.5 | 3.1-10.2 | 1.1 | .3- 2.1 |
| 3/16 - 3/8 | Input | 9.2 | 6.3-10.8 | 71.2 | 68.0- 76.8 | 28.4 | 22.7-32.0 | .5 | 0.0- .9 |
| | Output | 11.9 | 9.7-13.4 | 79.9 | 74.1- 84.5 | 19.6 | 14.9-25.9 | .5 | 0.0- 1.0 |

1/ Nip pressure set at 560 Pli.

or conditioning treatments are necessary to help the compression process reach the established goal.

If secondary processing treatments are employed after compression debarking, they should concentrate on beneficiating the smaller chip size fractions that contain the majority of the residual bark. This secondary output would then be recombined with the clean chip fraction from the compression debarker. Another alternative is to utilize the chips passing the ⅜-inch sieve for other products that can tolerate high bark percentages.

Nip pressure, nip setting, wood storage, and season of cut all influenced bark removal with the compression debarker. But we feel that the most important variable affecting debarking efficiency is the season of cut. We were able to remove approximately 70 percent more bark from wood cut in the growing season than from wood cut in the dormant season. The percent of bark removal and wood recovery varied little between topwood and bolewood. More variation in bark removal was observed for material stored 9 months in roundwood form than for material chipped fresh.

Nip pressure and spacing had a significant effect on bark removal and wood loss. A compromise setting of 1,400 pounds per lineal inch nip pressure and 0.020-inch nip spacing should yield reasonable bark removal with limited wood loss for the species tested during most seasons of the year.

## SOME RECENT PUBLICATIONS
## OF THE
## NORTH CENTRAL FOREST EXPERIMENT STATION

Fire Weather and Behavior of the Little Sioux Fire, by Rodney W. Sando and Donald A. Haines. USDA For. Serv. Res. Pap. NC-76, 6 p., illus. 1972.

Canoeist Suggestions for Stream Management in the Manistee National Forest of Michigan, by Michael J. Solomon and Edward A. Hansen. USDA For. Serv. Res. Pap. NC-77, 10 p., illus. 1972.

The Changing Market for Hardwood Plywood Stock Panels, by Gary R. Lindell. USDA For. Serv. Res. Pap. NC-78, 7 p., illus. 1972.

Size of Oak Advance Reproduction: Key to Growth Following Harvest Cutting, by Ivan L. Sander. USDA For. Serv. Res. Pap. NC-79, 6 p., illus. 1972.

An Improved Growth Intercept Method for Estimating Site Index of Red Pine, by David H. Alban. USDA For. Serv. Res. Pap. NC-80, 7 p., illus. 1972.

Projecting the Aspen Resource in the Lake States, by William A. Leuschner. USDA For. Serv. Res. Pap. NC-81, 32 p., illus. 1972.

Improve Forest Inventory With Access Data—Measure Transport Distance and Cost to Market, by Dennis P. Bradley. USDA For. Serv. Res. Pap. NC-82, 21 p., illus. 1972.

Canadian Forest Products Shipped Into the North-Central Region, by Eugene M. Carpenter. USDA For. Serv. Res. Pap. NC-83, 22 p., illus. 1972.

Aspen Symposium Proceedings. USDA For. Serv. Gen. Tech. Rep. NC-1, 154 p., illus. 1972.

A Method of Evaluating Crown Fuels in Forest Stands, by Rodney W. Sando and Charles H. Wick. USDA For. Serv. Res. Pap. NC-84, 10 p., illus. 1972.

## ABOUT THE FOREST SERVICE . . .

As our Nation grows, people expect and need more from their forests — more wood; more water, fish, and wildlife; more recreation and natural beauty; more special forest products and forage. The Forest Service of the U.S. Department of Agriculture helps to fulfill these expectations and needs through three major activities:

- Conducting forest and range research at over 75 locations ranging from Puerto Rico to Alaska to Hawaii.
- Participating with all State forestry agencies in cooperative programs to protect, improve, and wisely use our Country's 395 million acres of State, local, and private forest lands.
- Managing and protecting the 187-million acre National Forest System.

The Forest Service does this by encouraging use of the new knowledge that research scientists develop; by setting an example in managing, under sustained yield, the National Forests and Grasslands for multiple use purposes; and by cooperating with all States and with private citizens in their efforts to achieve better management, protection, and use of forest resources.

Traditionally, Forest Service people have been active members of the communities and towns in which they live and work. They strive to secure for all, continuous benefits from the Country's forest resources.

For more than 60 years, the Forest Service has been serving the Nation as a leading natural resource conservation agency.