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(Debarking Hardwoods)
Project Reports

PROJECT REPORT FORM

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BARK AND CHIP SEPARATION STUDY

INTRODUCTION

The background for this research has its origins in at least two separate sets of circumstances. First, Dr. Kremers became interested in bark-wood separation which could be enhanced by activating the cambium of dormant wood (1). Among the methods which he proposed (and which were carried out in the Pulping Laboratory) was one of treating whole unbarked pulpwood bolts with dilute acids at various temperatures. A few scattered tests involved chips with bark still attached. Concurrently, Dr. Einspahr proposed that an efficient utilization of aspen plantations could be realized by harvesting immature trees, with a rotation somewhere around 10 years. Since it is generally acknowledged (2-4) that the economics of the use of small-diameter wood (e.g., pulpwood tops, limbs, and thinnings) is poor for several reasons, including the difficulties attendant to debarking, some way of by-passing the usual wood-handling sequence was sought. Available as alternatives (though not to the writer's knowledge actively pursued at the Institute) are: (1) chemical debarking (5-9), (2) pretreatment of wood before barking (9-15), and (3) use of barking devices especially designed for small-diameter wood billets (16-19) or (4) cooking without debarking (20).

To keep the record clear, it must be acknowledged that the sequence of events to be described was not the result of intricately planned activity, nor did it receive impetus from a close scrutiny of the literature. Had the situation been considered and treated as a cooperative project, use might have been made of the Institute Abstract Bulletin and the appropriate bibliographic series. It would then have been learned that the idea of chipping unbarked wood and separating the bark from the chips has received considerable attention. Harvin, et al. (21) have reported on an extended investigation of debarking turkey oak (Quercus laevi), a species noted for its small diameter and crooked form. The preferred solution in this case was chipping unbarked wood and depending on an air-stream separation to recover bark-free chips. Blackford (22) discussed three methods for removing bark from chips made from unbarked wood. He favored the Hosmer mechanical crusher (23), but mentioned also the Bauer air float and the Vac-sink process, then under study by Battelle Memorial Institute. The latter gained commercial recognition when Union Bag installed it to debark southern pine slabwood chips which they purchase from local sawmills (24). This method applies vacuum to a tank of water containing southern pinewood chips and bark, causing the wood to sink while the floating bark is skimmed from the surface.

Liiri (3, 4) also found it possible to make a bark-wood separation based on water immersion. Using birch, he had problems making the wood sink, and he calculated that the use of artificial means of inducing this reaction would make the method commercially unattractive.

Last, but far from least, Grondal (25) told of successfully separating the bark from red alder (Alnus rubra Bong) when he used fresh green chips from winter-cut wood immersed in a tank of water. The bark was observed to sink, while the bark-free wood floated.

Even without this background, when confronted with the problem of removing bark from small-diameter wood billets, as a memo of June 6, 1966, from Heller to Howells reports, a decision was made to chip the wood and dispose of the bark later. The Kremers (1) concept of activating the cambium with weak acid entered into the operation, but when a control test without the acid was equally effective, the addition of acid was discontinued. Einspahr-to-Howells (June 16, 1966) and Howells-to-Smith (June 23, 1966) memoranda describe the reasons why it was concluded that the applicability of chip-bark separation to aspen on a year-round basis should be made an Institute project.

The primary objective planned at the outset of the project was to learn whether the apparently good results noted during experiments carried out in June could be expected at the other seasons of the year. A second objective was to learn the effect of wood storage on the separation technique. The inclusion of small-diameter trees, measurements of moisture distribution through the cross-sectional area of the sample, and actual measurement of bark and wood components were included at various times during the progress of the project.

RAW MATERIAL

The only wood species considered at this time is aspen. A memorandum, Benson to Peckham, dated August 18, 1967, provides data concerning the wood supplied to the Pulping and Papermaking Laboratory for test purposes.

EXPERIMENTAL

The first tree presented in the study was cut on July 14, 1966, and received in the Pulping Laboratory the same day. On the 15th of July, the stem was cut into four equal-length billets, which were numbered consecutively, starting with the butt cut. Sections 2 and 4 were identified and placed in outdoor, covered storage. Sections 1 and 3 were chipped in the Carthage 4-knife chipper, and all but a galvanized washtubful (18 x 18 x 11-in.) was discarded. The test specimen was put into a stainless steel tank of about 65 gal. capacity containing approximately 50 gallons of water. A Patterson Uni-power stirrer created a vortex so that the wood particles were quite continually immersed. At the end of five minutes, the stirrer was shut off and a sharp stream of water from a garden hose was used to wash the floating chips. The floating fraction was removed with a skimmer made of 4-mesh wire cloth, and transferred back to the tub. When air dried, the weight was determined, and a representative portion was oven dried to learn the moisture content. Table I contains the information obtained from the first log tested and is typical of the form in which the data were accumulated. The pertinent data concerning this part of the operation are found on lines 2 and 3.

The bark, along with some wood particles, settled to the bottom of the tank and was drained from there into a muslin-covered wash box. When dewatered to a point where handling was feasible, this fraction was transferred to a 4-mesh wire screen having a further covering of window screening. When dry (usually requiring only two or three days), the fines passing the window screening were recovered, oven dried, and weighed. Line 4, Table I, contains the data for the first aspen bolts to be processed. The coarse material was returned to the tank used previously and another separation was made. In general, the bark fraction from

TABLE I

TYPICAL DATA OF FLOTATION DEBARKING OF CHIPS FROM FRESHLY CUT ASPEN
(July 15, 1966)

1.	Wet weight of floating chips, g.	6972
2.	Content of recovered chips, o.d., %	98.6
3.	Weight of recovered chips, g.	6874
4.	Weight of bark fines, o.d., g.	76
5.	Weight of wood, 2nd separation, o.d., g.	168
6.	Weight of bark, o.d., g.	1840
7.	Total o.d. wood and bark in test, g.	8958
8.	Chips separated in 1st operation, %	76.7
9.	Chips recovered from bark fraction, %	1.9
10.	Total wood, %	78.6
11.	Bark fines, %	0.9
12.	Bark after 2nd flotation, %	20.5
13.	Total bark, %	21.4

this operation contained very little wood. The entire amount recovered after draining on the muslin surface was oven dried and weighed. This portion of the sample is recorded on line 6 in Table I. The wood skimmed off was likewise oven dried and weighed, and the amount recovered is given on line 5 in Table I.

On January 15, 1967, the 6-month storage phase of the work was initiated. The portions of the aspenwood not used on July 15, 1966, were now chipped and processed. Each month thereafter, the six-month-stored wood was evaluated, along with freshly cut wood. At the same time, the decision was made to begin the testing of small-diameter wood, and Tree TX-22B-56S-6 was submitted. Disks taken by the Genetics Section personnel were tested by them for moisture content, and heartwood and bark ratios. One half was stored; the other half was chipped and processed. The small-diameter wood (some of the top pieces were no more than 1 inch in diameter) did not work well in the 39-in. 4-knife Carthage chipper, and considerable amounts of unchipped material had to be discarded.

On July 19, 1967, the juvenile wood from the first sample tested had completed six months in storage. There were now four separate programs each month, viz., regular tree (fresh), regular tree (stored), juvenile tree (fresh), and juvenile tree (stored).

Table II provides data concerning freshly cut, commercial-size aspen trees and covers a full twelve months of testing of green wood. Also included are data for eleven months' testing of aspen bolts stored for six months. The history of eleven months of testing green juvenile wood is contained in Table III, along with information based on five evaluations of 6-month-stored juvenile wood.

Plans now in effect call for continued work on the merchantable-size tree stems now in storage and on juvenile wood until a 12-months' history of both green and stored wood has been completed. Tables presented in this report will be updated at the end of this phase of the program. Figure 1 is a graphical comparison of merchantable-size and juvenile aspenwood in terms of the first and second phases of bark-free wood recovery. Figure 2 shows the same kind of data for stored wood.

TABLE II

COMPARISON OF SEPARATION YIELDS OF FRESH VS. 6-MONTHS-STORED ASPEN WOOD AND BARK

(Commercial-size Trees)

		Wood, %			Bark, %		
Condition	Date	1st Sepn.	2nd Sepn.	Total	Fines	Heavy Fraction	Total
Fresh	7-15-66	76.7	1.9	78.6	0.9	20.5	21.4
Stored	1-19-67	76.2	2.8	79.0	2.9	18.1	21.0
Fresh	8-16-66	63.8	6.9	70.7	1.6	27.7	29.3
Stored	2-20-67	73.1	8.0	81.1	1.7	17.2	18.9
Fresh	9-27-66	74.6	4.2	78.8	1.1	20.1	21.2
Stored	3-14-67	78.2	0.2	78.4	1.4	20.2	21.6
Fresh	10-17-66	71.9	6.7	78.6	1.3	20.1	21.4
Stored	4-25-67	77.4	1.9	79.3	1.5	19.1	20.6
Fresh	11-18-66	64.2	15.0	79.2	1.1	19.7	20.8
Stored	5-24-67	74.4	3.1	77.5	1.1	21.4	22.5
Fresh	12-15-66	36.5	35.5	72.0	1.8	26.2	28.0
Stored	6-20-67	63.4	13.6	77.0	1.3	21.7	23.0
Fresh	1-15-67	37.7	34.6	72.3	3.5	24.2	28.7
Stored	7-19-67	76.0	1.1	77.1	1.5	21.4	22.9
Fresh	2-20-67	39.5	31.3	70.8	3.2	26.0	29.2
Stored	8-23-67	71.5	1.2	72.7	1.9	25.4	27.3
Fresh	3-15-67	49.9	26.1	76.1	2.1	21.8	23.9
Stored	9-20-67	76.5	0.6	77.1	2.4	20.5	22.9
Fresh	4-25-67	67.6	7.8	75.4	1.3	23.2	24.5
Stored	10-19-67	75.6	1.4	77.0	2.0	21.1	23.1
Fresh	5-24-67	68.4	6.6	75.0	1.2	23.8	25.0
Stored	11-23-67	75.5	1.9	77.4	1.9	20.6	22.5
Fresh	6-21-67	64.0	5.5	69.5	0.9	29.6	30.5

TABLE III

COMPARISON OF SEPARATION YIELDS OF FRESH VS. 6-MONTHS-STORED ASPEN WOOD AND BARK

(Juvenile Trees)

Condition	Date	Wood, % 1st Sepn.	Wood, % 2nd Sepn.	Wood, % Total	Bark, % Fines	Bark, % Heavy Fraction	Bark, % Total
Fresh	1-25-67	81.8	7.6	89.4	1.7	8.9	10.6
Stored	7-19-67	91.0	0	91.0	1.2	7.8	9.0
Fresh	2-27-67	75.0	12.1	87.1	2.0	10.9	12.9
Stored	8-23-67	91.6	0	91.6	1.0	7.4	8.4
Fresh	3-27-67	83.4	6.5	89.9	1.2	8.9	10.1
Stored	9-20-67	91.2	0	91.2	1.8	7.0	8.8
Fresh	4-27-67	86.5	1.6	88.1	0.7	11.2	11.9
Stored	10-19-67	92.2	0	92.2	2.0	5.8	7.8
Fresh	5-24-67	78.4	1.6	80.0	1.2	18.8	20.0
Stored	11-22-67	89.8	0	89.8	1.7	8.5	10.2
Fresh	6-21-67	77.6	7.1	84.7	1.0	14.3	15.3
Fresh	7-24-67	80.4	2.4	82.8	1.7	15.5	17.2
Fresh	8-23-67	77.9	2.9	80.8	0.9	18.3	19.2
Fresh	9-20-67	77.5	7.8	85.3	1.4	13.3	14.7
Fresh	10-20-67	76.0	1.8	86.8	1.2	12.0	13.2
Fresh	11-22-67	71.8	12.4	84.2	1.6	14.2	15.8

FIGURE 2
RECOVERY OF WOOD AFTER WATER FLOTATION
STORED WOOD STUDY

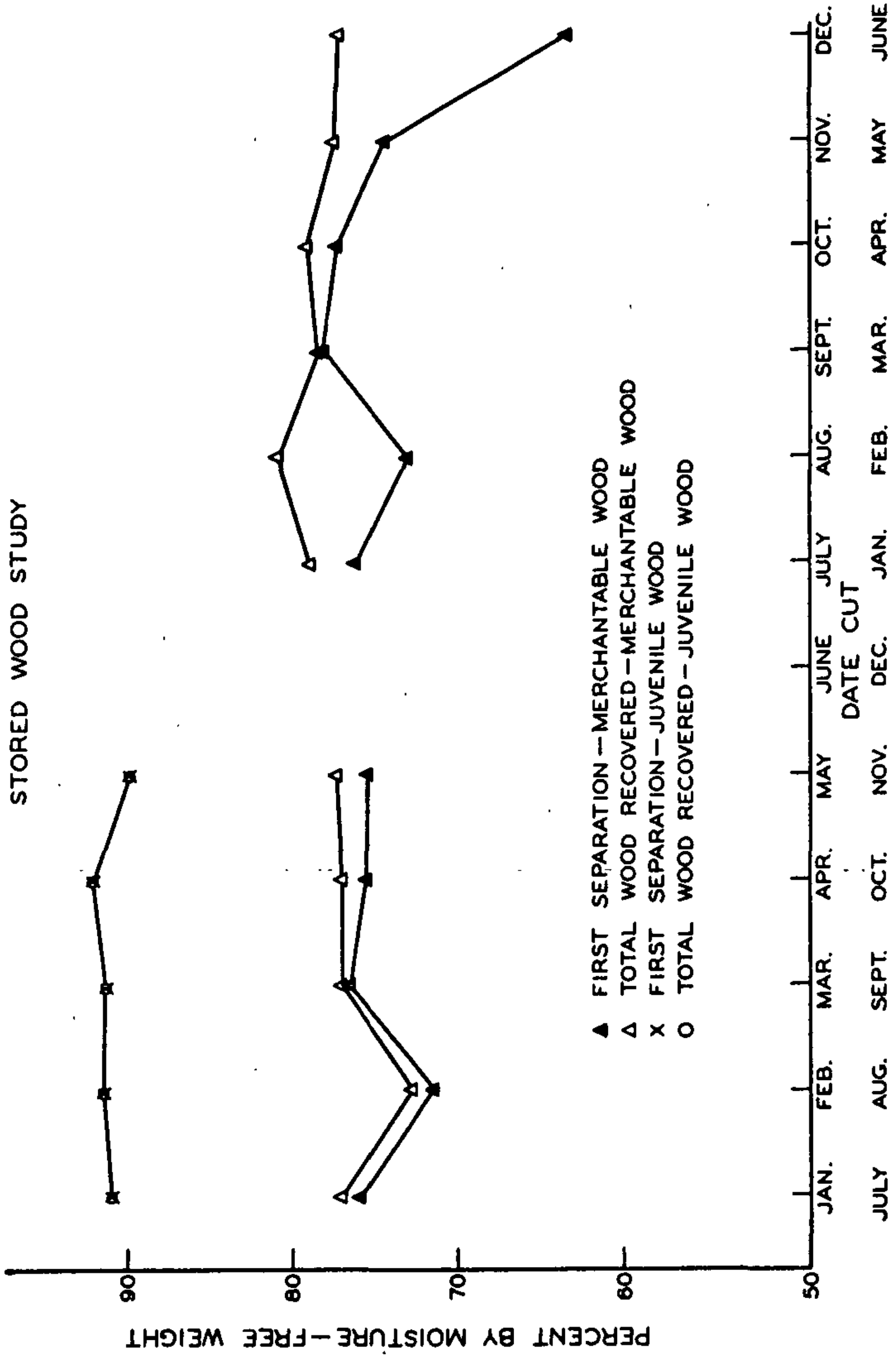
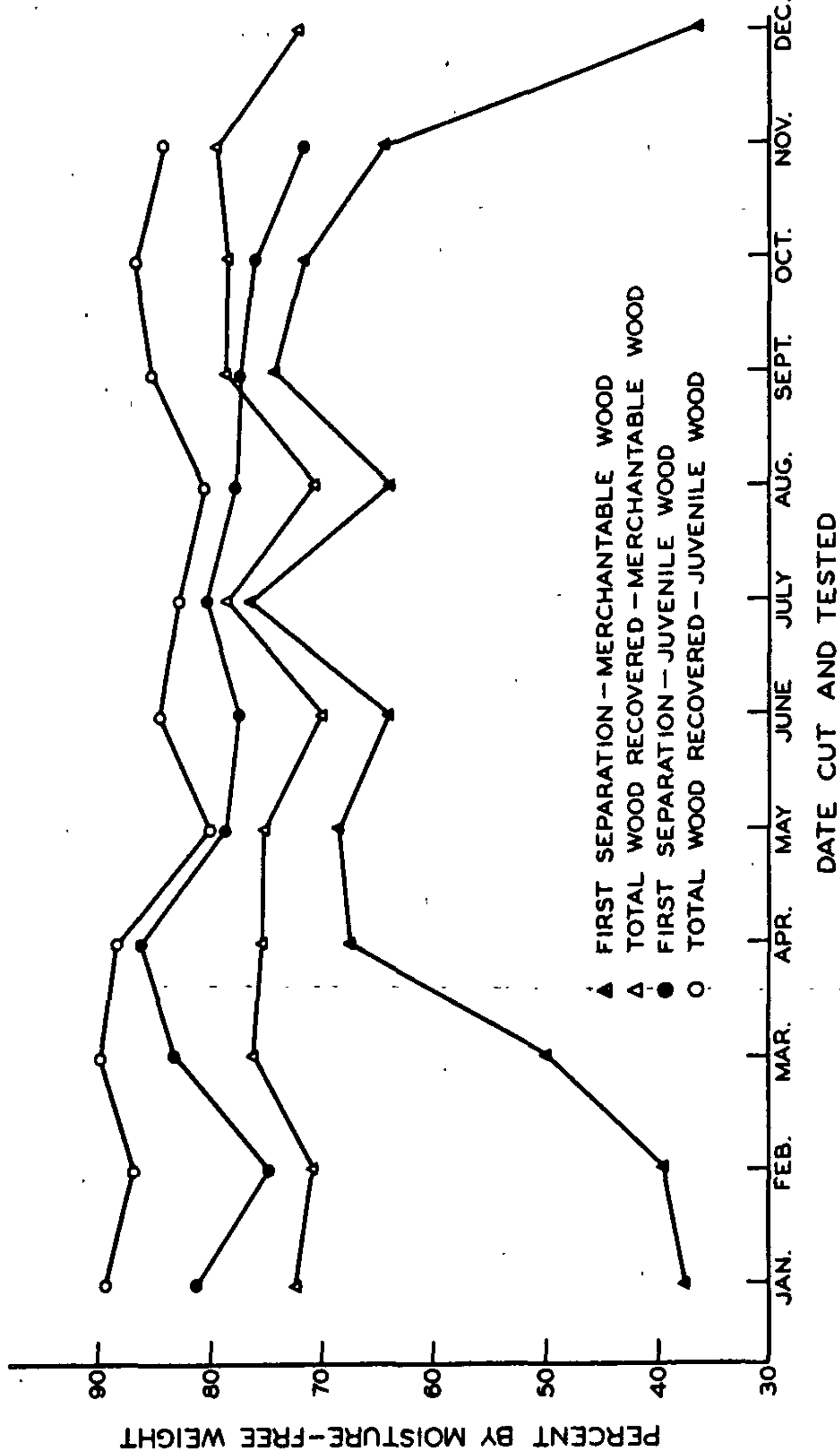


FIGURE 1
RECOVERY OF WOOD AFTER WATER FLOTATION
GREEN WOOD STUDY



DISCUSSION OF RESULTS

The experimental design suffered from oversimplification, the main problem being the unequivocable assignment of the term "wood" to the floating mass and "bark" to that which did not float. It is quite apparent that everything designated "wood" might not be acceptable to some pulping operations. However, if this is kept in mind, some general comments can be made.

(In the interests of clarity, the work connected with juvenile wood will be considered separately and commented on in a section immediately following this one.)

MERCHANTABLE-SIZE WOOD

1. The conventional chipper tends to fracture the wood-bark interface when unbarked aspen bolts are processed.

2. The amount and degree of rupture is strongly dependent upon the strength of the bond between the two substances. The bond, in turn, is relatively loose in the spring and tight in winter.

3. Aspenwood normally floats when immersed in water, while the bark sinks.

4. There are at least two conditions which can cause deviations from the above generality. Sapwood closest to the bark, when suffused with liquid from early spring activity, will often sink, as will wood particles attached to heavy pieces of bark at any time of the year. Conversely, large chips will float even if they have some bark attached.

5. Air drying of the recovered sunken fraction from unbarked aspen tends to cause rupture of any chip-bark unions present. Subsequent water immersion of this fraction provides a rapid and relatively complete separation of bark and wood. This is graphically illustrated in Fig. 1.

6. Tests covering a twelve-month span (July, 1966, through June, 1967) indicated that a single water-float separation would permit an average of 59.6% of relatively bark-free wood to be recovered. However, if the four winter months are not included (December through March), 68.9% by weight of the substance in the unbarked wood is recoverable through flotation.

7. The data taken over a twelve-month period also indicate that if the sunken (bark-rich) fraction is air dried and subsequently immersed in water and the recovered floating material is added to that obtained in the first separation, the average recovered wood amounts to 74.8% of the weight of unbarked aspen. The effectiveness of the drying step is indicated by the fact that isolating the data for the winter-cut wood raises the average recovered fraction only to 75.7%.

8. While it is recognized that the flotation method of separating aspen bark from the wood of unbarked bolts is not completely thorough, it would seem to be a reasonably efficient method. Actual measurement of representative samples of the bolts processed during the period from February through June, 1967 (see memorandum from Benson to Peckham dated August 18, 1967) indicates that bark makes up 24.4% of the weight of the bolts; results from the water-separation tests show an average of 26.6% discarded as bark.

9. The amount of wood substance recovered in the reflotation of the dried, sunken material varied from 2.4 to 49.3% of the total amount segregated. Increased adhesion and consequent settling of wood-bark particles was noted in November and continued to be a major factor through March.

10. Covered outdoor storage of freshly cut aspen bolts for a period of six months was an effective means of improving the degree of separation of wood and bark by flotation. (See Table II and Fig. 2.) Winter-cut wood processed during the summer had, on the average, very little more wood associated with the sunken bark in the initial separation than summer-cut wood chipped in the winter. (Of the total wood recovered from summer-cut, stored aspen, 4.1% was obtained in the second flotation; 5.4% floated in a second pass of the bark of winter-cut, stored aspen.)

11. Storage of aspen bolts tends to reduce the actual amount of bark entering the system, simply from losses due to handling. As indicated earlier, trees cut from February through June were found to average 24.4% bark by weight. In the same five-month span, the sunken material classified as "bark" was found to average 26.6% by weight of the material recovered from the system when processed green. Four of the five samples which went into storage have now been tested. The average "bark" value is 24.9%, in spite of one tree (February cut) having an unusually high value.

JUVENILE WOOD

1. Most of the comments made concerning merchantable wood also apply to the juvenile wood tested.

2. It appears that the amount of bark associated with juvenile wood is substantially less than that found in the case of wood of merchantable size, as reported by Benson in his memorandum of August 18, 1967, to Peckham. The average of five samples of merchantable wood was 24.4% bark, while twice that number of plantation trees were found to average 19.9% by weight of bark. When processed immediately after cutting, the amount of bark recovered after chipping was found to average 14.6%. These figures are erratic, however, since the individual numbers used in determining the mean varied from 10.1 to 20.0%.

3. The test could contain a bias caused by poor chipping. The small-diameter sticks were not reduced to chips in anything approaching a uniform manner. Samples chosen for processing inevitably excluded many of the larger pieces, which probably contained abnormally large percentages of bark.

4. Stored juvenile wood samples separate so well that to date there has been no wood sinking with the bark. (See Table III and Fig. 2.)

5. Bark identified as such in the stored samples is present in substantially smaller amounts than is found in the equivalent fresh wood (8.8 compared to 13.1%).

6. The chipping program based on stored juvenile wood has several months to go. However, no great variation from the already-cited data is expected, since five of the seven samples remaining were harvested in the late spring, summer, and early fall.

CONCLUSIONS

Several basic facts have been established by the experimental work performed to date.

1. Particles of bark and aspenwood differ sufficiently in density so that they can be separated by suspension in water, with the wood floating and the bark sinking.

2. The fundamental difference in wood and bark densities exists in both juvenile and merchantable-size wood.

3. In any sample of chips from unbarked aspenwood there will be a majority of chips which have never been associated with bark. These will nearly always float. There will be some chips from which the bark has not been broken by the impact of the chipper blades. These will either sink or float, depending on the amount of bark attached.

4. In any separation of bark carried out by flotation of chips from unbarked aspenwood there will be some bark in the chip fraction and some chips in the bark fraction. The amount of cross contamination is strongly affected by cutting date. The smallest amount of wood sinking with the bark seems to occur in late spring and early summer when the bark is still loosely attached to the sapwood. In early spring, the sapwood may be so suffused with sap that it too will sink. The winter months cause the greatest incidence of wood sinking. The pulpwood sticks are not only frozen, but the bond between wood and bark is especially strong.

5. Juvenile aspenwood has been shown to have less bark per unit weight of wood than mature aspen (memorandum from Benson to Peckham, August 8, 1967). By any method of comparison (e.g., initial separation, total wood recovered fresh, separation efficiency after storage) the juvenile wood is better adapted to bark separation by flotation than is merchantable-size wood.

6. It has been found that when a chip with attached bark is dried, the bond ruptures, and on return to the water the usual separation between the different materials will occur. This means that, where necessary, dried or partially dried bark can be returned to a flotation operation with good assurance that associated wood can be recovered.

7. When freshly cut aspen was stored out-of-doors but covered for six months, the flotation separation was improved. Natural drying appeared to weaken the bond between wood and bark and to cause the bark to be more friable. Bark loosening and fracturing as occurring upon impact of the chipper blades seems to be an important feature of the process. Data on the subject of the effect of storing juvenile wood prior to chipping are not complete, but after five months' experience, wood has yet to be found in the bark from the first separation.

8. The work completed to date would indicate that flotation separation of bark from the chips made from unbarked aspen bolts is feasible. A commercial installation might well be only lightly housed and consist of a long, narrow pond into one end of which the chipper would discharge. Some means of agitation should be provided to insure separation and immersion of the various particles to allow each to react individually to its natural tendency to sink or float. At the end of the tank, the floating chips would be swept off to a conveyor feeding the chip bins or digesters. A live bottom on the tank would continuously remove the

sunken fraction, which might be drained and conveyed through an oven heated by fluegases. When dried to that state where rupture between bark and wood occurs, the material could be processed in another, smaller system from which the bark would go to a bark press preparatory to burning. Depending on the local situation, spent liquor might be utilized to retard freezing of the tank during winter. In cases where ponding of effluents is practical, the water from the process might be impounded to allow the settling of entrained dirt before discharge.

FUTURE WORK

Laboratory procedures were designed to permit gathering the greatest amount of basic information with the least expenditure of time and effort. As a result, there remain a number of unanswered questions at this point. Continuing research might be initiated in the following directions:

1. Spot checks of data (perhaps quarterly) using merchantable wood, this time making a chip-by-chip separation of the final product into two categories--wood and bark. This would allow a check on previous data and provide information on the actual cleanliness of the chip fraction and the amount of wood substance being discarded.

2. A more suitable laboratory apparatus should be designed and used instead of the present equipment in making the investigation suggested in (1) above.

3. A spot check of the method might be carried out, preferably in late spring, utilizing species other than aspen.

4. A separate investigation could explore the effect of chip storage (as opposed to storage in bolt form) on the efficiency of aspen bark removal by a flotation process. A detailed plan of attack would take into account the time of cutting and chipping, the size of the pile, the pattern of sample removal from the pile, and a number of other pertinent factors.

5. A spot check on the results obtained with juvenile wood could be made, this time obtaining a more suitable chipping device for the small wood. A limb chipper, such as used by professional tree care companies or public utilities maintenance departments might be borrowed periodically for the reduction of the wood to chips.

6. It is not presently known whether the wet chips recovered from the flotation chamber would require modifications in pulping procedures. This could be investigated.

7. The author of this report has suggested several times that juvenile wood might, under certain conditions, be more conveniently pulped in the unbarked rather than the barked form. While not directly connected to this particular research subject, the question should be considered.

ACKNOWLEDGMENTS

The Genetics Section supplied all of the wood for this program and made physical measurements, which were recorded in a memorandum from Benson to Peckham dated August 18, 1967. The laboratory experiments were conducted by Robert Kilgas.

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