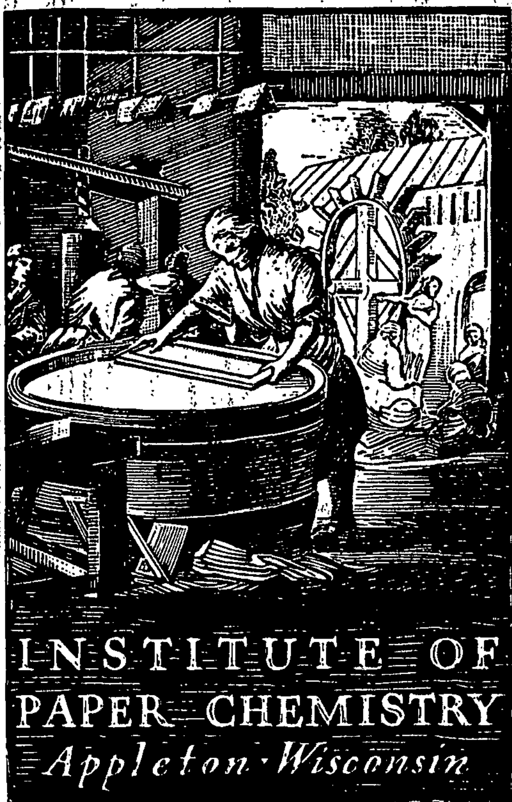

SEGREGATION OF WOOD CHIP/BARK MIXTURES USING LIQUID FLOTATION PROCEDURES

Project 2977

Report Four

A Progress Report

to

MEMBERS OF GROUP PROJECT 2977

March 23, 1973

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

SEGREGATION OF WOOD CHIP/BARK MIXTURES USING LIQUID FLOTATION PROCEDURES

SUMMARY

The fourth and last quarter of Project 2977 involved investigations into the flotation behavior of Douglas-fir and western hemlock, and included investigations of various flotation system modifications meant to improve the segregation of wood chips from bark chips. The tree species were described and pure fractions of wood chips and bark chips were tested to determine the influence of moisture content, chip size, dwell time in the flotation medium, and type of wood (core or slab) on the flotation behavior of the wood or bark.

Douglas-fir followed the expected pattern with higher moisture content chips sinking before lower moisture content chips, smaller chips sinking before larger chips, slabwood sinking faster than corewood which sank faster than bark. There was a differential in the flotation behavior of inner and outer bark, the inner bark sinking very early, the outer bark floating with the flotation time for composite pieces dependent upon the ratio of inner to outer bark. Adequate procedures to separate inner from outer bark as a means to a multistage flotation segregation system, discarding the inner bark as early sinking material, and leaving the outer bark as material floating after the wood had sunk, were not attained. However, the flotation segregation was accelerated with the use of a steam pressure system and fairly high percentages (78-88%) of the wood were recovered with moderate bark contamination, largely attributed to the influence of inner bark. Over one-half of the wood not recovered from the large, "on 3/4-inch," chips was corewood, although it had comprised about one-tenth of the original chips.

Western hemlock basic flotation tests showed considerably different flotation behavior. Neither wood nor bark chips showed flotation response to moisture content differences for the ranges investigated (20 and 45%). Bark chips sank sooner than the slabwood chips which sank slightly faster than the corewood. The smaller chips sank faster than the larger chips. Observations indicated the inner bark sank quickly while the outer bark tended to float. However, no means were available to separate the two types of barks. Modifications tested for improvement of segregation included mechanical beaters, mechanical compression, steam pressure, and the addition of wetting agents. None were good enough for further intensive testing.

Of particular interest is the review section which summarizes the flotation information of all the species tested. Suggested in the review are flotation segregation systems for each of the species showing good segregation potential in the testing. Sugar maple, aspen, and paper birch are listed as compatible in flotation segregation if the paper birch system is used. Bur oak and shagbark hickory showed opposite tendencies and are not considered compatible in a single flotation test. Wood-bark chip segregation systems are also suggested for loblolly pine, Douglas-fir, and white spruce. None are suggested for eastern cottonwood or western hemlock.

INTRODUCTION

This report marks the completion of Project 2977, "Segregation of Wood Chip/Bark Mixtures Using Liquid Flotation Procedures." Flotation behavior and wood/bark chip segregation procedures have now been investigated for six hardwoods and four conifers. Flotation behavior for all species was determined and workable or promising segregation systems have been found and suggested for eight of the ten species.

After several delays in receiving the tree samples for the testing of the last two species, the investigations for the final period of this project were begun in December 1972. The last two species were West Coast conifers, Douglas-fir and western hemlock. The work covered basic flotation tests, designed to determine flotation characteristics of wood and bark, and modified flotation tests, which investigated system changes likely to bring about a successful liquid flotation segregation of bark from wood chips.

The report covers the results of the flotation work for Douglas-fir and western hemlock. Also included is a review of the work on all species investigated during the project period.

METHODS AND MATERIALS

In the initial stages of this project some arbitrary standards were set regarding objectives acceptable for segregation of wood chips from bark. "Depending on the mill, the process, and the end product, the acceptable level of bark contamination lies somewhere between virtually no bark in the wood to as high as 10%. For a practicable approach to the problem it was decided that 1 to 3% was a reasonable bark contamination percentage, and further reduction of bark would be considered a problem specific to the particular mill." In addition, it was decided that 10% is the maximum acceptable allowance for wood loss.

The basic flotation test used in the last report period, which included dwell time and excluded the compression step used in the earlier test, was used on the last two species, western hemlock and Douglas-fir. Since the last two species to be tested were conifers, "corewood" (still arbitrarily described as the first 8 annual rings) became a factor. The result was that, along with the influence of such factors as chip size, moisture content, and dwell, the differential flotation behavior of corewood to bark and slabwood (wood beyond the first 8 annual rings) was also studied.

SAMPLE COLLECTION AND PREPARATION

The final species tested were:

Douglas-fir [Pseudotsuga menziesii (Mirb.) Franco]
Western hemlock [Tsuga heterophylla (Rafn.) Sarg.]

Eight-foot bolts from two trees of each species were supplied by Crown Zellerbach Corporation with the Douglas-fir arriving Oct. 4, 1972 and the western hemlock Nov. 27, 1972. The description of the bolts and the trees from which they came is given in Table I. The Douglas-fir bolts came from the bottom bolts of

TABLE I

SAMPLE TREE DESCRIPTIONS

Material	Age, yr.	Height, ft.	Diameter at 4.5 Ft., in.	Average Specific Gravity[a]: Wood, Core	Wood, Slab	Wood, Total	Bark, Steam Pressure Treatment[b]	Bark, No Treatment	Bark, % by vol. of bolt	Corewood, % by vol. of bolt
Douglas-fir	68	87	10.5	0.409	0.504	0.495	0.336	0.412	10.0	10.3
	72	87	10.5	0.368	0.471	0.459	0.319	--	10.6	
Western hemlock	37	80	11.0	0.341	0.305	0.313	0.324	0.390	8.8	9.3
	56	78	10.1	0.348	0.331	0.336	0.300	--	6.8	

[a]Based on ovendry weight (g.)/green volume (c.c.).

[b]Specific gravities of bark taken after a steam pressure treatment (240°F. to a maximum 7 p.s.i. held momentarily) gave low determinations.

trees growing near Molalla, Oregon at approximately 1500 feet elevation. The western hemlock bolts came from the 16-24 foot section of two trees growing near Veronia, Washington at approximately 800 feet elevation.

Sample disks were taken one foot in from each end of each bolt for specific gravity, percentage of bark, and corewood percentage determinations. To loosen the bark, the disks were processed in an autoclave by running the pressure to 7 p.s.i. and then releasing the pressure. Duplicate specific gravity determinations were made for corewood (the first 8 annual rings counting from center), slabwood, and bark using TAPPI "on the balance" method T 18 m-53. The values obtained agreed with those reported in the literature (Appendix Table XII) where the wood was concerned but appeared low for the bark. On rechecking, it was found that the steam pressure treatment of the barks resulted in an abnormally low specific gravity determination. Bark specific gravity for both the steam-pressure treatment and no treatment are presented in Table I, along with the other tree dat

As can be seen from the values in Table I, steam treatment of bark befoı determining specific gravity influences the specific gravity differential between the bark and wood. Although the steam pressure treatment decreased the specific gravity of the bark of both species, the wood-bark specific gravity differential was increased for Douglas-fir but decreased for western hemlock. The effect of bark steam treatment on the flotation work was not fully realized until the work was near completion. The basic finding was that the steam pressure treatment can be used to change the specific gravity differentials between the bark and wood of certain tree species.

The corewood of each of the bolts for each species was marked and a carriage saw used to cut the slabwood from the corewood. The slabs were tied in bundles and chipped by species. The corewood was also chipped separately by species. The chipper used was a 41-inch, 4-knife machine made by Carthage Machine Company, and the newly sharpened knives were set to deliver chips at a nominal 3/4-inch length.

After chipping the slabwood and the corewood, chips of each species were screened on a 24-inch Sweco vibratory screen fitted with 3/4, 1/2, and 1/4-inch mesh screens. The chips were charged to the top (3/4-inch mesh) screen where the obviously oversized materials were picked off manually. The screen delivered the sized materials continuously so that 4 screenings were recovered, i.e., (1) on 3/4-inch, (2) through 3/4-inch and on 1/2-inch mesh, (3) through 1/2 and on 1/4-inch mesh, and (4) through 1/4-inch mesh. The data concerning this preliminary work are given in Table II. The differences in the proportions of the various sizes of chips appeared to be related to the resistance of the wood to the impact of the chipper blades. Over half the chips of both species were received on the 1/2-inch mesh screen.

The fresh weights of each size class and type of wood were determined and representative samples taken to determine moisture content. In addition, representative fractions of "on 1/4-inch" and "on 3/4-inch" slab chips were hand sorted into wood or bark chips. There were then pure samples of corewood, slabwood, and bark of "on 1/4-inch" and "on 3/4-inch" available for testing.

Basic Flotation Testing Procedure

Bark and wood chips of "on 1/4-inch" (small) and "on 3/4-inch" (large) size were tested at 20 and 45% moisture contents. Both corewood and slabwood were tested for all conditions.

TABLE II

CHIP DESCRIPTIONS

Chip Size	Composition, % by fresh weight			Moisture Content at Chipping[a] (Fr. wt.-o.d. wt./fr. wt.), %				Bark, % by dry weight	
	Core	Slab	Comb.	Core	Slab	Bark	Chip Mixture	Size Class	Total Bark
				Western Hemlock					
Oversize	0.69	1.5	1.4	43.7	--	--	57.9	--	--
On 3/4-inch	22.13	16.3	17.0	42.5	66.4	60.6	--	10.8	23.3
On 1/2-inch	57.80	57.3	57.3	51.5	--	--	66.6	8.2	59.5
On 1/4-inch	15.47	20.3	19.7	55.9	66.1	45.0	--	6.9	17.2
Fines	3.91	4.6	4.6	51.6	--	--	64.1	--	--
				Douglas-fir					
Oversize	1.85	1.0	1.1	26.8	--	--	43.7	--	--
On 3/4-inch	21.09	13.7	14.7	25.0	45.1	43.9	--	16.2	20.0
On 1/2-inch	54.51	57.4	57.0	24.1	--	--	42.9	12.1	57.5
On 1/4-inch	18.92	23.9	23.3	23.5	43.0	45.7	--	11.6	22.5
Fines	3.63	4.0	3.9	25.5	--	--	39.9	--	--

[a]Percentages are based on fresh weight after chipping. Moisture content = [100] - [(ovendry weight/"fresh" weight) x 100].

All tests were run in duplicate. The ovendry weights of the samples used for the flotation tests were approximately 75 g. for western hemlock bark, 100 g. for Douglas-fir bark, 150 g. for all corewood, and 200 g. for all slabwood. Sample chips were adjusted to the proper moisture content, either by adding distilled water or by drying the chips to the appropriate weight. The adjusted moisture content was verified at the end of each run using the actual ovendry weight of the sample. All wood samples were found to be within ± 4% of the intended moisture content but the bark samples were more variable. Specifically, the Douglas-fir "on 3/4-inch" bark chips had higher moisture contents than intended. Problems with the bark can be attributed to both the small quantity of sample, which was due to a scarcity of supply, and to variability between inner and outer bark. The inner bark tends to take up water more readily than the outer bark so, depending on the ratio of the two barks in a sample, the moisture content may vary.

The flotation was initiated in the clear acrylic vessel described in Progress Report One. The vessel was filled with 20 liters of city tap water and the temperature adjusted to 22°C. The surface area of the water was 560 sq.cm. After the chip sample was placed in the vessel, the top was closed with a device which kept the chips submerged at least 6 cm. below the water surface. A hand-operated 4-blade paddle agitated the chips for the first five minutes. At the end of this time the top was removed and the floaters skimmed off and placed in a glass vessel of a diameter similar to the acrylic vessel but filled with about 6.5 liters of water. The remainder of the flotation took place in the glass vessel with sinkers being taken out at the appropriate intervals. The recovered chips were air dried overnight and then oven dried 24 hours and their ovendry weight determined.

The data were compiled for the various flotations, the averages for the duplicated runs determined and these values listed in tables by species. This information is included and used in later sections of this report when discussing the reaction to flotation of the wood and bark chips for each of the species.

As was stated earlier, "pure bark" and "pure wood" samples were tested to facilitate the description of the process and the interpretation of the data.

A complete study must take into account how a wood-bark chip mixture might behave. To accomplish this, the data available on pure fractions were used to interpret, by means of a mathematical formula, the percentage of bark that would remain as "contamination" in the recovered wood. The term used to describe the results of this calculation is "bark contamination factor" (BCF).

The amount of wood recovered is listed as "accumulated wood recovery" (AWR). This figure represents the total percent of wood that can be recovered in a given time interval. In the case of the two coniferous species investigated, the wood was separated and tested in two categories, corewood (center 8 annual rings) and slabwood (rings beyond the eighth). In these cases, AWR was calculated according to the original percentage of each of these woods in ratio to the flotation behavior of the wood. Whether the wood is sunken or floating is indicated and the time interval is assumed to be from the start to the time stated, unless otherwise designated.

The BCF is the assumed amount of bark in the material recovered from a theoretical wood-bark mixture expressed as a percentage of the ovendry weight of the recovered material (wood and bark). For the purposes of this report, a theoretical mixture of 25% bark is used. The ratio is quite arbitrary and is in fact high for most species.

Modified Flotation Testing Procedure

If a species did not show reasonable segregation, 90% or more wood recovery with less than 3% bark contaminating the wood, the flotation behavior was studied and a decision made as to what modifications might give reasonable segregation. The modifications were then tested with preliminary runs on wood-bark mixtures of "on 1/2-inch" chips. After the preliminary runs, the best previously tested modification was then run in duplicate on pure fractions of "on 1/4-inch" and "on 3/4-inch" wood and bark chips.

Since the modifications varied from species to species, the procedures for the test are not described here but are described in the results section of each species. Modifications considered were: water temperature, chemical additions, atmospheric pressure changes, compression, moisture content changes, sequence variation, and mechanical manipulation of chips.

The two principal pieces of apparatus used for the modified tests in this report period were a 10-gallon resin kettle and a mechanically-driven glue spreader. The resin kettle is fitted with a pressure top and a steam jacket and can be pressurized directly or heated to create pressure indirectly. For the purposes of the modified tests, the kettle was partially filled with heated water, the chips submerged in the water, and the kettle pressurized directly with live steam.

The glue spreader was used simply as a source of spring-loaded rolls that were used to compress the chips. It has two rolls, one steel idler roll opposed by a chain-driven steel roll covered with a thin, grooved rubber cover.

RESULTS OF FLOTATION EXPERIMENTS

DOUGLAS-FIR

Basic Flotation Tests

Basic flotation tests were run on bark, corewood (first 8 annual rings counting from center), and slabwood (wood outside core) chips. Results were expressed as ovendry weight percentages of chips sinking at the various time periods. The percentages were based on the total ovendry weight of the material (bark, corewood, or slabwood) before the start of the flotation.

The results of the basic flotation tests for Douglas-fir are presented in Table III. The values are averages of duplicate determinations. In general, agreement between duplicates was good with the bark tests showing the most variability. The differing characteristics of inner and outer bark are thought to be a contributing factor to the variation. The inner bark tended to sink, the outer bark tended to float, and composite chips varied with the ratio of the two types of bark accounting for much of the variation.

Inner bark, compression wood, and knots were the major contributors to the sinking portion at 5 minutes for the 20% moisture content chips. Moisture content of chips had the most effect on the first five minutes of flotation with greater amounts of the bark and slabwood of the 45% moisture content sinking at that time. Slabwood was the major type material sinking from 15 minutes to 6-hour flotation intervals. At the end of 168 hours most of the slabwood had sunk and 38-72% of the bark remained floating depending on the chip size and moisture content. The smaller and wetter chips sank more readily. From 16 to 80% of the corewood remained floating with more sinkers in the smaller wetter chips.

TABLE III

DOUGLAS-FIR BASIC FLOTATION TEST

Percent of Original Material Recovered as Sunken or Floating Chips at Stated Interval[a]

	On 1/4-Inch Chips			On 3/4-Inch Chips		
	Wood			Wood		
	Corewood	Slabwood	Bark	Corewood	Slabwood	Bark
Moisture content, %						
Objective	20.0					
Actual	22.5	20.0	22.5	21.0	21.5	33.5
Percent of material sinking from:						
0-5 min.	1.2	2.8	2.4	0	0.2	0.2
5-15 min.	0	0.1	0	0	0	0
15-30 min.	0	0.7	0	0	0	0
1/2-1 hr.	0	0.7	0	0	0	0
1-4 hr.	0	3.0	1.0	0	0	0
4-6 hr.	0	1.6	1.0	0	0	0
6-24 hr.	2.2	29.0	8.9	1.4	7.2	1.6
24-48 hr.	4.7	28.0	11.9	1.8	31.4	4.7
48-72 hr.	8.8	13.8	5.6	3.5	19.2	2.1
72-96 hr.	12.6	8.4	6.7	1.4	11.7	4.4
96-120 hr.	16.8	5.6	6.0	1.7	13.8	4.2
120-144 hr.	14.9	3.8	6.0	2.4	6.6	3.2
144-169 hr.	13.2	1.8	6.5	7.9	4.0	7.4
Percent of material floating at 168 hr.	25.6	0.7	44.0	79.9	5.9	72.2
Moisture content, %						
Objective	45.0					
Actual	45.5	45.5	45.5	45.0	46.8	51.5
Percent of material sinking from:						
0-5 min.	4.7	36.6	15.5	1.1	33.6	7.4
5-15 min.	0	0.8	0	0	0.2	0
15-30 min.	0	0	0	0	0	1.0
1/2-1 hr.	0	0.7	0	0	0	0
1-4 hr.	0.4	4.8	2.6	0	3.9	0
4-6 hr.	0	0	0.7	0	2.0	0
6-24 hr.	2.9	24.2	4.8	1.8	11.0	6.0
24-48 hr.	7.2	9.7	5.0	1.0	10.4	15.0
48-72 hr.	14.0	7.6	5.3	2.6	12.2	5.6
72-96 hr.	12.6	6.0	6.6	3.9	9.5	2.4
96-120 hr.	14.1	5.2	5.6	2.3	6.0	5.3
120-144 hr.	12.3	2.4	6.1	9.6	5.0	4.2
144-168 hr.	15.8	1.4	9.8	19.8	2.8	2.6
Percent of material floating at 168 hr.	16.0	0.6	38.0	57.9	3.4	50.5

[a]Data in table are averages of duplicate determinations and are percentages based on ovendry weights. Corewood is considered to be the first eight annual rings and slabwood is rings nine and beyond. Moisture content % = [100] - [(ovendry weight/"fresh" weight) x 100].

By assuming the wood recovered was the amount of wood either sinking or floating during given intervals and by assigning the appropriate percentages of corewood and slabwood, the AWR (accumulated wood recovery) may be determined by a summation of the wood recovered in the specific intervals, i.e., AWR = summation of specified intervals of (ratio of corewood x percent of corewood recovered) + (ratio of slabwood x percent slabwood recovered).

From the above data it can be determined what percentage of original bark sinks or floats with the wood during a given interval and the bark contamination factor (BCF) determined by computing what percentage of bark would have remained with the wood through specified intervals. More simply: BCF % = [% bark recovered/(% bark recovered + 3 (AWR %))].

For the purpose of this study, a percentage of corewood equal to what was in the original sample was assumed. The BCF was based on a theorized wood-bark chip mixture of 25% bark by ovendry weight as was assumed for the previous species. This is an admittedly high percentage in comparison to what was found in the logs used (13.2% by weight); however, any percentage of bark might be found in a mixture depending on the source of the chips. Unbarked mill residues or unmerchantable tops, for instance, may have a higher percentage of bark.

Table IV groups the data presented in Table III to show the basic wood-bark segregation possibilities with simple water flotation. The data were grouped to provide information for the three best recovery groupings and the AWR and BCF computed for each. As evidenced in the table, no good segregations were made. The best recovery took place at 20% moisture content with 3/4-inch chips where, after 168 hours, 86.3% of the wood was recovered with 9.6% bark contamination (BCF). For an example of how the original wood-bark mixture affects the calculated BCF,

TABLE IV

DOUGLAS-FIR BASIC FLOTATION TEST[a]

	On 1/4-Inch Chips						On 3/4-Inch Chips					
	% of Original Material			Recovered Portion[b] (Sinking Chips)	AWR, %[c]	BCF, %[d]	% of Original Material			Recovered Portion[b] (Sinking Chips)	AWR, %[c]	BCF, %[d]
	Wood						Wood					
	Core-wood	Slab-wood	Bark				Core-wood	Slab-wood	Bark			
Moisture content, %												
Objective	20.0											
Actual	22.5	20.0	22.5				21.0	21.5	33.5			
Percent of material sinking from:												
0-6 hr.	1.2	8.9	4.4		93.6	15.1	0	0.2	0.2		75.9	7.0
6-120 hr.	45.1	84.8	39.1		90.4	13.8	9.8	83.3	17.0		82.1	7.6
120-144 hr.	14.9	3.8	6.0				2.4	6.6	3.2			
144-168 hr.	13.2	1.8	6.5		88.6	16.3	7.9	4.0	7.4		86.3	9.6
Floating at 168 hr.	25.6	0.7	44.0				79.9	5.9	72.2			
Total	100.0	100.0	100.0				100.0	100.0	100.0			
Moisture content, %												
Objective	45.0											
Actual	45.5	45.5	45.5				45.0	46.8	51.5			
Percent of material sinking from:												
0-5 min.	4.7	36.6	15.5		97.8	17.4	1.1	33.6	7.4		91.0	15.3
5 min.-144 hr.	63.5	61.4	36.7		61.6	18.7	21.2	60.2	39.5		56.2	18.8
144-168 hr.	15.8	1.4	9.8		64.5	21.4	19.8	2.8	2.6		60.7	18.8
Floating at 168 hr.	16.0	0.6	38.0				57.9	3.4	50.5			
Total	100.0	100.0	100.0				100.0	100.0	100.0			

[a]Data presented here are compiled in a manner which indicates some of the better wood/bark segregations possible on a simple water flotation over a week's time. Data are based on more detailed duplicate determinations given in Table III. Moisture content percents = [100] - [(ovendry wt./"fresh" wt.) x 100].

[b]Lines indicate the grouping of fractions for recovery.

[c]AWR = Accumulated Wood Recovery = (0.093 x corewood recovery %) + (0.907 x slabwood recovery %) — decimal figures are the ratios of that wood in the original bolts.

[d]BCF = Bark Contamination Factor = Percent of bark by ovendry weight contaminating wood recovered from an original mixture of 75% wood and 25% bark. Arithmetically, BCF = (% of original bark recovered with the sample)/(3 AWR + % of original bark recovered with the sample).

if the original chip mixture had 10% bark, rather than the 25% assumed for the above data, the wood recovery (AWR) would remain the same (86.3%) but the calculated BCF would be just 4.6%.

Modified Flotation Tests

Basic flotation tests for Douglas-fir indicated segregation of bark chips from wood chips was hampered by the tendency of inner bark to sink. Most of the sinking bark had inner bark saturated to the point that the whole chip sank. In several cases it was found with fresh chips that if the outer bark was separated from the inner bark, the outer bark floated and the inner bark sank.

From the above observations it appeared that a two-stage flotation system should be developed. The first stage flotation would be used to take off the inner bark as sinkers and the second to recover bark-free wood as sinkers. To do this the inner bark had to be separated from the outer bark and the moisture content of the chips had to be controlled so that wood would float while the inner bark, which absorbs water more quickly than the wood, would sink. An alternative to this would be to refloat the first sinkers after they were air dried. In this case the air-dried bark would take up water quicker than the wood and would sink leaving floating wood for recovery. The second flotation stage would incorporate a simple preflotation steam-pressure treatment of the floating chips from the first flotation after which an accelerated segregation in 22° water would take place with the wood sinking and bark floating.

The above theory is a reasonable solution to the problem; however, as will be described, the difficulty of separating inner from outer bark did not allow a successful completion of the investigation. The pulp-cake breaker, used with previous species to separate inner from outer bark, was ineffective in separating inner from outer bark of the Douglas-fir. In Table V, the results of a flotation using chips passed through the pulp-cake breaker are contrasted to results from untreated chips and with other modifications tried.

The observations verified that neither the pulp-cake breaker treatment nor the compression treatment facilitated inner-bark outer-bark separation or the sinking of bark chips. The inner bark was less friable than previous barks tested and tended to be resilient to the beating action of the pulp-cake breaker. The outer bark was also resilient and what was broken off dirtied the chips with specks. The bond between the inner and outer bark was strong enough to prevent a "slippage" separation in compression through rollers.

The steam pressure treatment in the pressure cooker accelerated the sinking of wood chips and left a large percentage of the bark still floating. Reducing the moisture content of chips tended to leave more wood chips floating unrecovered with the bark.

While the treatments designed to improve segregation did not give the levels of wood recovery and bark contamination the original standards called for, reasonable improvements were made to the point that testing of pure fractions was thought to be more profitable than continuing with new modifications. It was decided to use only the steam pressure treatment on chips of 45% moisture content. The dwell time was kept at 5 min. but the pressure was raised to 15 p.s.i. (See Fig. 1 for the schematic diagram of the modification test of pure samples.)

The averages of the results of duplicate tests are given in Table VI. Both AWR and BCF were computed for, first, wood recovery as sinkers in the flotation after the steam pressure treatment, and, second, for the wood recovered as sinkers for both the first and poststeam-pressure-treatment flotations. Agreement

TABLE V

DOUGLAS-FIR PRELIMINARY MODIFIED FLOTATION TESTS[a]
(Using "On 1/2-Inch" Chips)

		Flotation Test Number					
		1	2	3	4	5	6
Moisture content, %[b] of original materials		45.3	44.2	42.8	43.1	45.2	35.3
Chips mechanically beaten before processing		--	Once	Twice	Twice	--	--
5-Minute agitated flotation on 22°C. water, % of original material							
Floating:	bark	77.0	67.6	76.9	75.4	76.4	97.5
	wood	60.0	68.6	69.0	67.4	57.9	97.6
Sinking:	bark	23.0	32.4	23.1	24.6	23.6	2.5
	wood	40.0	31.4	31.0	32.6	42.1	2.4
Steam pressure treatment in 90°C. water of floating chips							
Pressure, p.s.i.		--	--	--	10	10	13
Dwell, min.		--	--	--	5	5	6
Agitated flotation of treated chips on 22°C. water, % of original material							
Floating:	bark	--	--	--	69.3	75.0	92.5
	wood	--	--	--	12.2	6.0	38.5
Sinking:	bark	--	--	--	6.1	1.4	5.0
	wood	--	--	--	55.2	51.9	59.1
Reflotation of air-dried first sinking chips, % of original material							
Floating:	bark	--	24.0	4.1[c]	--	19.7	--
	wood	--	23.0	1.6[c]	--	38.9	--
Sinking:	bark	--	8.2	19.0[c]	--	3.9	--
	wood	--	7.4	29.4[c]	--	3.2	--

[a]Values in the table are ovendry weight percentages based on the ovendry weight of either bark or wood chips processed.

[b]Moisture content = [100] - [(ovendry weight/"fresh" weight) x 100].

[c]Includes compression between steel rolls.

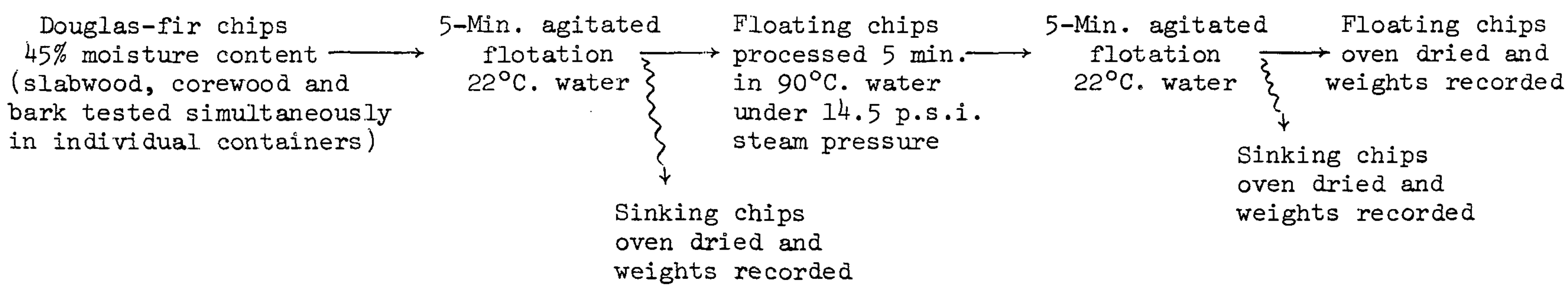

Figure 1. Schematic Diagram for Douglas-fir Modified Flotation Pure Fraction Test. In Application Sinking Chips Represent Chip Recovery for Use and Floating Chips Represent Chips to be Discarded (Mostly Bark)

TABLE VI

DOUGLAS-FIR MODIFIED FLOTATION TEST STEAM PRESSURE TREATMENT[a]

	On 1/4-Inch Chips					On 3/4-Inch Chips				
	% of Original Material			AWR[b] Sinkers, %	BCF,[c] %	% of Original Material			AWR[b] Sinkers %	BCF,[c] %
	Wood					Wood				
	Core	Slab	Bark			Core	Slab	Bark		
Moisture content, %[d]	48.6	44.6	47.0			45.2	44.2	44.7		
Sinkers recovered after:										
First flotation	6.0	26.2	9.6	87.8	11.1	4.4	27.3	6.8	78.1	4.6
Steam-pressure flotation treatment	53.4	66.6	23.4	65.3	10.7	14.5	58.7	4.6	54.1	6.6
Floaters recovered	40.2	7.2	67.0			81.1	14.0	88.6		
Reflotation of first flotation sinkers recovered as floaters	4.8	22.4	8.2			4.4	22.8	5.6		

[a] Data represent averaged results of duplicate determinations and are percentages based on ovendry weights.

[b] AWR = Accumulated Wood Recovery = (0.093 x corewood recovery) + (0.907 + slabwood recovery) — the decimal figures being the ratios of that wood in the original bolts. Recovery periods included for figures are indicated with brackets.

[c] BCF = Bark Contamination Factor = percent of bark by ovendry weight contaminating wood recovered from an original mixture of 75% wood and 25% bark. Arithmetically, BCF = (% of original bark recovered with the sample)/(3 AWR + % of original bark recovered with the sample).

[d] Moisture content % = [100] - [(ovendry wt./"fresh" wt.) x 100].

between duplicate tests was good. More bark contaminated the small "on 1/4-inch" chips than the large "on 3/4-inch" chips. Wood recovery from 78 to 87% was realized and the percentage of bark contaminating the wood was as low as 4.6% in the case of large chips. Corewood accounted for a relatively greater percentage of the wood lost than the slabwood, comprising over one-half of the large wood chips not recovered.

The problem of segregating bark chips from wood chips by liquid flotation can undoubtedly be solved with more investigation for Douglas-fir. Developing a procedure to remove the chips with a high proportion of inner bark before the chips are treated with steam pressure is one of the keys. The other key is the finding of the best pressure and dwell time necessary to maximize wood recovery without including bark. Determining the proper chip moisture content before treatment is also a factor worthy of further investigation.

WESTERN HEMLOCK

Basic Flotation Tests

As with Douglas-fir, basic flotation tests were run in duplicate on pure chips of the western hemlock bark, corewood (center 8 annual rings), and slabwood (wood outside the center 8 annual rings). Effects of chip size, chip moisture content, and dwell on flotation behavior were determined. Accumulated wood recovery (AWR) and a bark contamination factor (BCF) were computed for the appropriate intervals.

The results of the test are listed in Table VII. Shown are the percentages of various materials, by size and moisture content and by recovery during given intervals. The larger chips tended to remain buoyant longer than the smaller chips for all materials. No differences in flotation behavior due

TABLE VII

WESTERN HEMLOCK BASIC FLOTATION TEST

Percent of Original Material Recovered as Sunken or Floating Chips at Stated Interval[a]

	On 1/4-Inch Chips			On 3/4-Inch Chips		
	Wood			Wood		
	Corewood	Slabwood	Bark	Corewood	Slabwood	Bark
Moisture content, %						
Objective	20.0					
Actual	22.0	21.0	23.5	20.0	21.0	22.0
Percent of material sinking from:						
0-5 min.	0.7	1.4	0.3	0	0.2	0.4
5-15 min.	0	0	0.3	0	0	0.1
15-30 min.	0	0	0.4	0	0	0
1/2-1 hr.	0.2	0.1	1.0	0	0.5	0.2
1-4 hr.	0.7	1.1	10.6	0	2.2	0.4
4-6 hr.	0.2	0.2	6.8	0.6	0	0.2
6-24 hr.	8.5	18.2	40.6	1.7	5.6	5.8
24-48 hr.	16.1	30.9	13.2	4.4	5.2	6.0
48-72 hr.	21.7	21.2	6.6	2.6	10.9	7.6
72-96 hr.	29.4	15.0	4.4	2.6	19.0	9.4
96-120 hr.	10.5	9.5	2.2	4.8	25.9	11.2
120-144 hr.	6.7	1.3	2.3	9.0	15.8	11.7
144-168 hr.	2.9	0.7	1.5	9.9	7.9	8.2
Percent of material floating at 168 hr.	2.4	0.4	9.8	64.4	6.8	38.7
Moisture content, %						
Objective	45.0					
Actual	43.5	45.5	47.0	45.0	46.5	45.5
Percent of material sinking from:						
0-5 min.	1.8	2.1	9.2	6.2	0.5	0
5-15 min.	0	0	0	0	0	0
15-30 min.	0	0.1	0.6	0.8	0	0
1/2-1 hr.	0.1	0.2	2.2	0	0	0
1-4 hr.	1.0	1.2	6.0	0.2	1.9	0.3
4-6 hr.	0	1.2	1.8	1.4	0.5	2.8
6-24 hr.	8.4	13.2	40.5	4.2	5.2	41.8
24-48 hr.	12.1	14.0	12.1	4.3	7.2	41.1
48-72 hr.	22.2	17.0	5.0	3.3	13.1	6.0
72-96 hr.	19.4	21.8	3.8	5.4	12.7	3.8
96-120 hr.	15.6	20.7	3.6	12.0	18.5	2.3
120-144 hr.	8.9	6.5	3.0	9.9	18.5	0.3
144-168 hr.	5.8	1.4	2.2	12.7	14.2	1.2
Percent of material floating at 168 hr.	4.7	0.6	10.0	39.6	7.7	0.4

[a]Data in table are averages of duplicate determinations and are percentages based on ovendry weights. Corewood is considered to be the first eight annual rings and slabwood is rings nine and beyond. The corewood was 9.3% of the total bolt. Moisture content = [100] - (ovendry wt./"fresh" wt.).

to moisture content were found in the small bark chips. Although the summary data do not show it concisely, a careful evaluation of the duplicate results of the wood chips indicated a similar lack of influence of the original sample moisture content on the small wood chips. On the large bark chips, the drier, 20% moisture content, chips remained buoyant longer than the wetter, 45% moisture content, chips. Differences in flotation between the large wood chips, due to moisture content of the original sample, appeared to be negligible.

The recovery summary data were further evaluated and the best accumulated wood recovery (AWR) and bark segregation (BCF) possibilities computed. The results, listed in Table VIII, indicate no satisfactory simple recovery system is apparent for use on mixtures of large and small chips. The best possibility for the large-size chip was a 48-hour flotation of chips with a preflotation moisture content of 45%. The wood can be recovered as floating chips at 48 hours from this system with an AWR of 84.5% and a BCF of 5.2% if an original mixture of 75% wood and 25% bark was assumed. The BCF would be reduced if the original mixture had a lower percentage of bark.

No satisfactory simple wood-bark segregation by water flotation system was evident for the small wood chip recovery. One of the best systems recovered the wood sinking between 48 and 168 hours. The result was a recovery of 67.8% of the wood with 8.0% bark contamination (1/3 of the starting amount).

Modified Flotation Tests

In working with the basic flotation evaluations of the western hemlock tests it became apparent there were several problems that must be dealt with to effect a satisfactory wood-bark chip segregation by flotation system. First of all, the chipped bolts had a higher moisture content than the conditions for the

TABLE VIII

WESTERN HEMLOCK BASIC FLOTATION TEST[a]

	On 1/4-Inch Chips						On 3/4-Inch Chips					
	% of Original Material						% of Original Material					
	Wood						Wood					
	Core-wood	Slab-wood	Bark	Recovered Portion[b]	AWR, %[c]	BCF, %[d]	Core-wood	Slab-wood	Bark	Recovered Portion[b]	AWR, %[c]	BCF, %[d]
Moisture content, %												
Objective				20.0								
Actual	22.0	21.0	23.0				20.0	21.0	22.0			
Percent of material sinking from:												
0-6 hr.	1.8	2.8	19.4	→	96.7	19.6	0.6	2.9	1.3	→	85.2	18.9
6-24 hr.	8.5	18.2	40.6	→	79.4	11.3	1.7	5.6	5.8	→	79.9	18.4
24-168 hr.	87.3	78.6	30.2	→	80.0	14.3	33.3	84.7	54.2	→	92.1	25.2
Floating at 168 hr.	2.4	0.4	9.8				64.4	6.8	38.7			
Total	100.0	100.0	100.0				100.0	100.0	100.0			
Moisture content, %												
Objective				45.0								
Actual	43.5	45.5	47.0				45.0	46.5	45.5			
Percent of material sinking from:												
0-24 hr.	11.3	18.0	60.3	→	81.6	10.8	12.8	8.1	44.9	→	80.8	18.4
24-48 hr.	12.1	14.0	12.1	→	67.8	8.0	4.3	7.2	41.1	→	73.9	5.8
48-168 hr.	71.9	67.4	17.6	→	82.6	13.8	43.3	77.0	13.6	→	91.5	16.7
Floating at 168 hr.	4.7	0.6	10.0	→	68.8	11.8	39.6	7.7	0.4	→	84.5	5.2
Total	100.0	100.0	100.0				100.0	100.0	100.0			

[a]Data presented here are compiled in a manner which indicates some of the better wood/bark segregations possible on a simple water flotation over a week's time. Data are based on more detailed duplicate determinations given in Table VI. Moisture content percents = [100] - [(oven-dry wt./"fresh" wt.) x 100].

[b]Lines indicate the grouping of fractions for recovery.

[c]AWR = Accumulated Wood Recovery = (0.093 x corewood recovery %) + (0.907 x slabwood recovery %) — decimal figures are the percentages of that wood in the original bolts.

[d]BCF = Bark Contamination Factor = Percent of bark by ovendry weight contaminating wood recovered from an original mixture of 75% wood and 25% bark. Arithmetically, BCF = (% of original bark recovered with the sample)/(3 AWR + % of original bark recovered with the sample).

basic flotation tests called for. Floating some fresh chips on water immediately after chipping had resulted in an apparently good segregation with wood sinking and bark floating. The first order of the investigation called for a closer look at the influence of chip moisture content on flotation behavior. A means of exploiting the flotation behavioral differences between western hemlock inner and outer bark was a second area for investigation. Inner bark sinks immediately and outer bark usually floats. Therefore, the possibility of a multistage segregation system exists with the inner bark being eliminated as early sinking chips in the first bath and wood recovered in later baths as either sinkers or floaters. A third area of investigation called for the discovery of a means to saturate inner bark with water, thus causing the bark to sink before the wood.

For efficiency, several modifications for a segregation system were evaluated simultaneously. For the purposes of reporting, a single modification is discussed at a time as much as is practical. Because of this reporting approach, a different logic may suggest itself than what was used in action.

The results of the preliminary modified flotation tests, showing modifications tried and the array of chip moisture content utilized, are presented in Table IX. The test for moisture content influence is indicated in the left-hand columns and was simply a 5-minute flotation of a mixture of wood and bark, medium-sized (on 1/2-inch) chips after which a determination was made of the percentage of wood or bark chips sinking and floating. As can be seen in the data, bark and wood chips behaved similarly with 1.7% of the wood and 0.4% of the bark sinking at 20% moisture content and 100% of both sinking at 75% moisture content. The data clearly show no segregation can be anticipated because of moisture content adjustments. Looking back at the original moisture content of the bolt when chipped, Table II, it is noteworthy that the wood chips had a higher moisture content than

TABLE IX

WESTERN HEMLOCK MODIFIED FLOTATION TESTS[a]

(With Steam-Pressure and Adjustment of Chip Moisture Content)
(Using on 1/2-inch chips)

Sample Description and Moisture Content	22°C. Water Flotation (Agitated) % of Material at 5 Min.		Poststeam Pressure Treatment to Flotation on Agitated 22°C. Water for 5 Min. — % of Material After 5 Min. Flotation		Preflotation Treatment Conditions		
	Sinking	Floating	Sinking	Floating	Steam Pressure, p.s.i.	Dwell, min.	Bath Temp., °C.
75% Wood	100.0	0					
Bark	100.0	0					
65.6% Wood	61.5	38.5					
Bark	65.9	34.1					
53.1% Wood	12.4	87.6	53.2	34.4	14.5	5	90
Bark	19.5	80.5	51.7	28.8			
44.8% Wood	0.1	99.9	8.5	91.4	14.5	5	90
Bark	0	100.0	45.9	54.9			
BCF				16.7			
32.6% Wood	1.4	98.6	21.9	76.7	14.5	5	90
Bark	0.1	99.9	69.8	30.1			
BCF				11.6			
20% Wood	0.4	99.6	16.2	83.4	15.0	6	90
Bark	1.6	98.4	58.9	39.5			
BCF				13.6			

[a]Percentages of materials are based on ovendry weight. Moisture content % = [100] - [(ovendry wt./"fresh" wt.) x 100].

the bark where the small chips are concerned. This was perhaps due to the higher amounts of the scaly outer bark in the small chips than in the larger ones. The point worth emphasizing is that bark and wood chips may have a moisture content differential that can be exploited when the chips are fresh but will be lost with storage because of a tendency of the moisture contents to equalize.

Further modifications tried with the steam pressure treatment are indicated in Table IX with the moisture content tests previously discussed. The test used consisted of a 5-minute agitated flotation on 22°C. water after which time the floating chips were transferred to the pressure cooker and the sunken chips were extracted and ovendry weights determined. The floating chips were immersed in a 90°C. bath in the kettle which was then pressurized with steam to 14.5 p.s.i. for a 5-minute dwell time. When the pressure was released, the chips were transferred from the pressure cooker to a 22°C. bath where the chips were stirred for 5 minutes and then removed as either floating chips or sunken chips and the ovendry weights determined. The results indicated the best wood recovery occurred at original chip moisture contents of 45% or less with less bark contamination at the lower moisture contents. The best BCF was obtained using chips with a pre-flotation moisture content of 20%. In that run, 39.5% of the bark remained with an 83.5% wood recovery and a BCF of 13.6%. Changes could have been made with the pressure cooker treatment conditions to cause more bark to sink, but it was apparent that more wood would sink as well.

Efforts were made to separate the inner bark from the outer bark by using the pulp-cake breaker and the steel compression rolls of the glue spreader. The bark proved too resilient and the bond between inner and outer bark too strong to effect any reasonable segregation with either apparatus. Further work toward inner-outer bark separation was terminated.

Because of the spongy nature of the inner bark it was felt that methods to encourage water saturation of the inner bark would result in early sinking of the bark chips leaving the wood chips behind as bark-free floaters. The compression through the glue spreader's steel rolls was followed to determine the effects of the treatment toward that end. Ten passes through the steel rolls resulted in negligible additional bark sinking as is evidenced in Table X. The reason appeared to be that the inner bark was too resilient and returned to its original shape before the chips reached the water bath. The water spray maintained on the rolls was not sufficient in supply or direction to allow for saturation of the bark air spaces with water. Subsequent compressions seemed to squeeze out water with the chips absorbing approximately an equal amount after compression. The resiliency problem could be solved if the chips could be compressed under water; however, the apparatus to do the job was unavailable and the time was not available for developing one.

A last attempt to encourage water absorption by bark was made using a chemical wetting agent, Pluronic L-92 (Wyandotte Chemical Co.). The thought was the wetting agent would be more effective and work faster on the bark than the wood, resulting in the desired effect of water-saturated bark sinking before the wood. The tests were empirical in nature with two application points for the wetting agent used in conjunction with the pressure cooker system. The first test floated the chips on water with the 1% Pluronic L-92 after the pressure cooker treatment, and the second called for a pretreatment soak in 1% Pluronic L-92 water solutions. The results, Table X, indicated minimal response of the bark to the treatment.

Because allotted time and funds had been exhausted, further work with western hemlock was terminated. No good segregation systems were found for

TABLE X

WESTERN HEMLOCK MODIFIED FLOTATION TESTS OF WETTING AGENT AND MECHANICAL COMPRESSION INCLUSIONS[a]

(Using "on 1/2-inch" chips)

Sample Description and Moisture Content	First Flotation, 5 min., agitated in 22°C. water		Additional Flotations and Treatments			
	- - - - - - - Percentage of Original Material - - - - - - -					
	Sinking	Floating				
44.9%			After 10 Compressions Through Steel Rolls			
			Sinking	Floating		
Wood	0.6	99.4	7.7	91.7		
Bark	7.5	92.5	27.1	65.4		
BCF[b]				19.2		
32.2%			Steam-Pressure Treatment (14.5 p.s.i., 5 min. dwell in 90°C. water) to Flotation on 1% Pluronic L-92 (wetting agent) 22°C. solution			
			Initial Sinkers	1-Hour Sinkers	2-Hour Sinkers	2-Hour Floaters
Wood	0.1	99.9	18.1	7.2	0.6	74.1
Bark	0.0	100.0	73.5	7.8	1.3	17.3
BCF[b]						7.2
12.0%			1/2-Hour Soak in 1% Pluronic L-92 (wetting agent) Solution to Steam Pressure Treatment (14.5 p.s.i., 5-min. dwell in 90°C. water) to 5-min. Agitated Water Flotation on 22°C. Water			
			Sinking Chips	Floating Chips		
Wood	0.0	100.0	21.0	79.0		
Bark	0.0	100.0	55.3	44.7		
BCF[b]				15.8		

[a]Percentages are based on the ovendry weight of the indicated material in the original sample. Moisture content % = [100] - [(ovendry wt./"fresh" wt.) x 100].

[b]BCF = (% of original bark recovered in the sample)/[3 (% of original wood recovered in the sample) + (% of original bark recovered in the sample)].

western hemlock during the course of this investigation. It appears the flotation characteristics of the wood and bark of western hemlock are too similar to allow development of a simple wood-bark chip liquid flotation segregation system for the species.

REVIEW OF PROJECT PROGRESS

The original proposal for this project had three objectives. The first was the optimization of the aspenwood-bark chip segregation via the liquid flotation system described by Einspahr, et al. (1). The second was the use of that system to test liquid flotation segregation on other hardwood species of similar wood-bark specific gravity relationships. The third was the use of further modifications of the system to investigate species of differing wood-bark specific gravity relationships. At strong recommendation from project sponsors, three conifers were included in the testing.

At the beginning of the project some standards had to be set in order to evaluate all species on a comparable plane. In practice, the percentage of bark in a chip mixture could be almost any value, depending on the source of chips, e.g., residues, tree tops, or whole tree chips. Data available at The Institute of Paper Chemistry indicated whole trees might have 20-30% bark and so standards were set, for comparative purposes, so that all chips would be considered to come from a mixture of 25% bark and 75% wood.

The standards for chip cleanliness were difficult to set. Most papermakers prefer no bark with the wood but different processes or products have different tolerances which range between 0 and 10%. In fact, recent developments in both papermaking technology and wood supply have resulted in mill managers becoming more tolerant of bark contamination. At any rate, minimum standards of

90% wood recovery with 3% or less bark contamination, by weight, from a theorized 25% bark-75% wood chip mixture were established. In all probability, the estimates of the bark contamination for the tests run were higher than what might have resulted from actual mixtures; e.g., the metro-chiparvester chips from whole trees, described in Progress Report Two, had only 10-15% bark in the "woods run" chip mixture as opposed to the 25% bark theorized for this project's tests.

During the course of the project, factors influencing flotation behavior were controlled as much as possible in an effort to gain a fuller understanding of the flotation behavior of the wood and bark of each species. Large and small chips were tested at two different moisture contents, "wet" (45%) and "dry" (20%). Flotation of the chips on water was studied. As the investigation progressed, some lightly accepted facts regarding flotation differences between inner and outer bark and between the interior and exterior wood were put into proper perspective. Chemical, mechanical, and atmospheric modifications of the flotation system were also tested. The successful modifications are presented in the following section. If additional details on modifications tried are desired, they can be found in previous reports in sections for the appropriate species.

Table XI summarizes the result of the flotation work with each species investigated. The column after "Species" listing the flotation tendencies for wood and bark, sometimes separates the information into inner and outer bark and corewood (center 8 annual rings) and slabwood (annual rings beyond year 8). Also indicated is the relative tendency of the materials to sink or float and the order in which the materials can be expected to sink in certain cases.

In suggesting flotation systems it is assumed that sinking and floating portions of a flotation can be segregated in a variety of ways, such as chambered

TABLE XI

SUMMARY FLOTATION TEST RESULTS OF TEN SPECIES STUDIED FOR PROJECT 2977[a]

Species	Wood		Bark		Flotation System Suggested	Recommended Chip M.C.	Classification to Chip Size Necessary
Acer saccharum sugar maple	Sinks (2)		Inner sinks (1)	Outer floats	Multistage with pulp-cake breaker	20	None
Betula papyrifera paper birch	Sinks (2)		Inner sinks (1)	Outer floats	Multistage with pulp-cake breaker & pressure cooker	20	Probably none
Carya ovata shagbark hickory	Floats		Sinks		Single stage	20	None — but would allow 2-4% more wood recovery
Picea glauca white spruce	Floats		Sinks		Single stage with compression	20-35	None — but would allow 2-4% more wood recovery
Pinus taeda loblolly pine	Sinks		Floats		Single stage with pressure cooker	45+	None
Populus deltoides eastern cottonwood	Floats		Floats		None	--	--
Populus tremuloides quaking aspen	Floats		Sinks		Single stage with compression	20	None
Pseudotsuga menziesii Douglas-fir	Core floats	Slab sinks	Inner sinks	Outer floats	Single stage with pressure cooker	45+	Recommended. Large chips will be cleaner than small chips
Quercus macrocarpa bur oak	Sinks		Floats		Single stage	45	None
Tsuga heterophylla western hemlock	Floats		Inner sinks	Outer floats	None	--	--

[a]The suggested flotation systems in the table are based on tests made during the project period. Generally, it is expected the systems will provide a recovery of 90% or more of the wood chips with 3.0% or less bark contamination by ovendry weight from a mixture originally consisting of 75% wood and 25% bark. The main exception is Douglas-fir which had a wood recovery of 78-87% with 4.6-11.1% bark. No satisfactory segregation was obtainable by flotation for eastern cottonwood or western hemlock.

[b]Flotation tendency describes the flotation characteristics of the wood and bark of a tree species in the relationship of one to the other. In some cases (if there were usable flotation differences), the wood is subdivided into corewood (center eight annual rings) and slabwood (rings beyond year eight) and the bark subdivided into inner or outer bark if there were usable flotation differences. Only one material is categorized as floating and the others are listed in order of tendency to sink 1 or 2.

flotation vessels, live bottoms, etc. In fact, if a market is available for a variety of chip qualities, wood chips of various degrees of purity can be taken off for utilization at specified time periods and systems previously tested and termed unsatisfactory may become quite practical.

The suggested flotation systems have been separated into two categories, single stage and multistage. Single stage simply implies a single flotation in which the bark either sinks or floats and wood is recovered as the opposite fraction. In the multistage flotation more than one flotation is implied where the first step usually eliminates a portion of the bark as sinkers, the second or later stages remove either bark as discards or wood for recovery. In both categories, modifications are added for certain species such as chip beaters to separate inner from outer bark, steel roll compressions to encourage bark to sink before wood by accelerated absorption, and steam pressure treatments to accelerate water uptake of either wood or bark and, thus, hasten its sinking.

Two species, western hemlock and eastern cottonwood, have no suggested flotation systems for wood-bark chip segregation because an adequate differential in flotation behavior between bark and wood was lacking. In both species, flotation possibilities might still exist if inner bark could be separated from outer bark by means other than those tried.

The recommended chip moisture content (wet weight basis) are levels that worked in testing. In most cases a wider range can probably be tolerated or different levels might even improve the segregation.

The last column indicates the importance of chip size to flotation behavior. Generally, the size class became important when it contained proportionately different amounts of one kind of wood or bark or the chips had a greatly different absorption rate.

SUGGESTED WOOD-BARK CHIP SEGREGATION SYSTEM FOR ASPEN, SUGAR MAPLE, AND PAPER BIRCH

In aspen the average specific gravity for wood is 0.36 and for bark 0.50. The wood is expected to sink before the bark. Very little modification was necessary for the aspenwood-bark segregation system. Controlling chip moisture content, fresh weight basis, to 20% and using steel rolls for compression midway in the flotation can result in 95-99% wood recovery with 0.1-2.0% bark contamination. See Project 2977, Progress Report One, p. 17, for details. Figure 2 presents the flow diagram for the procedure along with flow diagrams for sugar maple and paper birch liquid flotation wood-bark chip segregation.

Sugar maple had average specific gravities of 0.59 for wood and 0.56 for bark. By beating the chips the inner bark can be separated from the outer bark and the inner bark then quickly absorbs water and sinks in flotation. Because of the low moisture content of the chips, the wood takes approximately 24 hours to have an acceptable amount sink for good recovery. The bark continues to float slightly longer than the wood. The flotation tests described in Reports One and Two indicate improvements to the system are necessary.

Paper birch has an outer bark which repels water and a friable pithy inner bark. The wood, as with sugar maple, has a specific gravity nearly equal to its bark (0.52 as opposed to 0.54). Beating the chips again separates inner from outer bark allowing the inner bark to sink first in flotation. The floating chips can then be put under pressure in a hot water bath accelerating water uptake by the wood. An ambient water flotation then segregates the wood as sinkers from the outer bark which still floats. More details on paper birch flotation behavior can be found in Reports One and Two.

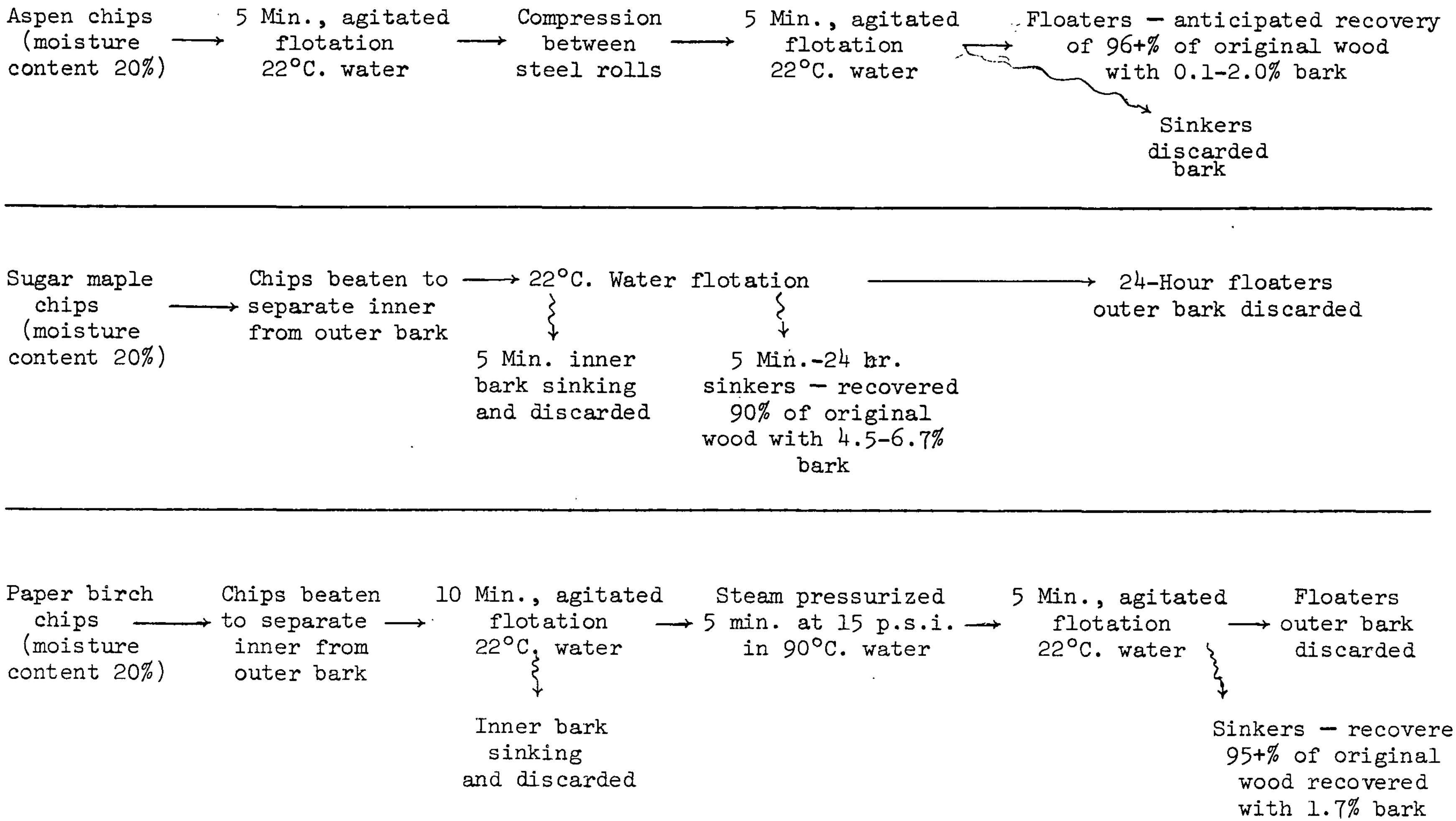

Figure 2. Given Above are Schematic Diagrams for Suggested Wood-Bark Chip Liquid Flotation Segregation Systems for Aspen, Sugar Maple, and Paper Birch. It Appears Possible to Process all Three Species in Mixtures with the Paper Birch System

It is felt, both from the results of the flotation segregation of the metro-chiparvester chips and other test results, that the wood of any mixture of aspen, and/or sugar maple, and/or paper birch could be segregated from the bark if the paper birch system is used. If this proves true, a practical application would be possible to harvest certain northern forest types.

SUGGESTED WOOD-BARK CHIP SEGREGATION SYSTEM FOR BUR OAK AND SHAGBARK HICKORY

Bur oak was tested as a representative of the white oak family. If the test results of this species hold true for all oaks or even just the white oaks, a simple segregation with wide application to many regions is possible. The specific gravity of bur oakwood is heavier than the bark (0.38 vs. 0.65). Fresh-cut wood would have the moisture content desired for a clean efficient segregation. The system is simple. Pour the wood-bark chip mixture into water and the wood sinks for recovery and the bark floats to be discarded. Figure 3 shows the recommended flow diagram for bur oak and shagbark hickory. The higher percentage of bark shown with the anticipated wood recovery represents mostly sinking inner bark. Details of bur oak flotation are given in Report One.

The specific gravity values for shagbark hickory wood and bark are similar with both being around 0.60. Using chips of 20% moisture content results in an efficient, clean segregation with the bark sinking and the wood floating. Report Three gives details on the shagbark flotation behavior. The recovery is the opposite of the oak so that the two species, although often growing together in the same stands, cannot be processed together. For shagbark hickory the bark sinks and wood floats in a simple one-step flotation.

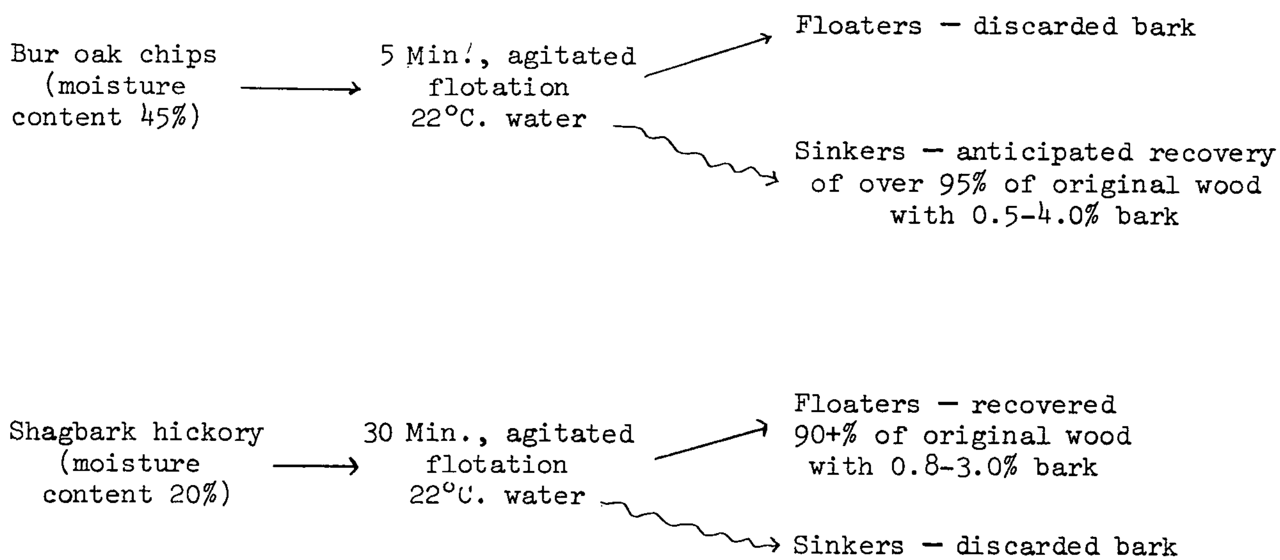

Figure 3. Suggested Wood-Bark Chip Liquid Flotation Segregation Systems for Bur Oak (a White Oak) and Shagbark Hickory

SUGGESTED WOOD-BARK SEGREGATION SYSTEM FOR LOBLOLLY PINE, WHITE SPRUCE, AND DOUGLAS-FIR

Reasonably successful segregation systems are suggested for three conifers: loblolly pine of the southern forests, Douglas-fir of the western forests, and white spruce from the northern forests. Figure 4 gives a flow diagram for the suggested wood-bark chip segregation systems for these species. The flotation behavior of corewood becomes important in segregation systems for coniferous species.

Chips of wood and bark of loblolly pine have been somewhat successfully separated using the vac-sink process [Wesner (2)]. In the vac-sink process, a vacuum is applied to a mixture of chips of wood and bark and when released causes the wood chips to pick up water and sink. The system used in The Institute of Paper Chemistry tests uses a reverse procedure. Chips with a fresh weight moisture content of 45-55% should be used. Steam pressure near 15 p.s.i. is applied to the mixture in a 90°C. water bath. When the pressure is released, the chips are transferred to a 22°C. water bath and the wood takes up water and sinks leaving the bark behind. Some difficulties in both systems have been noted due to the differential in flotation behavior of corewood as opposed to mature or slabwood. Depending on the amount of corewood in the chip mixture, up to 99+% of the wood can be recovered using the steam pressure system. Bark contamination is kept between 2 and 4%. A large percentage of the sinking bark recovered with the wood is inner bark and probably has negligible influence on paper quality.

Difficulties were encountered in developing a flotation segregation system for white spruce. The focus of the problem seemed to be on the pitch encountered with the spruce bark. A pitch glaze on the bark tended to inhibit

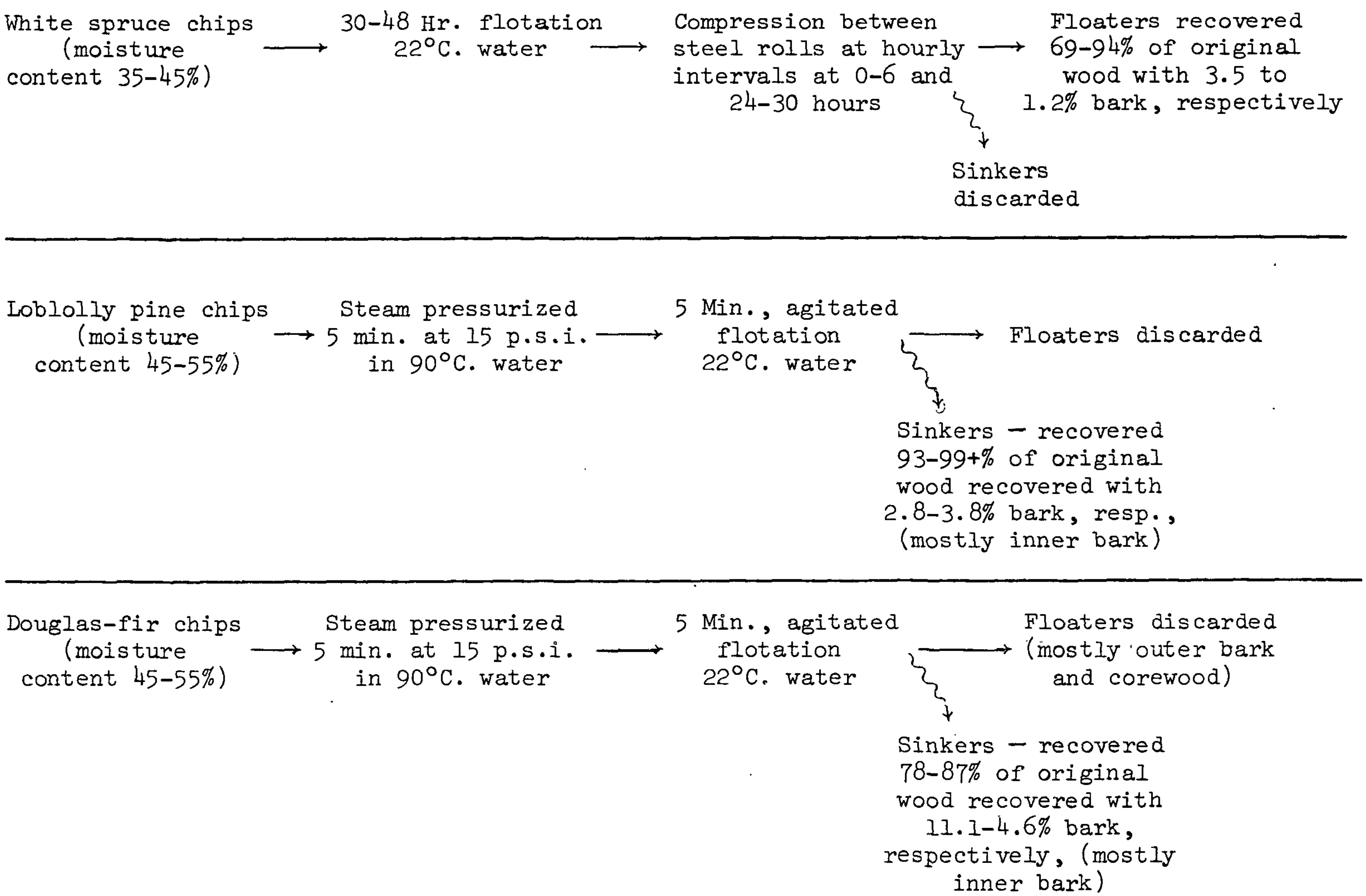

Figure 4. Suggested Wood-Bark Chip Liquid Flotation Segregation Systems for White Spruce, Loblolly Pine and Douglas-fir

water uptake and the ultimate sinking of the bark chips. This problem was solved by repeated compressions between steel rollers over a 30-hour period, at which time wood recovery was near 96% with 1.7-2.3% bark contamination. While the system seems to work within the standards set, more modifications are necessary for the development of a system with a practical processing time.

The wood-bark chip segregation system developed for Douglas-fir was very similar for that used for loblolly pine. The use of the system results in less than optimum wood recovery and more than the acceptable bark contamination. Wood recovery between 75 and 90% can be anticipated with 4-11% bark contamination from a mixture of 25% bark and 75% wood. Two factors influencing the flotation adversely are the buoyancy of the corewood and the tendency for the inner bark to sink with the wood. If the influence of these two factors could be minimized, an acceptable flotation segregation system for Douglas-fir would be realized.

ACKNOWLEDGMENTS

The program involved has been a team approach involving ideas, talent, advice, and patience from personnel of the Division of Natural Materials and Systems and the Division of Materials and Engineering Processes. The authors would particularly like to acknowledge the assistance of Allen Schumacker and Delmar Schwalbach for their help in preparing the logs and their perseverance and patience in sorting chips, and Mrs. Marianne Harder for her all around assistance with specific gravity determinations, chip sorting, preparation of data, and assistance with the report.

LITERATURE CITED

1. Einspahr, D. W., Benson, M. K., and Peckham, J. R. Observations on a bark and wood-chip separation procedure for aspen. Forest Prod. J. 19, no. 7:33-6(1969).

2. Wesner, A. L. U.S. pat. 3,032,188(May 1, 1962).

3. Isenberg, I. H. Pulpwoods of the United States and Canada. 2nd ed. Appleton, Wis., The Institute of Paper Chemistry, 1951. 187 p.

4. I.U.F.R.O. Forest Biomass Studies. 15th I.U.F.R.O. Congress, U. of Fla., March 15-20, 1971. 205 p.

5. Mitchell, H. L. Patterns of specific gravity variation in North American conifers. Proc. Soc. Am. Foresters 1964:169-79.

6. Peck, E. C. Specific gravity and related properties of softwood lumber. U.S.D.A. Tech. Bull. No. 343, Feb., 1933.

7. U.S. Forest Products Laboratory. Wood handbook. U.S.D.A. Agriculture Handbook 72, 1955.

8. Dobie, J. Factors influencing the weight of logs. B. C. Lumberman 49, no. 9:36-46(1965).

9. Knigge, W. Investigations of the average density of North American Douglas-fir stems as a function of various growth conditions. Holz Roh-Werkstoff 20, no. 9:352-60(1962).

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APPENDIX

TABLE XII

WOOD AND BARK SPECIFIC GRAVITIES AND REFERENCES

		Specific Gravity[a]					
		Wood			Bark		
Tree Species	Reference	Heartwood	Sapwood	Whole	Inner	Outer	Whole
Douglas-fir	(8)	--	--	--	--	--	0.50
	(3)	--	--	0.40-0.45	--	--	--
	(6)	0.44	0.43	0.44	--	--	--
	(3,7)	--	--	0.45	--	--	--
	(9)	--	--	0.50	--	--	--
	(4)	--	--	--	0.45	0.43	0.43
Western hemlock	(4)	--	--	0.41	0.45	0.56	0.44
	(6)	0.40	0.40	0.40	--	--	--
	(5)	--	--	0.42	--	--	--
	(3)	--	--	0.38	--	--	--

[a]Specific gravity = O.D. weight/green volume.