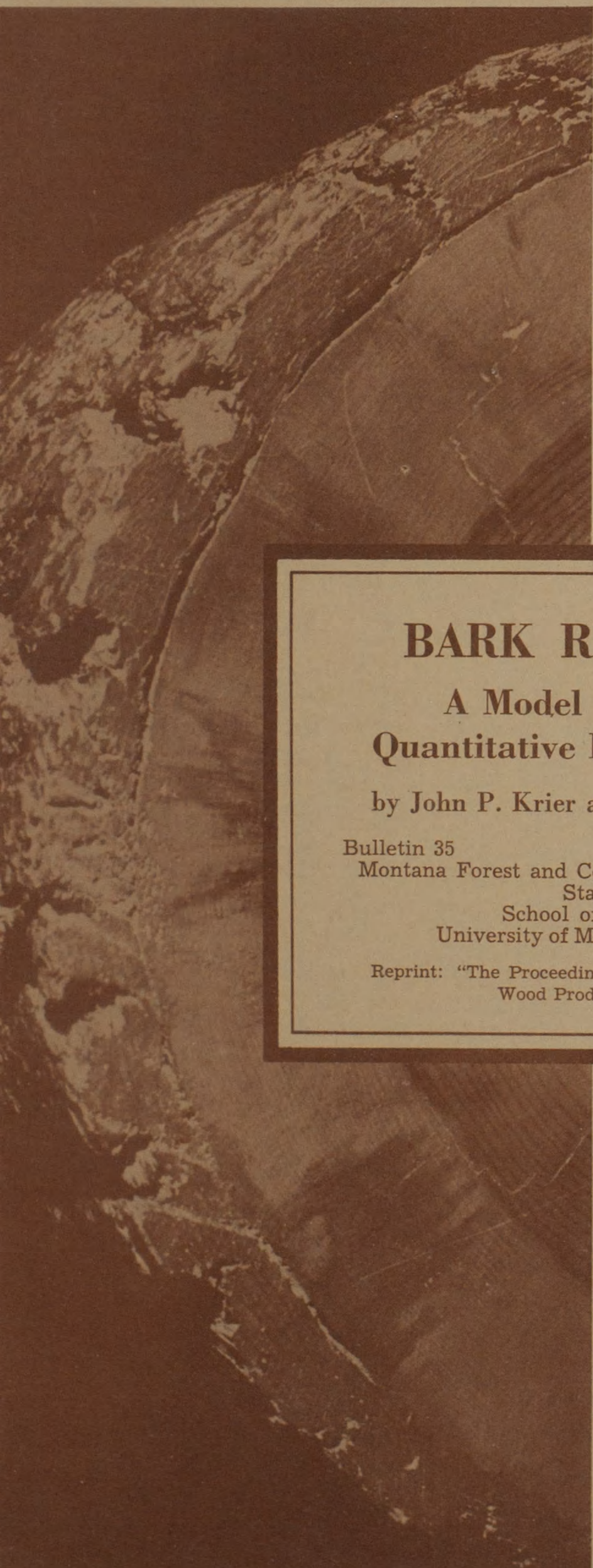

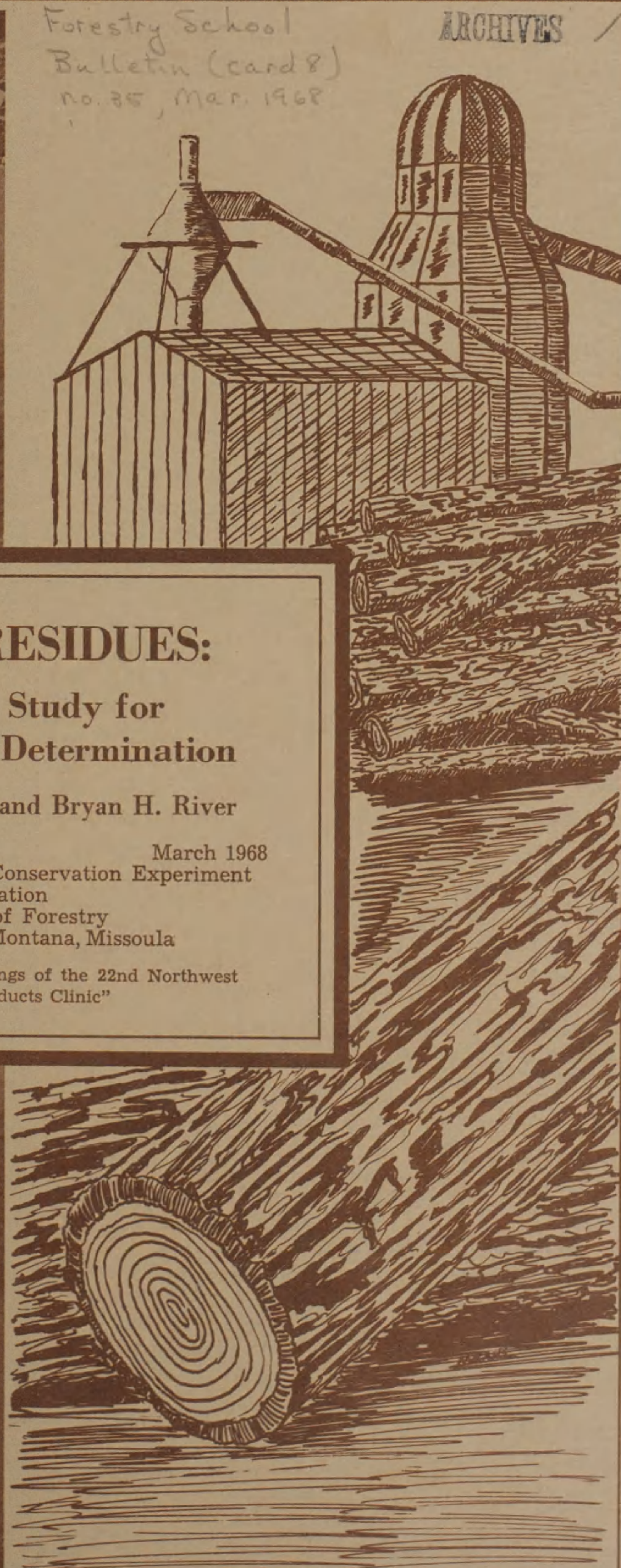

BARK RESIDUES:

A Model Study for Quantitative Determination

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BARK RESIDUES: A MODEL STUDY FOR QUANTITATIVE DETERMINATION

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Surplus bark is currently the most perplexing residue problem facing the wood conversion industries. The volume of bark residual is so great that it must be continually removed from the mill sites. Removal is normally accomplished by burning. The initial cost combined with costs of operation and maintenance of a residue burner are large enough to affect a marginal profit industry. These costs can become even higher, depending on air-pollution control measures. New technology has developed methods for converting slabs and edgings from a liability to an asset. That problem having been relieved, the utilization of bark is now receiving increasing attention.

Accelerating technological research promises that the profitable conversion of bark into useful products is not far off. A prerequisite to the selection of any location for a conversion industry is a knowledge of the quantity of raw material available in a proposed area. This study was directed toward that end.

Objectives

The first objective of the study was to develop a simple technique for measuring the quantity of bark on a log. The second objective was to provide a method for determining the quantity of bark residue generated by a mill through the use of log scale data. The third objective was to actually use the methods derived to measure the amount of bark available in a given area.

Methods, Equipment, And Techniques

Several methods were considered for measuring the volume of bark on a log. In order of decreasing precision but increasing simplicity they are:

1. Measure the volume of the log by water immersion, before and after bark removal.

2. Measure the volume of a disk cut from a log, before and after bark removal.

3. Photograph the log ends and determine the relative percentages of bark and wood.[1]

4. Measure the diameters inside and outside the bark and compare the volumes of the cylinders; then correct the volume data for fissures and voids.

The first three methods require special scales, cameras, or immersion tanks. The last method was chosen because it could be applied easily, using tools normally found at a sawmill. In the present study the following number of logs were measured: 191 Inland Douglas-fir (*Pseudotsuga menziesii*), 183 ponderosa pine (*Pinus ponderosa*), and 181 western larch (*Larix occidentalis*). In most cases the logs measured were 32 feet long. They were converted to 16-foot logs for convenience and uniformity, and were scaled as such.

Bark Thickness

The logs were measured at both ends for bark thickness. A Swedish bark gauge was used in making the determinations. The averages and ranges of thicknesses by species and diameter class are shown in Table 1. The average bark thickness curves are shown in Figure 1. By using the curves, average bark thicknesses can be compared with any diameter class that a mill may be using. It may be desirable to check the fit of this data against the bark characteristics found at an individual mill, or against previously published data.

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[1] The percentages may be determined by enlarging the photograph and measuring the relative areas with a planimeter. An alternate method is to cut out and weigh the parts of the photograph representing bark and wood with a sensitive balance.

TABLE 1

Range and Average Bark Thickness (Inches)
by Species and Diameter Class

Diameter class		7.6 11.5	11.6 15.5	15.6 19.5	19.6 23.5	23.6 27.5	27.6 31.5	31.6 35.5
Ponderosa pine	Range	.41-1.20	.50-1.45	.50-2.30	.63-2.05	.77-1.82	.77-3.00	.50-2.20
	Average	.80	.92	1.18	1.17	1.28	1.48	1.51
	Frequency	32	32	29	31	28	24	7
Douglas-fir	Range	.44-1.34	.56-1.30	.65-1.43	.82-1.95	.85-2.90		
	Average	.70	.88	.93	1.13	1.76	[1]	
	Frequency	45	53	41	29	20	3	
Western larch	Range	.40-1.70	.27-1.12	.31-1.60	.37-1.15	.45-1.50	.50-1.40	.55-130
	Average	.76	.74	.75	.76	.84	.92	.84
	Frequency	30	30	30	27	34	21	9

[1] Logs in this class or above are very rare in this area and consequently do not effect bark yield in any significant degree.

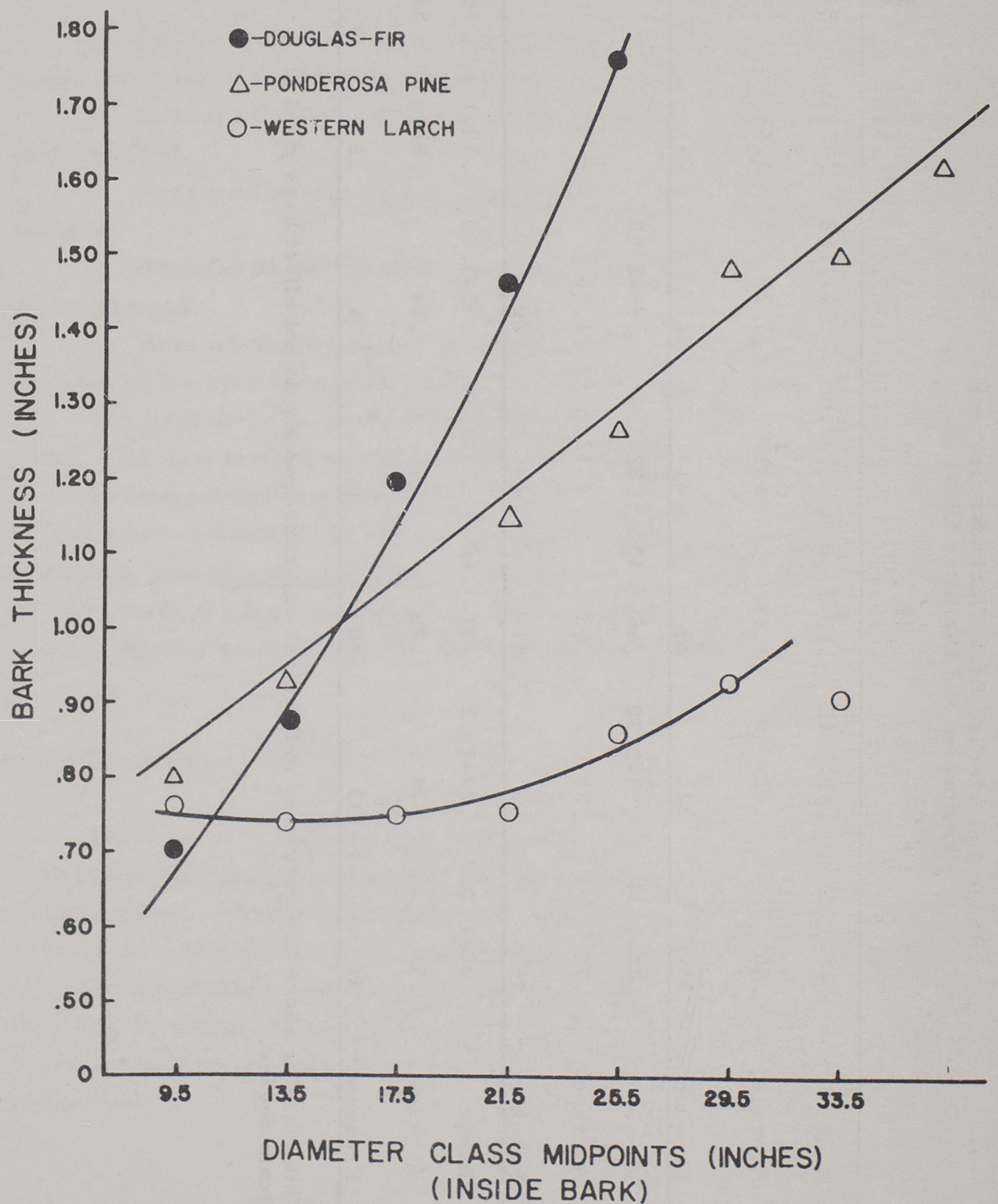

FIGURE I.- BARK THICKNESS BY SPECIES AND DIAMETER CLASS

Bark Volume Determination

At the same time that bark thickness measurements were taken, the log diameter outside the bark at both ends and the board foot scale were also measured and recorded. Diameters were measured with standard log calipers to the nearest tenth of an inch. Board foot volumes were determined with a standard Scribner Decimal C scale stick. The diameter inside the bark (DIB) was readily computed from the diameter outside the bark (DOB) and the bark thickness (BT).

DOB - 2(BT) = DIB

The average bark volume (uncorrected) was determined for each log using the following formulas:

$$\frac{\text{Large end DOB} + \text{Small end DOB}}{2} = \text{Log average DOB}$$

and

$$\frac{\text{Large end DIB} + \text{Small end DIB}}{2} = \text{Log average DIB}$$

The average DOB and DIB were then converted to relative areas of circles. Thus:

Log average cross-sectional area from DOB - Log average cross-sectional area from DIB = Log average bark cross-sectional area

and

Log average bark cross-sectional area x Log length = Log bark volume (Uncorrected)

The above method is basically the same as that described by Meyer (8) and by Dobie (2), although somewhat simplified. The log bark volume as calculated above makes no provision for fissures and voids, and therefore is not a true representation. Subsequent correction for this deficiency was applied. Other studies, such as those of Dost (3) and Lamb (6), have assumed a figure of 21 cubic feet of bark/Mfbm for mixed species without reference citation for method of calculation. Field (4) has similarly used a figure of 1000 pounds of bark per thousand board feet.

Calculation of Void Volume in the Bark Cylinder

The volume of the bark cylinder was determined from measurements taken at the ridges in order to avoid the fissures. This was done to ensure that the measurements reflected an average of the maximum bark thicknesses. As a consequence, the voids created by the irregularities and fissures in the bark had to be compensated for the final analysis.[1] This was done with correction factors determined for each species in the following manner: The logs selected were chosen for maximum variation in bark thickness and diameter. Those with damaged ends were rejected. Profiles of the bark cylinders of 10 to 20 logs per species were traced on paper. Later, in the laboratory, a smooth line was circumscribed around the high points of the bark outline to represent DOB, and a circle (or ellipse, where appropriate) was drawn inside the outline to represent DIB. Figure 2 shows an illustration of the technique. The center was cut out and the outside was cut away so that the resulting ring represented the cross-section area of the bark cylinder. The paper ring was weighed on a small torsion balance to the nearest one hundredth gram. The voids were cut away and the ring which represented the actual bark cross-sectional area was weighed again. The weight lost, i.e. the weight of the voids, divided by the weight of the complete ring (x 100) gave the percentage of voids. For example, the ring from one tracing of a pine log weighed 1.77 grams; after the voids were cut out the ring weighed 1.29 grams, a loss of 27 percent. Therefore the volume of the bark cylinder had to be reduced by 27 percent to get a true measure of the volume of bark present on the log. This determination could, of course, be accomplished from photographs as well as tracings.

For each of the three species considered, the average figures are:

Ponderosa pine	26 percent void volume
Douglas-fir	27 percent void volume
Western larch	28 percent void volume

These figures represent the percentage of the volume of the bark cylinder, as measured, which is actually void. They include not only the fissures in the bark, but also the voids resulting from irregularities in the outline of the wood cylinder itself.

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[1] Chamberlain and Meyer (1) published a further elaboration of Meyer's 1946 study (8), which takes voids and fissures into account. The paper is concerned with cordwood, however, and the correction factors developed are not readily applied to sawlogs.

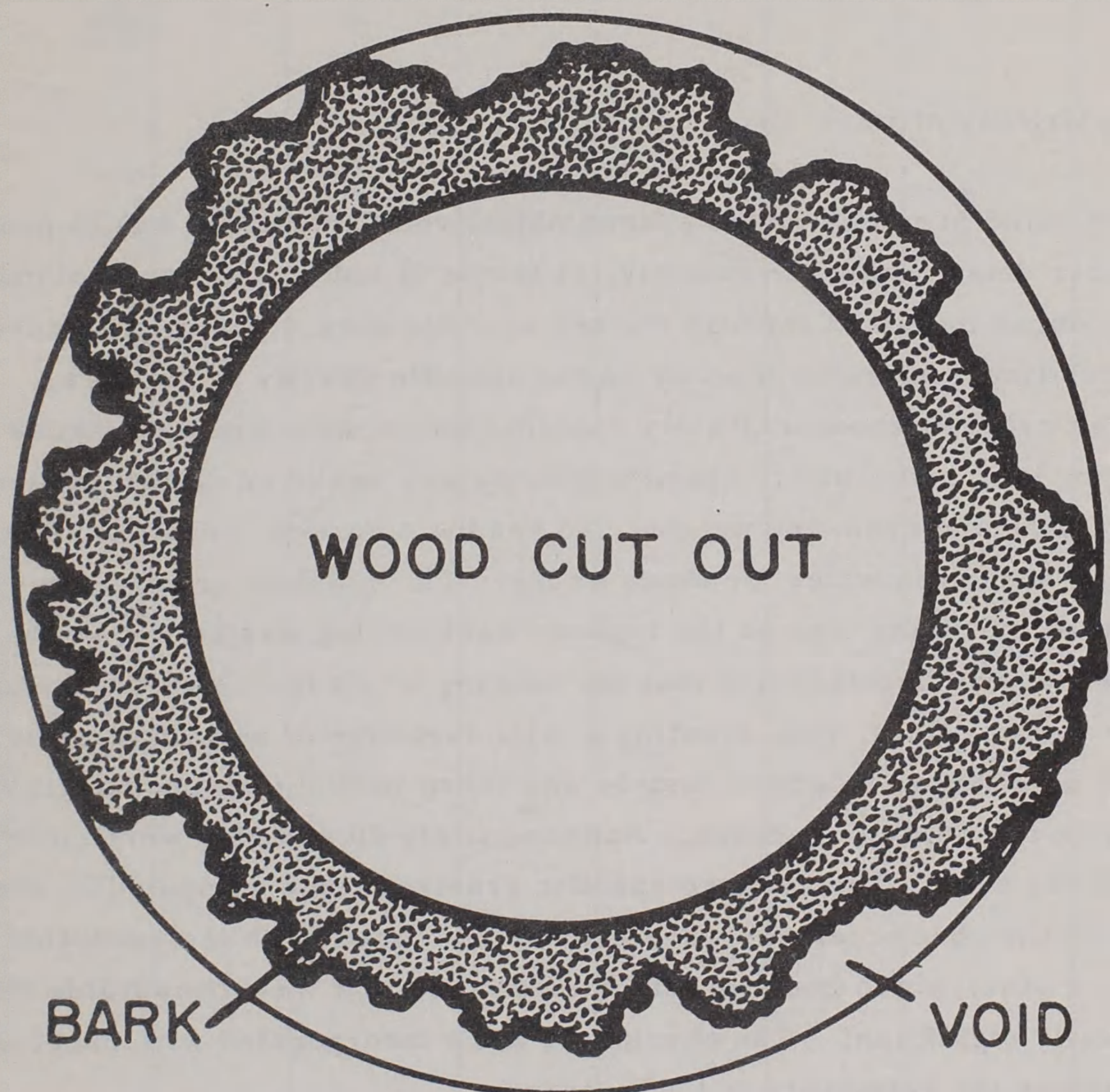

FIGURE 2.- ILLUSTRATION OF SAMPLING TO OBTAIN BARK VOLUME AND BARK VOID VOLUME

Table 2 and the graphs shown in Figures 3 and 4 summarize the corrected data concerning bark volume by species and diameter classes.

Specific Gravity of Bark

As noted previously, the second objective of this study was to provide a method for determining the quantity, in terms of both weight and volume, of bark produced by a mill through the use of scale data. The method developed for calculating bark yield depends on the specific gravity of the bark.

The original specific gravity measurements were made on pieces of bark from 1962 samplings. Specific gravity was based on determinations of green volume and oven-dry weight. To ensure a "green" condition, the samples were soaked in water for three weeks. The question arose as to whether the bark on the living tree or the typical "decked" log was as wet as the soaked samples. It was hypothesized that the soaking might have swelled the bark beyond its normal state, thus creating a false measure of specific gravity. To test this hypothesis, a larger sample was taken to find the specific gravity of the bark in the decked condition. Approximately 40 samples were collected from the log deck. The average specific gravity values computed by the original and by the check methods were exactly the same, with the exception of ponderosa pine, which had swollen by an amount that was measurable but not statistically significant. The check data were incorporated with previous data to strengthen the reliability of their means.

The bulk of the data on log and bark volumes and the specific gravity determinations were made by Lloyd Reesman, John Stephenson, and Tony Carlson while they were students at the University of Montana. The procedure was described in their unpublished paper, "A Preliminary Investigation of Bark Residue in the Missoula, Montana, Working Circle." Eugene Clawson, also a former student, performed the sampling check. Summarized results of the consolidated bark specific gravity determinations are as follows:

Species	Specific Gravity
Ponderosa pine	.31
Western larch	.35
Douglas-fir	.48

TABLE 2

Bark Volume (Cu. ft.)
by Species and Diameter Class

Diameter class		7.6 11.5	11.6 15.5	15.6 19.5	19.6 23.5	23.6 27.5	27.6 31.5	31.6 35.5
Ponderosa pine	Cu. ft. of bark per Mbf scale	51.2	26.2	32.0	23.2	21.6	19.5	19.3
	Cu. ft. of bark per cu. ft. of wood	.234	.192	.201	.162	.158	.146	.119
Douglas-fir	Cu. ft. of bark per Mbf scale	60.3	51.8	41.6	38.5	36.1	43.5	
	Cu. ft. of bark per cu. ft. of wood	.252	.200	.178	.193	.200	.230	
Western larch	Cu. ft. of bark per Mbf scale	41.8	25.7	18.7	14.8	13.6	12.1	9.8
	Cu. ft. of bark per cu. ft. of wood	.213	.149	.122	.107	.105	.096	.105

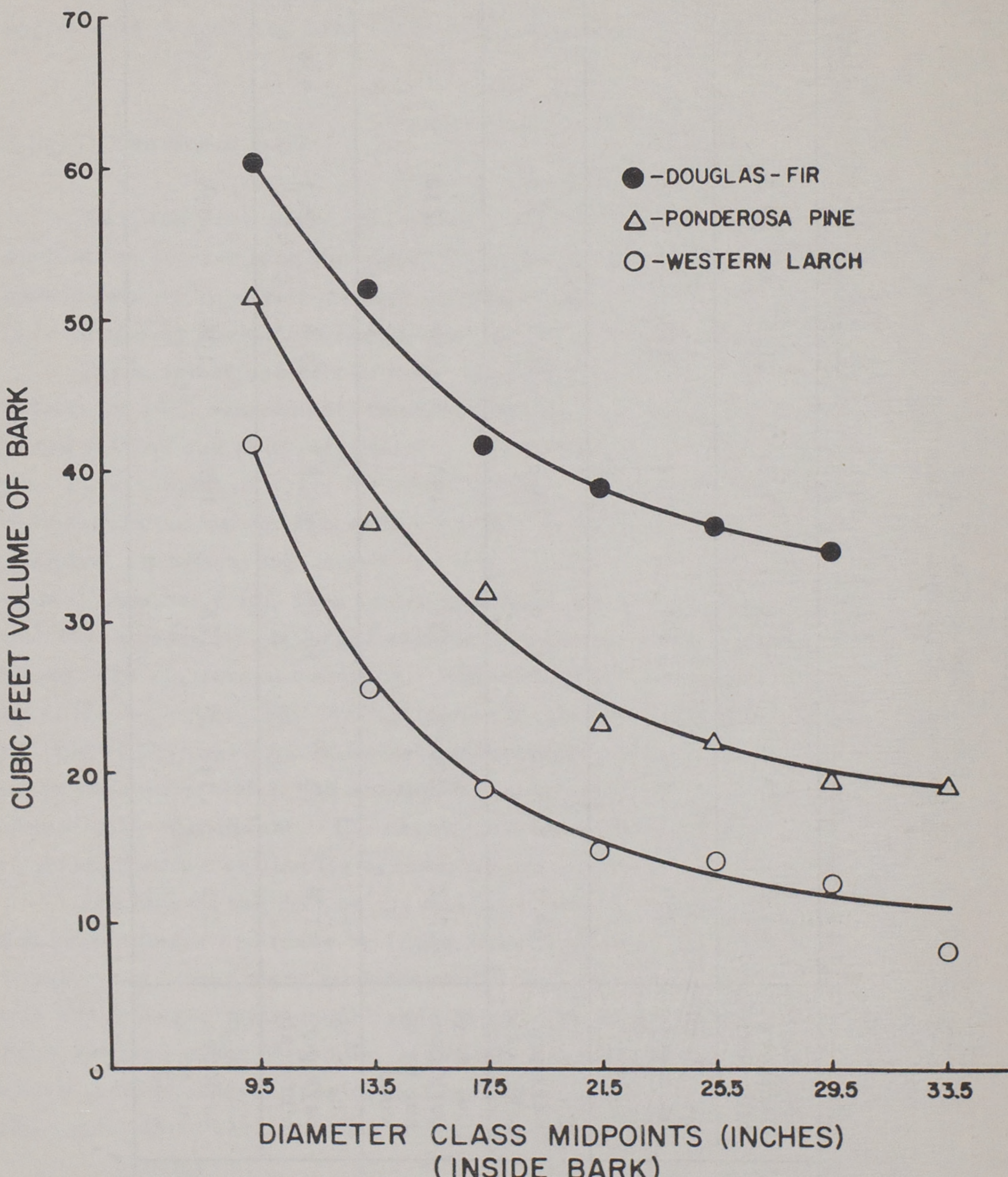

FIGURE 3.-VOLUME OF BARK (CUBIC FEET) PER MbF GROSS LOG SCALE BY DIAMETER CLASSES

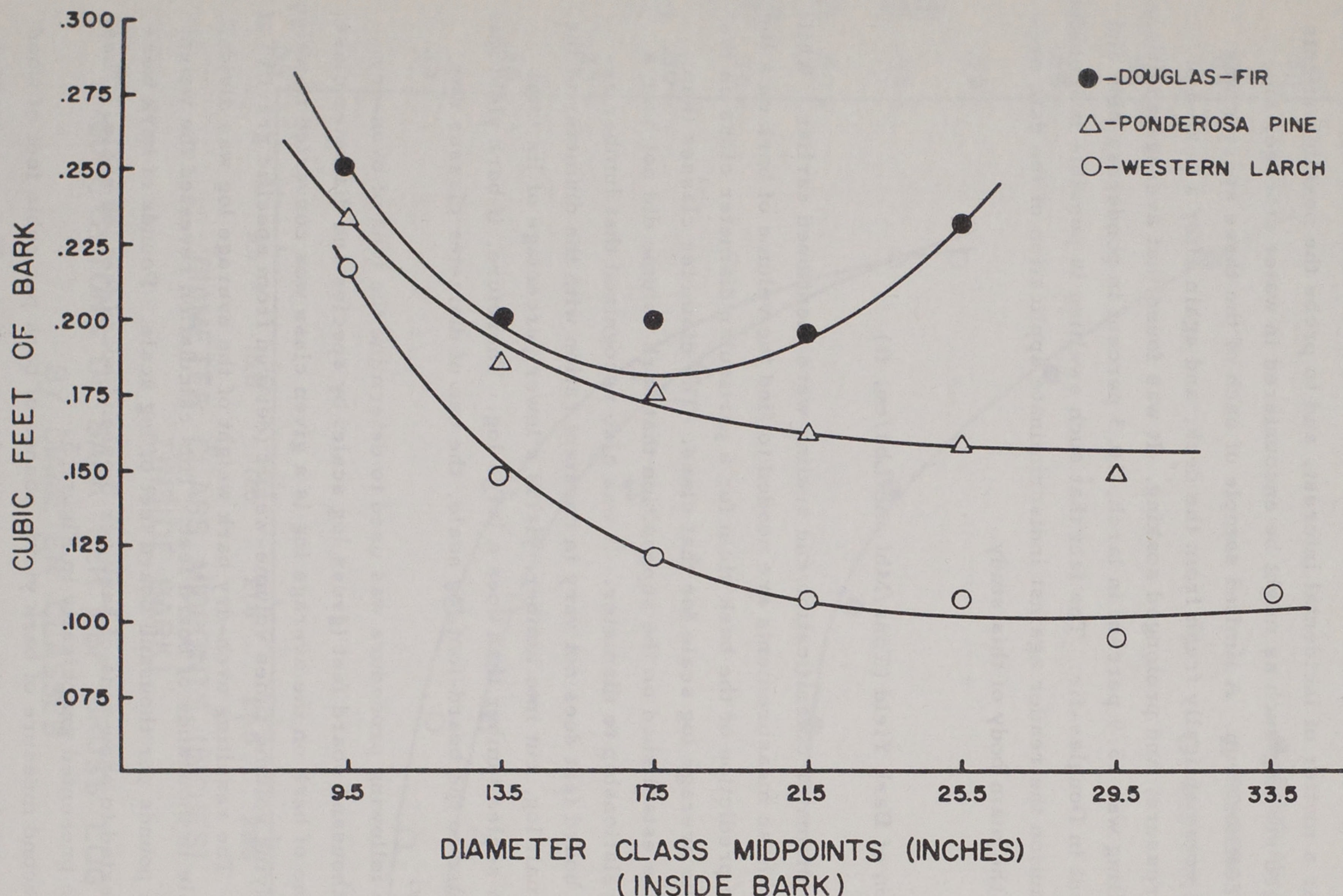

FIGURE 4.-VOLUME OF BARK (CUBIC FEET) PER CUBIC FOOT WOOD LOG CONTENT BY DIAMETER CLASSES

These figures may be considered valid throughout the Missoula working circle. As a matter of incidental interest, and to probe the possible effects of prolonged soaking such as might be encountered in water storage, an auxiliary test was run. A limited sample of each of the three species was measured volumetrically fresh from the deck, and again after a period of vacuum, pressure, and prolonged soaking. It was found that average additional bark swelling was 15.9 percent in larch, 10.3 percent in ponderosa pine and 2.5 percent in Douglas-fir. The fact that such swelling is possible is included here to caution the reader against indiscriminate application of the data presented in the main body of this study.

Calculation of Bark Yield (Tons/Mbf and Lbs/cu. ft)

The diameter classification and scaling were mentioned earlier. While neither of these measurements are needed to find the volume of bark on a log, they allow prediction of the bark yield for a particular diameter class on the basis of the average log scale for that class. The diameter classes themselves were established on the supposition that bark volume did not bear a constant relationship to diameter. It was also recognized that lumber recovery in board feet does not vary in constant ration with the diameter of the log. A small log, cut into lumber, yields a lower percentage of its total volume as scaled lumber than does a large log. Therefore, if bark yield was to be related to the board-foot log scale, the use of diameter classes was necessary.

The following procedure was used to determine the tons of oven-dry bark per thousand board feet (gross log scale) by species and diameter class. The volume of bark on the average log is a given class was converted to weight by multiplying volume times volume-weight (derived from specific gravity) of the bark. The resulting oven-dry bark weight of the average log was divided by its scale in thousands of board feet. This calculation revealed the weight of bark in pounds per thousand board feet of log scale. Pounds of bark were then converted to show tons of bark per thousand board feet log scale. These values are presented graphically in Figure 5.

A second measure of bark yield, pounds of bark per cubic foot of wood by species and diameter class, was similarly computed. The average bark volume of a log in a given class was converted to weight in pounds as described

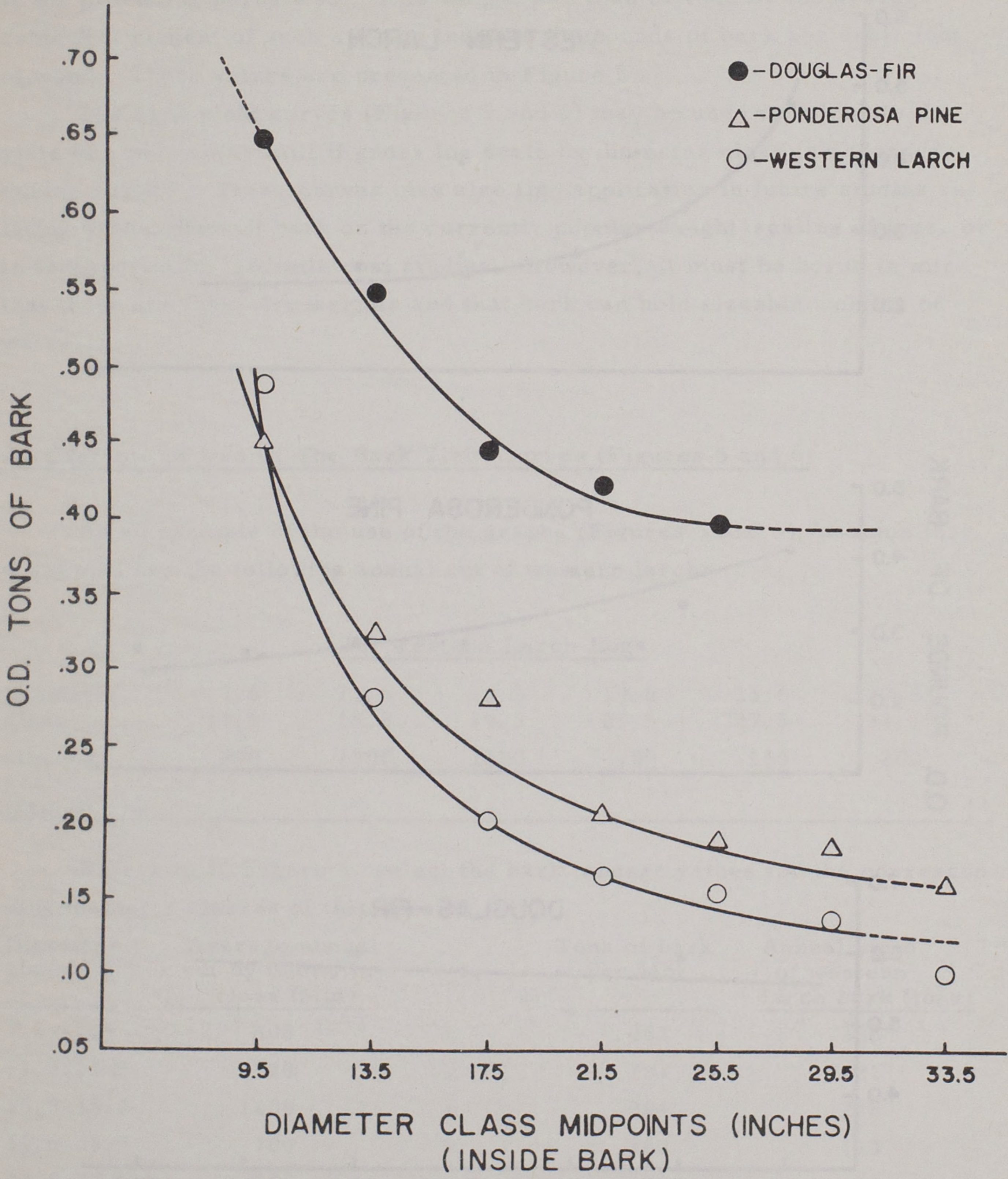

FIGURE 5.-TONS OF BARK PER Mbf GROSS LOG SCALE BY DIAMETER CLASSES

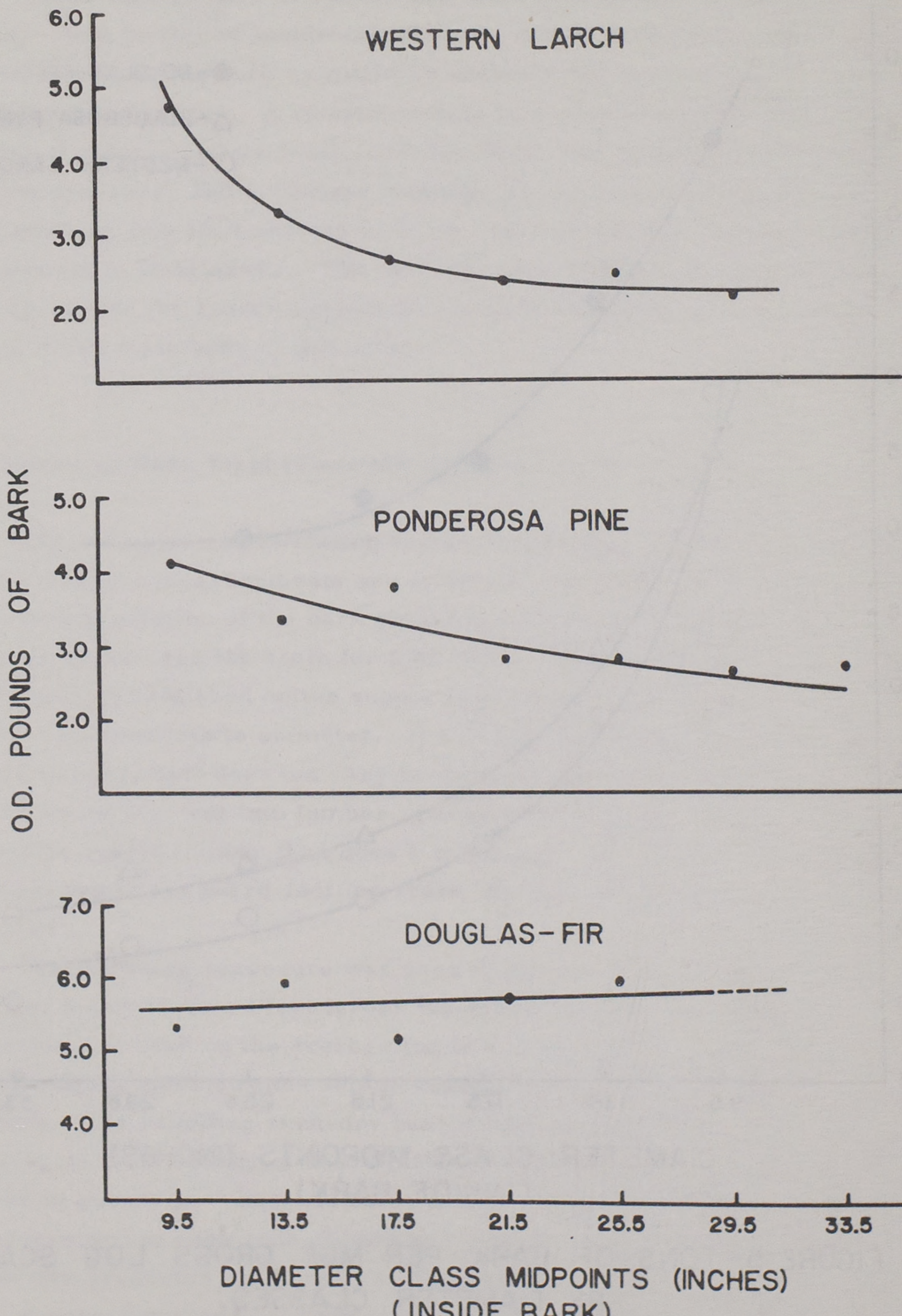

FIGURE 6.—POUNDS OF BARK PER CUBIC FOOT OF WOOD BY DIAMETER CLASSES

in the preceding paragraph. This weight was then divided by the average cubic foot content of such a log to indicate the pounds of bark per cubic foot of wood. These values are presented in Figure 6.

The bark yield curves (Figures 5 and 6) may be used to calculate the yield of a particular mill if gross log scale by diameter class is recorded during scaling. These curves may also find application in future studies relating to the effect of bark on the currently popular weight-scaling of logs, or in transportation ton/mile cost studies. However, it must be borne in mind that these are oven-dry weights and that bark can hold sizeable weights of water.

An Example Of Use Of The Bark Yield Curves (Figures 5 and 6)

As an example of the use of the graphs (Figures 5 and 6), assume that a sawmill has the following annual cut of western larch:

16' Western Larch Logs

Diameter class	7.6 11.5	11.6 15.5	15.6 19.5	19.6 23.5	23.6 27.5	27.6 31.5
Mbf log scale (gross)	800	1500	1200	700	500	200'

Referring to Figure 5, select the bark tonnage values for the corresponding diameter classes of this species.

Diameter class	Average annual cut by diameter class (Mbf)		Tons of bark per Mbf	Annual yield of western larch bark (tons)
7.6-11.5	800	x	.457	366
11.6-15.5	1500	x	.281	421
15.8-19.5	1200	x	.204	245
19.6-23.5	700	x	.162	113
23.6-27.5	500	x	.148	74
27.6-31.5	200	x	.132	26
Total	4900 Mbf		Total	1245 tons

By similarly using the scale data for the other species cut by the mill and the appropriate species curve from Figure 6, the total yield can be found.

The curves allow the mill operator to set up and use any diameter classes he may choose, as long as they begin at 7.6 inches and are in the same scale.

An industry such as the pulp industry, using a cubic measure instead of a board measure, would apply the values from the curves in Figure 6 in computing bark yield. The process would be similar to the board foot calculation and comparable results would be obtained.

Results

The technique for measuring the volume of bark on a log may be applied to any type of bark. Species with rough corrugated bark should have volumes corrected for voids. The method for this procedure that has been described here is applicable to large logs, while the methods described by Meyer (8) and Chamberlain and Meyer (1) may be more suitable for cordwood.

Curves have been established whereby mill operators in western Montana can quickly and easily compute the volume of bark residue they are generating. The curves in Figures 5 and 6 enable the mill operator to estimate his bark volume if the following conditions prevail: (1) gross log scale is recorded, (2) log size (diameter inside bark) is recorded along with the scale, and (3) fir and larch are scaled separately. An example of bark yield computation is given.

The bark yield of seven mills in the Missoula area has been estimated. This estimate was made under less than optimum circumstances, since the three conditions specified in the preceding paragraph are not normally met at present. However, it is felt that the best possible estimate may be of value, if only to point up the magnitude of the quantities involved.

Since the log sources of the mills in the Missoula area represented in the data of this study cover the major portion of western Montana, the data are believed to be valid for the entire area. In case there is doubt that the bark thickness characteristics of logs cut at a particular mill match those of this study, curves are provided (Figure 1) which may be used to compare the study data with local data. If local bark characteristics are not found to match those of Figure 1, then the entire sequence of volume and specific gravity determinations must be performed as described.

Estimated 1964 Bark Yield From Seven Missoula Sawmills

To date, there has not been an estimate of the bark resources of the Missoula area. Lack of accurate data prevents any more than a rough estimate at this time. As mentioned earlier, the mills do not now record gross log scale or average log size. In addition, fir and larch are frequently cut together and sold as a mixture; therefore, separate figures are usually not available for these two species. Since the bark yield varies so widely between species, lack of accurate data for cut and average size precludes anything other than a rough estimate. It is felt, however, that even a rough estimate is better than no estimate at all.

In 1964 the seven Missoula sawmills studies cut by species: ponderosa pine, 90 million board feet; Douglas-fir, 100 million board feet; western larch, 78 million board feet; and minor amounts of other species. Average log sizes varied with species and with purpose of the mill. Generally fir and larch cut for dimension average 13-14 inches DIB at the small end. Fir and larch cut for plywood averaged 14 and 18 inches respectively. Pine cut for shop lumber averaged 18-20 inches, and that cut for veneer averaged 24 inches.

Using the mills' lumber scale figures and appropriate average log size values, the bark yield in 1964 was estimated as shown below:

Species	Tons oven-dry bark	
Ponderosa pine	22, 202	
Douglas-fir	54, 312	
Western larch	20, 640	
Total	97, 154	tons of bark from 268 million board feet

Reducing these figures for a rule-of-thumb average shows that these mills generate approximately 725 oven-dry pounds of bark residue per thousand board feet log scale of materials processed. This is obviously significantly different from the 1000 pound figure of Field (4) and again points out the need for more specific data from different regions. Reference to Figure 3 likewise reveals the possible error of using a general figure, such as 21 cubic feet of bark per thousand board feet, in indiscriminate application. The need for a uniform basis for studies relating to quantitative determination of bark is clearly apparent.

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