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Selected Wood Properties of Eastern Redcedar
(*Juniperus virginiana*, L.)
Grown in Missouri

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ABSTRACT

Selected growth-quality parameters: moisture content, extractables content, specific gravity, and growth rate were measured for eastern redcedar grown in Missouri. Both standing trees (40) and 4" x 6" x 8' cants (78) from butt-logs were sampled for study. An additional 15 trees were used for measurement of moisture content changes in the heartwood and sapwood zones of standing trees over a nine-month period.

Pertinent findings were:

1. Moisture content in the heartwood zone of redcedar varied only ± 2 percent from an average value of 22 percent for 40 trees sampled.
2. Moisture content of sapwood of redcedar trees (15 trees sampled) showed a considerable variation over the nine-month period when samples were taken. The average value was about 105 percent; the range from 56 to 130 percent. Transition from high sapwood moisture content to low heartwood moisture content is abrupt for redcedar. The heartwood zone ranged from 19 to 25 percent for these 15 trees over the nine-month sampling period.
3. Acetone followed by water extractables content of heartwood averaged 6.4 percent and was fairly uniform along the radius for two heights sampled. Sapwood values were significantly lower, averaging 5.4 percent.
4. Considerable variation in acetone extractable content was found within a four-foot bolt of redcedar. In addition, kiln drying was found to significantly reduce the amount of acetone extractables obtained compared to acetone extraction of matched samples of air-seasoned wood.
5. Specific gravity (acetone, then water extractable-free basis) decreased from pith to bark and averaged 0.421 for 40 trees.
6. Rate of growth ranged from 3 to 28 rings per inch and averaged 10 rings per inch for 78 timbers sawed from butt logs. False rings were present throughout heartwood and sapwood zones of all trees examined.
7. Correlations between rate of growth and extractables content, rate of growth and specific gravity, and extractables content and specific gravity were non-significant.

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This bulletin is one of a series on selected wood properties of various commercial wood species of Missouri. The work was undertaken as a part of Project 535, supported primarily by McIntire-Stennis Funds, of the School of Forestry.

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E. A. MCGINNES, JR.¹, AND T. W. DINGELDEIN²

INTRODUCTION

Missouri's commercial forests, which occupy approximately one-third of the state's 45,000,000 acres, are composed predominately of hardwood species. There are four conifers native to the state: shortleaf pine, redcedar, bald cypress, and Ashe juniper (5). The latter is not of commercial importance. Growth-quality studies of native shortleaf pine have been reported previously (3). This study was designed to evaluate some properties of redcedar wood important in the manufacture of novelty items. This wood-using industry has been an important one in Missouri since the early 1940s (4).

There are 17 novelty firms in Missouri which employ 400 people, use 3.5 million feet of cedar annually, and produce an estimated 90 percent of the nation's redcedar novelty items. Redcedar is also utilized in Missouri for manufacturing closet lining and, to a lesser extent, specialty furniture and cedar chests.

The numerous styles of cedar novelties all stem from three basic patterns: the box, the flat plaque, and turned items. Processing techniques may vary with pattern, but each involves sawing of green wood, seasoning, fabricating, finishing, and packaging for shipment.

Redcedar is found throughout the state (5). However, it is most common in the Ozarks, particularly in the Southwestern Ozark region where 67 percent of the total amount used in the state was harvested in 1968 (2). The species is common on many sites throughout Missouri. Redcedar may invade old fields where it is often found with sassafras and persimmon. It is also found in almost pure stands on extremely dry, limestone glade areas (5). These dry sites are usually wet in the spring, permitting the redcedar to produce a fairly wide annual increment.

Redcedar is not listed as a wood of commercial importance on a national scale. As a result, research dealing with the anatomy and fundamental properties of this species is lacking or fragmentary at best. For this reason, basic data on standard indices of wood quality, such as specific gravity and growth rate, were obtained before undertaking studies directly concerned with minimizing various processing problems of redcedar novelty manufacturers. This bulletin presents results of these initial studies on moisture content, extractables content, specific gravity, and growth rate in Missouri-grown redcedar.

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METHODS

Wood-Moisture Relationships

To estimate the moisture content of standing trees, increment cores were removed from 40 trunks at 1-foot and 4-foot heights above ground in September, 1965. These trees were located on the Ava District of the Mark Twain National Forest. In another study, increment cores were taken at breast height from 15 trees in the Cedar Creek District, Clark National Forest, between April and December, 1968. The object of the December core sampling was to observe moisture content fluctuations over a growing season.

Increment cores were placed in plastic straws and immediately stapled at each end to prevent moisture loss. The cores were subdivided into either two-centimeter sections from pith to bark (40 trees from Ava); or into two sections, one all heartwood and the other all sapwood (15 trees at Cedar Creek). "Green" weights of these increment core sections were obtained as soon as possible after extraction of cores from the tree. Storage of cores under refrigeration was necessary in some instances for a maximum period of two weeks. Later tests indicated that storage did not influence results significantly.

Moisture content distribution measurements within cants (4" x 6" x 8') of redcedar seasoning on the yard of one manufacturer were obtained using a moisture meter. These results were checked with those of conventional oven-dry techniques on selected samples. Measurements of the yard-seasoned cants were made at approximately 1-foot intervals on the external surfaces of cants that had been stored for two and five week periods during May and June. These times were representative of the range of cant storage times during the study period. One cant of each storage time period was then band-sawed into 1-inch lumber and moisture readings were taken immediately at 1-foot intervals along the 8-foot length of the sawn boards. In this way, estimation of moisture content distribution within the cant was obtainable.

Moisture contents of novelty components, fabricated novelties, and finished novelties were also measured with the moisture meter. Moisture contents of several warped, returned (reject) novelties were obtained similarly. Thus, representative moisture contents of redcedar wood at different stages, from standing trees to novelty items in use were obtained.

Extractables Content

The extractable, or extraneous, materials content removed from wood is dependent upon several factors; among these are sample form, extracting solvent, and conditions (time, temperature, etc.) of sample exposure to the extracting solvent.

In this study, two types of Soxhlet extraction apparatus were used. One was of standard form and size with an extraction flask capacity of 300 ml. The other was a large, modified extraction assembly (Corning catalog no. 3885, 1967) with an extraction flask capacity of 2,200 ml.

Solvents, sequences of solvents, and extraction times were varied. The solvents used were: methanol, acetone, water, and ethanol-benzene ($\frac{1}{3}$, 95% ethanol— $\frac{2}{3}$, benzene). The solvent sequences were: acetone followed by water or acetone followed by alcohol-benzene and water. Extraction times varied from 24 to 96 hours.

Sample form was also varied in that wiley-milled material (passed 40-mesh but retained on 60-mesh screens) was used as well as increment core segments, or, in some instances, one-inch squares of wood ($\frac{1}{4}$ inch thick along the grain). In addition, heartwood, sapwood, and predominately knotty tissue samples were evaluated for various extractable contents.

The use of a fairly wide range of extracting solvents, sample forms and extraction times provides a good estimate of the amounts of materials removable by various extraction techniques. This work was done to give direction and basic information for further research on the influence of extractables on color properties of redcedar wood.

In all instances reported in this bulletin, samples were oven-dried prior to extraction, and extractable content is expressed as a percentage of this original oven-dry weight. This is because studies dealing with the influence of extractables on color change in redcedar are, for the most part, done on kiln-dried, solid wood. Therefore, the conventional use of "air-dried," wiley-milled material for extractable determinations would not be appropriate.

Specific Gravity

Specific gravity was determined using a modified maximum-moisture content procedure (3). Wood samples were extracted in acetone, then water, prior to measurement of maximum moisture content. Extraction has been found necessary for use of maximum moisture content procedures on some coniferous species (3, 6). Specific gravity estimates were obtained on increment core segments for the 40 trees from Ava at both the 1-foot and 4-foot height levels. Data were later combined as differences between heights did not prove significant.

Growth-Rate

Growth rate determination of redcedar is complicated by the frequent presence of one or more false "rings" formed during a growing season. Estimation of growth rates presented in this study was limited to data from cross-sectional disks removed from the bottom, middle, and top of 78 eight-foot cants of redcedar. These cants were delivered, on the yard, to three novelty manufacturers in the state. Data obtained from increment core measurements were not incorporated into growth-rate estimates presented in this bulletin. Examination of 40 increment cores from standing trees to provide additional estimates of growth rate resulted in significant experimental error. This error was attributed to improper identification of false rings as well as complications in determining ring width, arising from the wavy or convolute pattern of annual growth characteristic of redcedar.

RESULTS AND DISCUSSION

Wood-Moisture Relationships

Redcedar is one of several conifers that has an exceedingly dry heartwood. Data in Figure 1 illustrate this point and show that the variation in heartwood moisture content from pith to sapwood is negligible. Values for the 1- and 4-foot height level samples were combined as differences between heights were not significant.

Sapwood moisture content averaged 106 percent for the time sampled (September, 1965). The transition between a high sapwood and a low heartwood moisture content is abrupt. Similar results for additional redcedar trees obtained over a three-year period substantiate this statement.

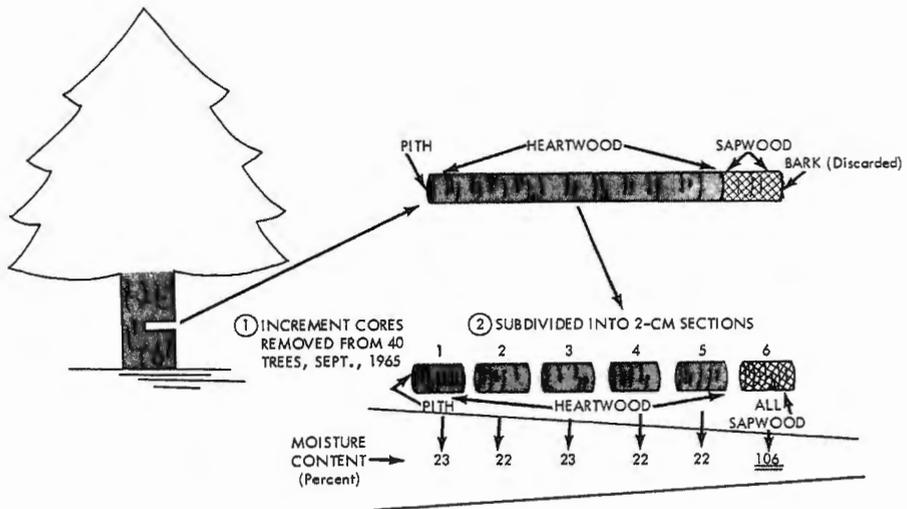


Fig. 1.—Pictorial diagram showing removal of increment cores from redcedar trees, subdivision of cores into 2-cm. segments from pith to bark, and moisture content distribution within heartwood and sapwood zones. Moisture content of sapwood is significantly higher than that of the heartwood.

Moisture content of the sapwood of redcedar varies significantly during the growing season (Figure 2). High and low sapwood moisture contents correlate well with available rainfall data, as might be expected. Although heartwood moisture content shows a similar response, the differences are not significant.

Novelty manufacturers receive most of their redcedar in the form of squared cants, or timbers, usually about 8 feet long. The amount of sapwood varies but is usually quite small. These cants may season on the yard for some time prior

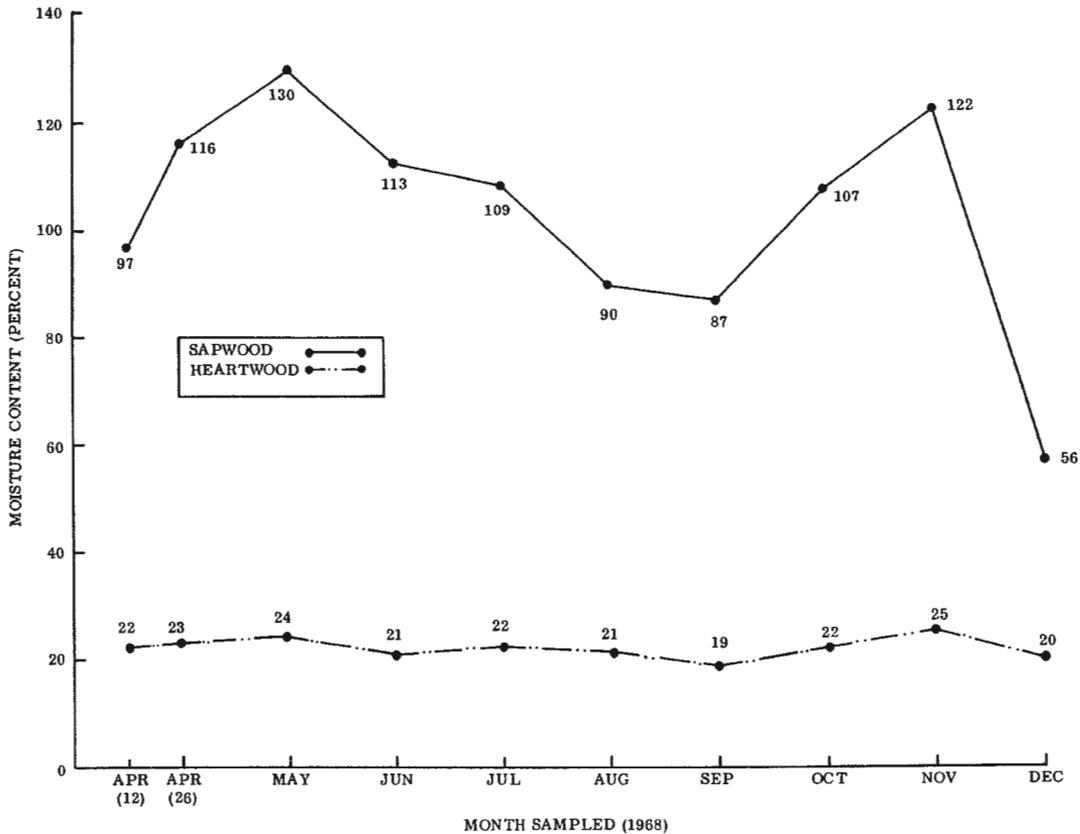


Fig. 2—Variation in moisture content of sapwood and heartwood of 15 redcedar trees over a period of nine months during 1968.

to processing. In this study, the length of time ranged from two to five weeks during dry, summer weather.

Figure 3 shows the distribution of moisture content in a 4" x 6" x 8' timber after two weeks seasoning on the yard. Values shown for board No. 8 are lower than values for the other exterior board (No. 1) because the exterior surface of board 8 was exposed directly to the atmosphere while the under side of the cant was facing the interior of the stack. Figure 4 shows moisture content distribution for a similar timber which had been air-seasoning on the yard for five weeks. Comparison between heartwood of standing redcedar (Figures 1 and 2) and timbers on the yard (Figures 3 and 4) showed that the center of the timber after two weeks seasoning was approximately as wet as when the timber was cut; whereas, five weeks of air seasoning had significantly reduced the moisture content throughout the heartwood zone.

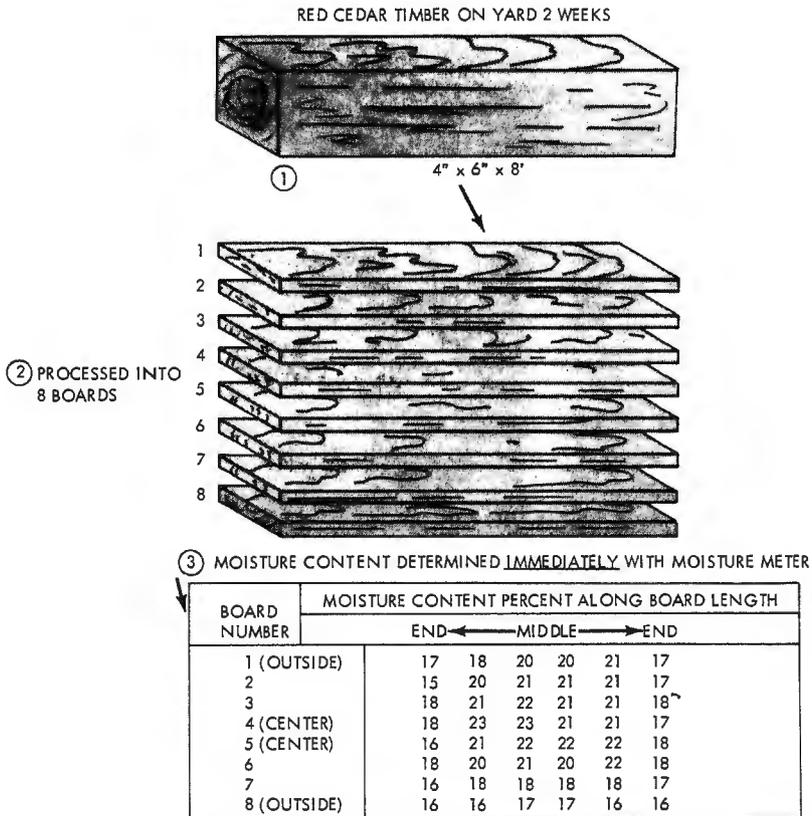


Fig. 3—Diagram showing distribution of moisture content within a redcedar timber after two weeks of air seasoning during summer months.

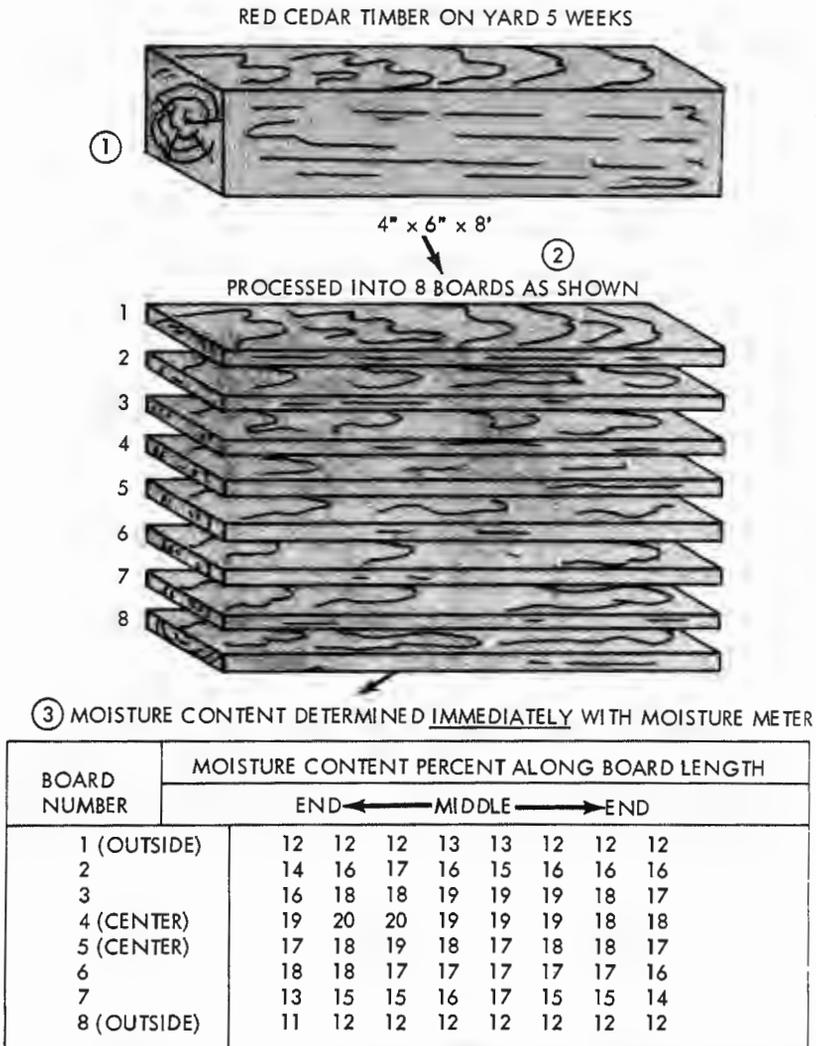
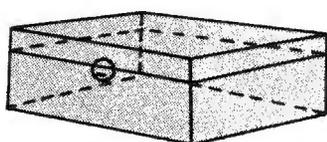


Fig. 4—Diagram showing distribution of moisture content within a red cedar timber after five weeks of air seasoning during summer months.

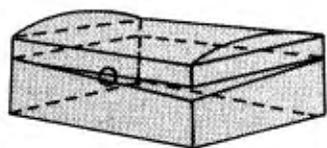
The upper novelty box in Figure 5 shows moisture content ranges for the various box components considered representative of novelty boxes that have been produced from air dried cedar, finished, and placed in storage to await shipment. Values are averages from 20 boxes tested. The lower novelty box in Figure 5 was one rejected in service, after badly warping, presumably due to shrinkage from moisture loss. Moisture content of five such boxes sampled ranged from 6.5 to 7.5 percent. This value could have been lower during service since determinations were made several weeks after the item had been returned to the manufacturer.

These data present a strong case for kiln-drying of redcedar that is to be used in novelty manufacture. The use of the kiln assures: (1) obtaining the generally accepted moisture content range of 7 to 8 percent for novelties and (2) minimizing the range of moisture content values about this selected mean.



BOX
MADE FROM
AIR-DRIED
WOOD

BOX PART	MOISTURE CONTENT RANGE (PERCENT)
Top & Bottom	10 - 12½
Sides	9 - 10
Ends	9½ - 12½



BOX
MADE FROM
AIR-DRIED WOOD
SUBJECTED TO VERY DRY
CONDITIONS IN SERVICE

BOX PART	MOISTURE CONTENT RANGE (PERCENT)
Top & Bottom	6½ - 7½
Sides	6½ - 7½
Ends	6½ - 7½

Fig. 5—Moisture content ranges within novelty box made from air seasoned redcedar compared with moisture content ranges of box subjected to very dry conditions in service. Box size (each instance) is approximately 2" x 4" x 6".

Extractables Content

Of the many tests and measurements of indices of wood quality, perhaps none is as demanding in control of test conditions as estimation of the amount of extractables content in wood.

In this investigation, all values are based on the weight of oven-dried (105° C. as tested with, and comparable to, 65° C., 28 inches Hg) wood. Differences between the two drying conditions on kiln-dried, solid wood were not significant based on 50 tests. This does not imply that values reported represent the *total* quantity of such extraneous substances originally present in the wood. To the contrary, redcedar is an extremely aromatic wood that contains numerous materials which are quite volatile. Substances in this category are lost (at least those located near the surfaces of seasoning wood) by oven-drying prior to extraction. Samples were oven-dried first in this study because: (1) a large number of samples were evaluated and therefore, oven-drying eliminated additional supplementary moisture content determinations; (2) samples selected to be representative of conditions in standing trees, were also used for estimation of original moisture contents and, therefore, had to be oven-dried prior to extraction anyway; (3) it was desirable to compare the amounts of extractable materials present in commercial kiln-dried wood to those in air-seasoned wood; and (4) future studies on the influence of extractables on wood color are to be done on kiln-dried, solid wood as it is used commercially.

Table 1 illustrates the influence of different extraction times for the same solvent and for different solvents and the fact that there is a significant "over-

TABLE 1—INFLUENCE OF EXTRACTION TIME AND SOLVENT
USED ON PERCENT EXTRACTABLES REMOVED FROM
"MATCHED" SAMPLES OF REDCEDAR HEARTWOOD

Sample Form	Solvent	Percent Extractables For Indicated ¹ Extraction Times	
		24 hrs.	72 hrs.
heartwood, wiley-milled, all from same bolt	Acetone	2.08	3.47
	1/3 Ethanol - 2/3 Benzene	2.97	4.14
	Water	3.10	6.23
	sum	<u>8.15</u>	
	Acetone, 1/3 Ethanol- 2/3 Benzene, Water (successive extractions, 24 hours, each)	<u>7.26</u>	---

¹Each entry mean of at least eight determinations

lap" between solvent types in terms of quantity and classes of substances they remove from redcedar. Acetone, alcohol—benzene, and water, used in succession as extracting solvents on wiley-milled wood, removed significantly less than the total for these solvents used individually on redcedar for different time periods. The measured "over-lap" probably exists between the acetone and ethanol-benzene fractions.

The range of acetone extractables present in a 4" x 6" x 8' bolt of cedar and the influence of kiln-drying on acetone extractables content are shown in Figure 6. Acetone extractables content of air-dried (average of 9% moisture) cedar, averaged 3.11 percent ranging from 0.5 to 9.5 percent. Matched samples which were kiln-dried to 8 percent moisture averaged 2.69 percent acetone extractables con-

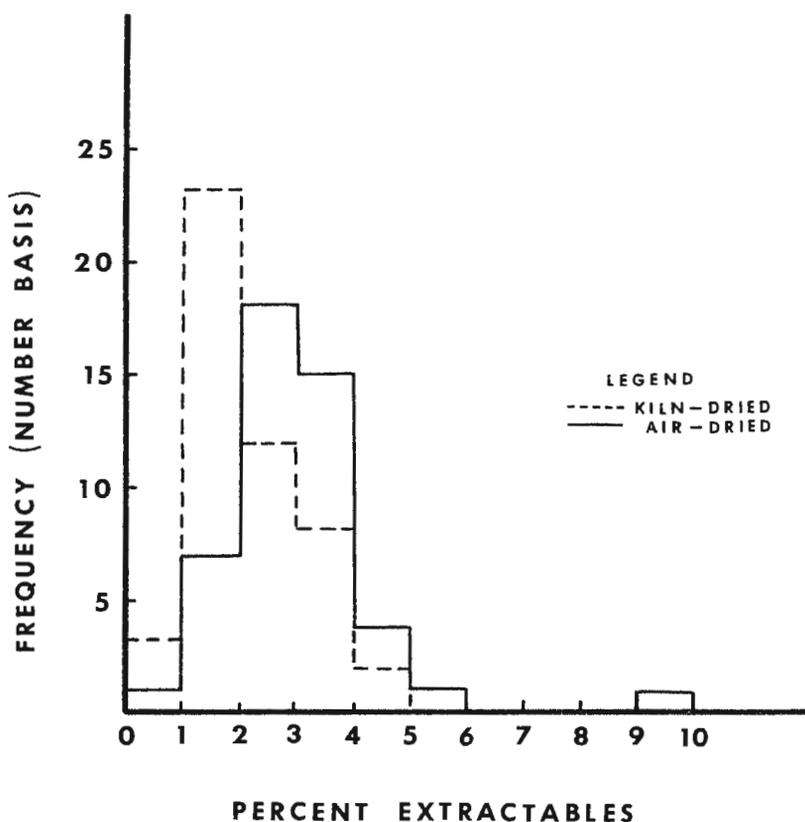


Fig. 6—Frequency diagram showing that kiln-drying significantly reduces amount of acetone extractable material in redcedar heartwood.

tent, ranging from 0.5 to 4.5 percent. In this experiment the bolt was sawed into consecutive $\frac{1}{4}$ -inch thick boards; odd-numbered boards were air-seasoned, and even-numbered boards were kiln-dried. Differences between acetone extractable contents for air-dried and kiln-dried redcedar were significant at the 5 percent level. These data are interpreted to mean that the process of kiln-drying either removes a significant quantity of acetone extractables, or else alters these substances so that they are not removed under the extraction conditions used as compared with air-dried material similarly extracted.

Data presented in Figure 7 indicate that successive extractions first with acetone, then water, remove about the same amount of materials throughout the heartwood (from the pith to the sapwood). This is illustrated for successive 2-cm. sections of redcedar as shown in Figure 7. Sapwood extractables content is significantly less than that of heartwood. This difference, significant at the 5-percent level, is assumed to be caused by a lesser amount of acetone soluble material in the sapwood. The range of acetone, water-soluble extractives in sapwood was from 1.07 to 16.45 percent.

Specific Gravity

Redcedar is not often utilized for purposes where strength is a dominant requirement, or as a fiber or cellulose source, but specific gravity determinations were obtained because such data were not available for Missouri redcedar. Specific gravity does influence shrinkage and is therefore of interest in novelty fabrication.

Specific gravity values for successive 2-centimeter increments from pith to bark are presented in Figure 8. All values are expressed on green volume, and acetone, then on water extracted, oven-dry basis. The trend for specific gravity to *decrease* from pith to bark is of interest as most coniferous trees show the reverse relationship. Data on fiber dimensions (such as length, width, wall-thickness) might explain this rather unusual trend in specific gravity pattern for redcedar, and such a study is planned.

The average specific gravity value obtained for redcedar in this study was 0.421; values ranged from 0.320 (a sapwood sample) to 0.580 (a 2-centimeter increment next to the pith). If values are adjusted for acetone and then for water extractables content, specific gravity estimates determined in this study are comparable to those reported elsewhere (1).

Growth Rate

Estimation of the rate of annual growth of redcedar is complicated by two features for the species: (1) the convolute or wavy configuration of tree growth as seen in cross-section views of the wood and (2) the presence of two or more "false" rings within a true annual growth increment. These two features are readily discernible in Figure 9. Note the numerous false rings throughout both the sapwood and heartwood zones of the tree.

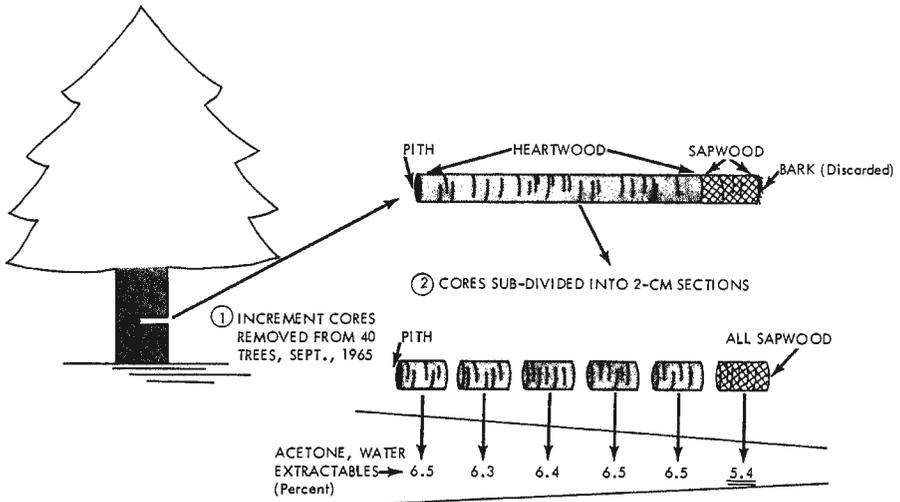


Fig. 7—Diagram indicating acetone-water extractables content of successive 2-cm. increments of redcedar from pith to bark. Sapwood contains a significantly lower quantity of extractables compared to heartwood zones.

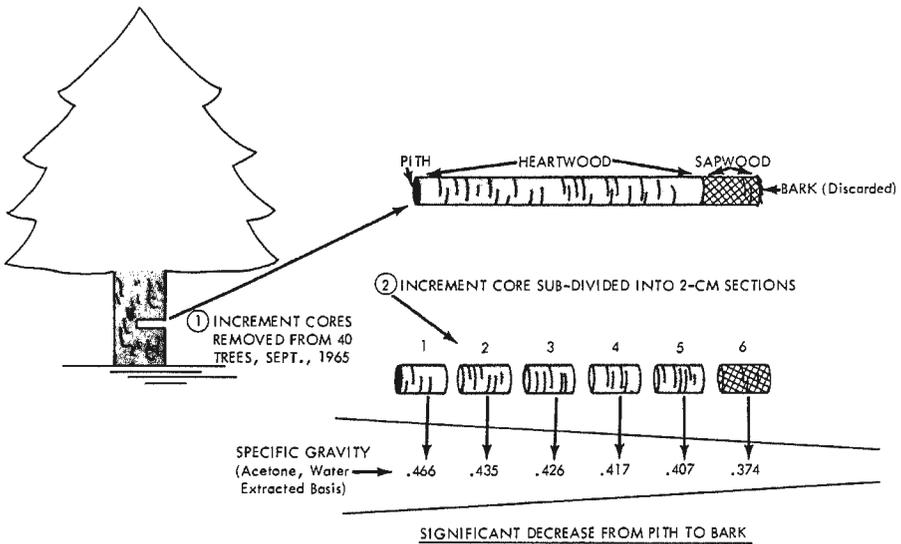


Fig. 8—Diagram showing a significant trend of decreasing specific gravity, from pith to bark, for successive 2-cm. increments of redcedar.



Fig. 9—Cross-section of redcedar. Determination of growth rate is complicated by both the wavy or convolute pattern of growth typical of this species plus the presence of numerous "false" rings formed during the growing season.

The wavy configuration of growth makes measurement of annual increment widths difficult on cores from standing trees. Growth-rate data presented in this study were made on cross-sectional disks as shown in Figure 10. Data in Figure 10 were obtained from 78 eight-foot butt-log cants. Redcedar produces a fairly wide annual increment in Missouri. Data indicate the *usual trend* for growth rate patterns in conifers; i.e., growth rate does decrease slightly with height and

from pith to bark. However, differences either between heights, or along a radius at a given height, were non-significant in this study. This may be due, in part, to the small range of height and diameter growth involved. Average growth rate is about 10 rings per inch. Growth rate ranged from 3-28 rings per inch. False annual rings were quite prevalent; in fact, they were the norm with only occasional samples void of such formation.

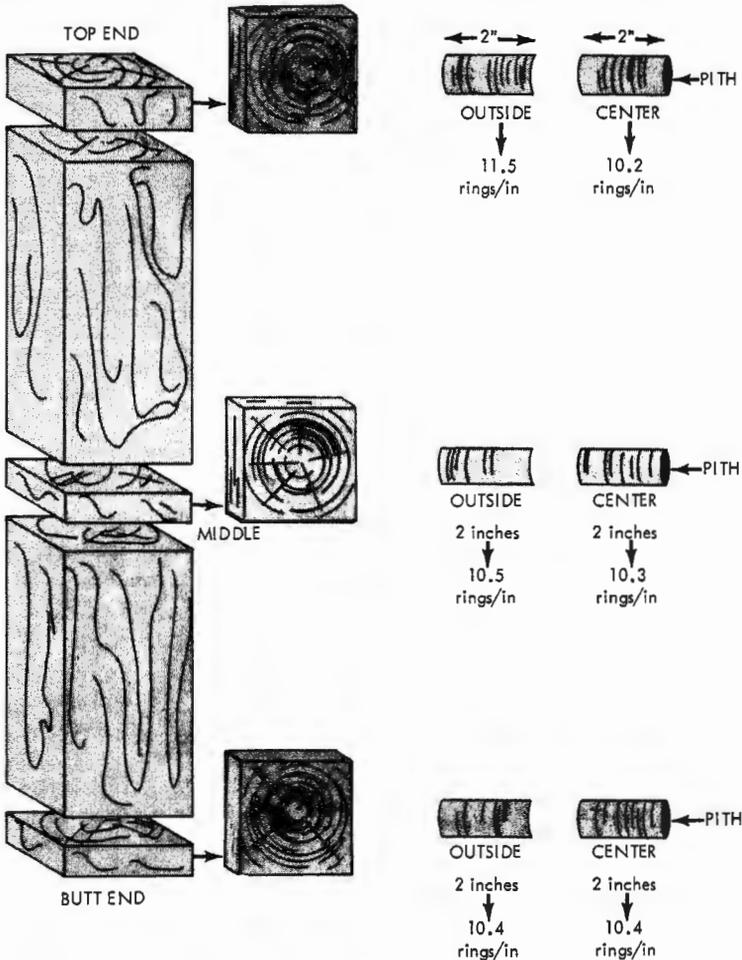


Fig. 10—Diagram showing growth rate pattern within 78, eight-foot butt timbers of redcedar.

CONCLUSIONS

Observations of interest to either researchers in growth-quality relationships of wood, or to users of this species for manufacture of various novelty items, closet lining, or other products include:

1. Redcedar trees have extremely dry heartwood in relationship to other conifers and most hardwood species. Based on data from 40 trees obtained in this study the heartwood zone of redcedar ranged only $\pm 2\%$ (average) along the radius from pith to bark from a mean value of 22%. By contrast, the range for 15 trees sampled over the growing season was 5 percent. Timbers seasoned for 5 weeks during average summer weather had moisture contents ranging from 12 to 20 percent within the bolt. Redcedar can seldom be air-seasoned below 10 percent moisture content, and the use of kiln-drying facilities to season the wood to 7 to 8 percent for satisfactory performance of novelty items is strongly recommended.

These lower moisture content values are particularly important (1) in consideration of the interior humidity conditions both in modern air-conditioned homes and in souvenir or gift shops and (2) under service conditions in hot, dry regions where thin, air-seasoned wood could dry and possibly warp. Of equal importance in using kilns to dry the wood is the ability to minimize the range of moisture content within and between pieces used in box components. Several novelty items made from air-dried wood that were tested in this study exhibited moisture content ranges of 2 and 3% between the box components. This range may be excessive and could lead to warping and splitting of merchandise in service when exposed to extremely dry conditions.

2. The sapwood of redcedar trees is quite wet and moisture content varied significantly throughout the year, based on data obtained in this study. This is presumably due to the amount of available moisture in the soil. The abrupt transition from high sapwood moisture content to low heartwood moisture content is striking. Microscopic investigation of the anatomical structure of redcedar wood plus determination of extractables formation and distribution within the cells in the vicinity of the sapwood-heartwood transition zone may provide additional information on this point. Such studies are being considered for future work.

3. Values obtained for extractables content of redcedar, as with most woods, are greatly dependent upon several test factors. Among these are wood form (solid or ground), extracting solvent, solvent sequence used, extraction time, and the temperature of the solvent in the extraction chamber. Acetone and water following the acetone were used as extracting solvents in this study to facilitate specific gravity determinations using a maximum moisture content procedure. Extractables contents were relatively constant throughout the heartwood zone at the tree heights where samples were taken. The sapwood contained a significantly lower amount of acetone-water extractables; and it is assumed that this

difference between heartwood and sapwood values was due to the greater amount of acetone extractables present in the heartwood.

4. Specific gravity decreased significantly from pith to bark. This is a departure from the normal pattern for within-tree variation of most coniferous species, but is not unique to redcedar. Average specific gravity for redcedar was estimated to be 0.421 on an acetone, water, extractable-free basis. As extractables content averaged about 6.4 percent, data reported should be increased by this amount in order to get specific gravity values approaching the conventional values given for "green" redcedar (1).

5. Average rate of growth for redcedar was 10 rings per inch; however, growth rate was variable and ranged from 3 to 28 rings per inch on the material sampled. False rings were prevalent in the material investigated.

6. Statistical evaluation of data indicated correlations were not significant between rate of growth and specific gravity, rate of growth and extractables content, or specific gravity and extractables content. Coefficients ("r") for the latter two correlations were -0.10 and -0.17 , respectively. These statistical analyses are based on data from 680 samples.

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