THE SIGNIFICANCE OF THE DISCOLORATIONS IN AIRCRAFT VENEERS:

SWEETGUM

October 1942

THIS REPORT IS ONE OF A SERIES ISSUED TO AID THE NATION'S WAR PROGRAM

No. 1376

UNITED STATES DEPARTMENT OF AGRICULTURE
AGRICULTURAL RESEARCH ADMINISTRATION
BUREAU OF PLANT INDUSTRY,
DIVISION OF FOREST PATHOLOGY
MADISON, WISCONSIN
IN COOPERATION WITH THE
FOREST PRODUCTS LABORATORY
FOREST SERVICE

THE SIGNIFICANCE OF THE DISCOLORATIONS IN AIRCRAFT VENEERS:

SWEETGUM

By

THEODORE C. SCHEFFER[1], Associate Pathologist
and
JOHN R. HANSBROUGH, Associate Pathologist

Division of Forest Pathology[2], Bureau of Plant Industry
Agricultural Research Administration
United States Department of Agriculture

Because of the pressing demand for plywood for the construction of gliders and airplanes questions have been raised concerning the strength of discolored wood in aircraft veneers. Miscellaneous discolorations are especially common in hardwoods. Among the latter, sweetgum recently has come prominently into the picture for aircraft construction, and is the subject of the study reported here.

The purpose of the study was threefold: to ascertain (1) the discolorations that are prevalent in sweetgum veneer; (2) the toughness[3] of the discolored veneer in comparison to that of comparable veneer of normal coloration; and (3) the suitability of the discolored veneer, as indicated by its toughness, for use in aircraft. Regarding the last objective it may be remarked that the plywood companies furnishing aircraft parts have had a tendency to reject much discolored stock, on the assumption that the offcolor

---

[1]The writers wish to acknowledge the generous cooperation of the Anderson-Tully Co. and Nickey Brothers, Inc., who aided in the selection of and furnished the veneer for this study. Appreciation is expressed to members of the Timber Mechanics Division of the Forest Products Laboratory, who gave helpful advice on the testing procedure and interpretation of the data and made available the special toughness machine with which the work was done.

[2]In cooperation with the Forest Products Laboratory, maintained by the Forest Service, United States Department of Agriculture, at Madison, Wis., in cooperation with the University of Wisconsin.

[3]Preliminary tests of normal and discolored wood indicate that the toughness of veneer as measured in the intermediate-capacity Forest Products Laboratory toughness machine gives a good indication of any probable reduction in strength properties. It would be desirable to measure other strength properties, but such tests would be too time-consuming to meet emergency needs.

might be a manifestation of decay. Avoidance of excessive rejections on this account may do much toward maintaining a supply of high-grade veneer timber adequate for present emergency needs.

SWEETGUM DISCOLORATIONS

The potentially significant discolorations occurring in sweetgum veneer were ascertained from information gained at four southern veneer plants, one plywood plant, and from an extensive period of research on the control of blue stain in sweetgum lumber. In contrast to certain other hardwoods, the wood of sweetgum was found to have but few types of discolorations, and they are rather irregular in occurrence and intensity. These discolorations are briefly described in the following paragraphs. Their significance in aircraft veneers is discussed on pages 6 to 8.

Figured Heartwood

Figured heartwood cannot be regarded as discolored in any sense implying an abnormal condition. Possibly as much as 85 percent of sweetgum heartwood contains a substantial amount of figure. The localized and rather sharply defined variation in the intensity of the heartwood color, which gives the figured appearance, nevertheless may be considerable (fig. 1) and has led to some questions as to the strength of highly figured heartwood.

Mineral Streak

In sweetgum, mineral streak, sometimes known as calico streak, is most conspicuous in the sapwood. It is a fairly common discoloration and may occur anywhere on the veneer sheet. Mineral streaks appear in variable lengths, from about 1/4 inch to as long as 3 feet (fig. 2). A rather characteristic feature of their shape is the comparatively very narrow width, which ranges from about that of a pencil line to usually not more than about an inch. The streaks follow the grain of the wood and terminate in points, or multiple points in the case of the larger ones. The color of sweetgum mineral streaks is predominantly light rust brown to dark reddish brown. However, greenish shades are common.

Mineral streaks are not apt to be confused with other discolorations after one has seen a number of them. The streaked wood tends to check more readily than bright wood when drying, though this tendency is much less pronounced with veneers than with thicker stock. Many of the streaks, particularly the darkest ones, contain zones that will give off carbon dioxide gas when dilute hydrochloric acid is applied to them. This is evidence of abnormal accumulations of mineral carbonates.

Although mineral streaks are also found in the heartwood, they probably always originate in the sapwood. Most if not all cases are believed to be a result of physiological disturbances created by minor injuries to the sapwood. Bird pecks are a common cause of many of the larger streaks. Possibly the reason mineral streaks are not found more often in the heartwood is that the prevalent figuring of the heartwood obscures them.

Pathological Heartwood

Narrow to broad ribbons of what appears to be heartwood are frequently seen in sweetgum veneer that has been taken from the sapwood of the bolt at a substantial distance from the main heartwood cylinder. For want of a better term this wood will be referred to as pathological heartwood, since most if not all of it is believed to be heartwood that has been formed earlier than normally as a result of injuries to the sapwood. Most pathological heartwood probably connects with the main heartwood cylinder, and represents a localized outward extension of the latter.

Pathological heartwood and mineral streak are sometimes found together, as might be expected if both are initiated by injuries of one sort or another. In fact, areas of pathological heartwood are sometimes closely interspersed with mineral streaks and sometimes even terminate in genuine mineral streaks (fig. 3).

Blue Stain

Blue stain is probably the most conspicuous of the sweetgum discolorations. It is confined to the sapwood and is caused by dark-colored fungi that grow into the wood and utilize the cell contents for their food. Blue stain generally occurs at one end of a veneer sheet, as a solid discoloration terminating in streaks running out into the clear wood (fig. 4, B). In some cases the stain may lie anywhere on the sheet, as elongated, pointed streaks (fig. 4, A). The color is usually bluish gray to steel gray, although brownish hues are not uncommon.

Such blue stain originates in logs that have not been utilized promptly. The causal fungi get in the log through the ends or at the side of the log through barked areas or on the bodies of wood-boring insects. Blue stain is favored by warm weather, and may occur during the greater portion of the year in southern sweetgum areas.

Often decay, though not necessarily visible, may be present with the blue stain, since the same conditions favor both.

Blue stain may be prevented in large measure for as long as 3 to 4 months by spraying the ends of the logs and barked areas with one of the

commercial antistain fungicides.[4] To insure its effectiveness, such treatment should be applied within 24 hours after the log is cut.

Decay

Advanced decay, which is sometimes known as rot or dote, needs little description. However, in its earlier stages decay may be noted simply as a discoloration of the wood. Decay is caused by wood-attacking fungi that are more destructive than those that are responsible for blue stain. Depending on the fungus, the early decay in sweetgum may be observed as a bleaching of the wood or as dull yellowish to brown discolorations. The off-color appearance can frequently be detected by the contrast with adjacent sound wood. In more advanced stages, decayed sweetgum is softer and brashier than the sound wood. Probing, and raising splinters with the point of a knife, will often disclose these differences, although such a test alone is not reliable, particularly if the decay has not progressed very much.

Decay may occur in both sapwood and heartwood. Heartwood decay generally develops in the standing trees, as a result of infection through branch stubs, fire scars, and other wounds. Sapwood decay usually takes place in the log and can be temporarily prevented by spraying, as suggested for blue stain.

TEST METHODS

Selection of Test Sheets

Clear veneer sheets containing representative discolorations were obtained at two plants. Since gum is usually not cut continuously, it was necessary to take mainly stock already on hand, and of two different thicknesses and types of cutting. The veneers selected were as given in the table of results.

The quarter-sliced material represents only a small part of the study and was taken from different parts of the same log. The rotary-cut material was selected at random and in such a way that for the most part each sheet can be considered to have come from a different log.

Preparation of Test Strips

At the Laboratory, the veneer sheets were placed for conditioning to a uniform moisture content in a room with a maintained relative humidity of

[4] See "Cause and Prevention of Blue Stain in Wood," Forest Products Laboratory Technical Note No. 225, rev. Sept. 1941.

65 percent and temperature of 80° F. During conditioning, outlines of the test strips were marked on the sheets with the aid of a template. All strips were laid out on straight-grained areas, and as nearly parallel with the grain as could be determined by eye. Wherever possible, a test strip laid out on a discolored area was matched by a strip laid out on clear wood paralleling the first and closely adjacent to it at the side or end. By such paired matching, the differential influence on the strength of the wood of factors other than those associated with a particular discoloration was reduced to a minimum. In some cases the matching was necessarily limited to groups of test strips within the same veneer sheets. In other cases, such as with all-heartwood and all-sapwood sheets, no matching was possible.

The marked test strips were first sawed out in rough, then machine planed on one edge, and finally carefully sawed to dimensions of 0.5 by 5 inches, ± 0.001 inch. The finished strips, placed upright in open boxes and held apart by the meshing of 0.5-inch hardware screen laid across the top of the boxes, were allowed to remain in the conditioning room for at least 48 hours more. At the end of this time they were weighed to 0.001 gram and measured for thickness to 0.001 inch. These measurements were used in computing the specific gravity. The strength tests were made on the same day as the weighings.

Toughness Tests

The strength of the different classes of veneer was measured in terms of toughness, which in turn is an expression of the inch-pounds of work required to break the test strips by the method used. Toughness is a measure of the ability of the wood to withstand shock, and is a strength characteristic that is most markedly influenced by any abnormalities of the wood structure (see footnote 3, page 1). The toughness tests were made on an impact machine of the pendulum type (fig. 5), which was developed at the Forest Products Laboratory and is especially suitable for handling veneer of moderate thickness. The span used was 2-1/2 inches, with the load applied at the center of the span.

Method of Evaluating Results

In all cases the results were derived as relative values (ratios), based on the toughness of normal wood. In this way the practical significance of the differences obtained can be most readily appraised. When matched pairs of specimens were obtainable ratios of the test results for each pair were computed first, for example, $\frac{\text{blue-stained sapwood}}{\text{adjacent bright sapwood}}$. These individual ratios were then averaged to give a geometric mean ratio.[5] Where matching by pairs

[5] The geometric mean is the n^{th} root of the product of n values. With the present data the geometric means are not much different from those obtained by ordinary averaging. However, with variable ratios, the geometric mean is the only one that expresses the same relative values of two items being compared regardless of which item is used as the basis of comparison.

was not possible the individual ratios were based on the group averages in each veneer sheet of the two items being compared. These sheet ratios were then averaged geometrically to obtain a single over-all ratio. In cases where no matching was possible the actual toughness values were averaged by sheets and the arithmetic mean sheet average was obtained. The respective ratios, then, necessarily were obtained last in each case.

Specific gravities, which were useful in interpreting the toughness data, were summarized in the same way.

TOUGHNESS RESULTS AND CONCLUSIONS

The relative toughness and specific gravity values obtained are listed in the accompanying table. In appraising the toughness results, consideration is given to the reliability of the respective values as well as their relative magnitude. All values less than 96 were examined mathematically to determine the possibility of their having differed from the corresponding control values (100) by chance alone.[6] Where the probability of accidental occurrence appeared to be greater than 1 in 20 the particular value is marked in the table with a double asterisk. No practical need was seen for determining the mathematical significance of values that were above or slightly below 100. The essential results and conclusions for each type of veneer studied are given in the following paragraphs.

Clear Sapwood Adjacent to Mineral Streaks

The sapwood adjacent to 75 areas of typical mineral streak was somewhat tougher than the sapwood in the samples without any discoloration. It is concluded that the proximity of mineral streaks does not reduce the toughness of the surrounding sapwood.

Plain and Highly Figured Walnut-Brown Heartwood

With both groups of plain, walnut-brown veneers the average toughness was less than that of sapwood sheets of the same thickness. The same result was obtained with two of the three groups of highly figured walnut-brown veneers. However, in three of the four cases in which a lower toughness was obtained the average values were not reliably different from 100. Judging from the aggregate result, and the fact that the differences cannot be

---

[6] The mean logarithms of ratios based on matched tests were checked by the standard "t" test of means. Ratios obtained from unmatched tests were checked by the significance of the differences between the actual values on which they were based, using the "t" test for the difference between means.

Toughness and specific gravity of sweetgum veneer test strips

Item tested and collection group	Number of sheets in test	Number of tests	Relative toughness: Quarter-sliced 1/16 inch	Relative toughness: Rotary 1/8 inch	Relative toughness: Rotary 1/16 inch	Relative specific gravity: Quarter-sliced 1/16 inch	Relative specific gravity: Rotary 1/8 inch	Relative specific gravity: Rotary 1/16 inch
			Percent	Percent	Percent	Percent	Percent	Percent
Sapwood								
Clear; no defects on sheets								
Collection group 1	14	45	*100			100		
Collection group 2	17	165		*100			100	
Collection group 3	7	75			*100			100
Collection group 4	3	34		*100			100	
Clear, but adjacent to mineral streaks								
Collection group 3	6	75			111 1/			104
Heartwood								
Plain walnut-brown								
Collection group 2	2	50		**82 1/			110	
Collection group 3	11	130			96 1/			108
Walnut-brown, highly figured						108		
Collection group 1	14	43	109 2/				112	
Collection group 2	8	69		**94 1, 3/				102
Collection group 3	11	147			**83 1/			
Gray, brown, highly figured								
Collection group 3	5	144			504 1/			104
Mineral streak								
Greenish-brown to greenish-gray color; in sapwood								
Collection group 2	3	16		91 3/			103	
Rust to dark brown color; in sapwood								
Collection group 2	6	22		94 3/			117	
Collection group 3	6	37			87 3/			109
Rust to dark brown color; in figured heartwood								
Collection group 3	11	24			88 4/			107
Rust-colored, interspersed with gray pathological heartwood; in sapwood								
Collection group 3	5	20			96 3/			110
Pathological heartwood								
Gray-brown color; in sapwood								
Collection group 3	4	16			96 3/			106
Blue stain								
Collection group 1	6	17	71 2/			92		
Collection group 2	8	48		91 3/			97	
Collection group 4	3	34		81 2/			98	
Early decay, or "dote"; in sapwood								
Collection group 1	9	17	74 2/			94		

1/ Ratio of $\frac{\text{average item toughness}}{\text{average sapwood toughness}}$. Values for the heartwood and sapwood necessarily were obtained from different veneer sheets; hence only a single ratio was obtained in each case, based on the average toughness of all sapwood sheets in the collection group.

2/ Geometric mean of the ratios of $\frac{\text{item toughness}}{\text{sapwood toughness}}$. The individual ratios were obtained for each sheet and were based on the sheet averages for item and sapwood.

3/ Geometric mean of the ratios of $\frac{\text{item toughness}}{\text{sapwood toughness}}$. The individual ratios were obtained for each pair of tests of closely side- or end-matched samples.

4/ Same as footnote 3, except based on heartwood toughness.

* The average actual toughness and specific gravity values for the sapwood control specimens were:

Group	Type of material	Thickness	Specific gravity	Toughness
		Inch		Inch-pounds per specimen
1	Quarter-sliced	1/16	0.425	1.66
2	Rotary-cut	1/8	.458	5.07
3	------do----------	1/16	.511	2.74
4	------do----------	1/8	.543	8.00

**May differ from the corresponding sapwood value by chance only; at least the result is not mathematically significant at the 5-percent probability level.

Z M 42886 F

explained by the respective specific gravities, it is concluded that walnut-brown heartwood, which is the most representative type of sweetgum heartwood, may in general be somewhat lower in toughness than sapwood. But if so, the difference is probably not of practical significance. Moreover, there is nothing in the results that would lead one to suspect that the figured heartwood is any weaker than the plain heartwood.

Of possible interest, but having no bearing on the practical aspects of the results, was the finding that the wood associated with the darkest areas of the figured heartwood clearly was about 10 percent lower in average toughness than that associated with the lightest areas.

Highly Figured Gray-Brown Heartwood

A number of samples of figured heartwood veneer were obtained in which the general coloration, although brown, was of a decidedly grayish cast. The contrast between the lightest and darkest areas was unusually pronounced, with a tendency for the common boundaries to be a deep gray. The general appearance was slightly suggestive of wood containing some decay infection except for the fact that the particular effect was too uniformly distributed over the sheets. Nevertheless this veneer was being sorted out and packaged with lower-grade stock.

The toughness of this veneer was surprisingly high, being at least five times as great as that of the sapwood. In fact, more than half of the test strips could not be broken in the machine.

Without testing a larger number of samples one cannot conclude that all sweetgum heartwood having substantially less than the usual brown color would tend to be tougher. However, one might tentatively consider it to have at least ordinary toughness.

Mineral Streak

The toughness of the veneer having mineral streak was reliably reduced in all cases by amounts between about 4 and 13 percent. The degree of toughness reduction was not noticeably related to the color of the streak or to the fact of whether it was in heartwood or sapwood. Considering the fact that the chance for the occurrence of contiguous mineral streaks in the plywood layers is small, unless a comparatively large amount of it is concentrated on the sheet mineral streak should not be regarded as hazardous in aircraft sweetgum veneer. In line with the observed accumulation of minerals in many mineral streaks, it is interesting to note that the specific gravity of the streaked wood in all cases averaged higher than that of the adjacent wood.

Pathological Heartwood

The toughness of pathological heartwood appears to be little if at all lower than that of sapwood, even though it contains a small amount of mineral streak.

Blue Stain

The blue-stained sapwood was variously reduced in average toughness by between about 9 and 29 percent. Such reductions are fully in line with those obtained in previous tests made on blue-stained wood of larger dimensions.[7] A few streaks of blue stain in the veneer should be no cause for concern. However, since conditions that favor the development of blue stain also favor decay, heavily stained veneer should be examined with special care for any evidence of decay before accepting it for use in aircraft.

Decay Discolorations

The adverse influence of decay fingi on the strength properties of wood is so well established that only a small amount of veneer containing incipient decay that might escape visual inspection was included in this study. The toughness of this infected veneer was about 26 percent less than that of the adjacent sound wood. Even in the early stages of decay, shock resistance, of which toughness is a measure, is nearly always reduced and to a larger degree than other strength properties. To be on the safe side, veneer containing any amount of decay whatsoever should be trimmed out of sheets to be used in aircraft.

SUMMARY

Highly figured heartwood was fully as high in toughness as the plain heartwood. Mineral-streaked and blue-stained veneer was not as tough as comparable veneer without discoloration. However, these discolorations should not be objectionable in aircraft stock except possibly in certain cases where a large amount is concentrated on the sheet. Since conditions favoring blue stain also favor decay, heavily blue-stained veneer should be examined with particular care to see that no decay is present. Veneer containing decay, even in the early stages when it may be evidenced mainly by a discoloration of the wood, should be trimmed out of sheets to be used in aircraft. Early-decay discolorations in sweetgum are usually dull yellowish to brown or, by some fungi, a bleached appearance may be imparted to the wood. With a little experience, brownish decay discolorations are not apt to be confused with mineral streak.

[7] Chapman, A. Dale, and Scheffer, Theodore D. Effect of blue stain on specific gravity and strength of southern pine. Jour. Agr. Res. 61: 125-134. 1940.

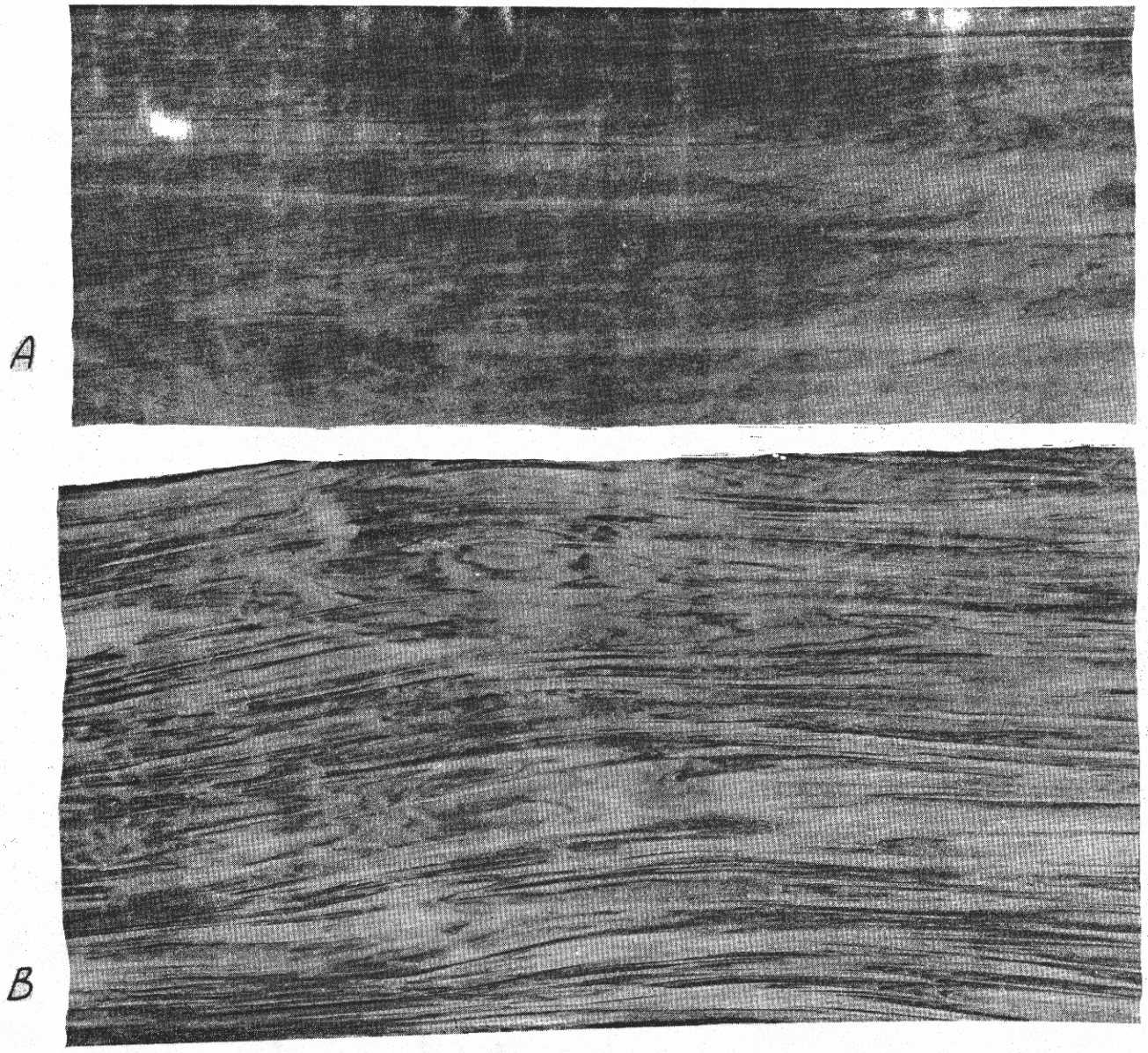

Figure 1.--Rotary-cut veneer, showing (A) plain heartwood and (B) highly figured heartwood of sweetgum.

ZM 42768F

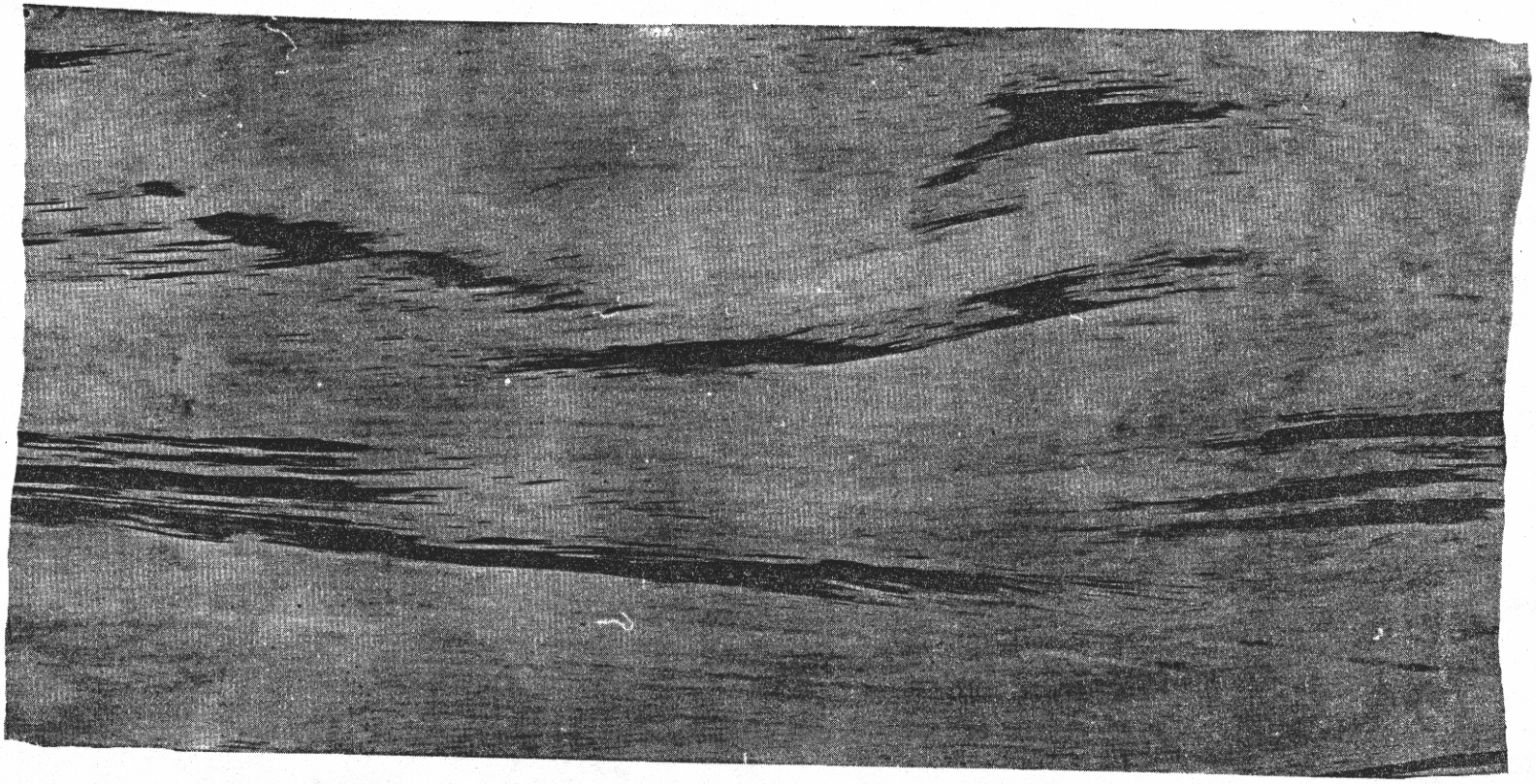

Figure 2.--Rust-brown mineral streak in the sapwood of rotary-cut sweetgum veneer.
ZM 42764F

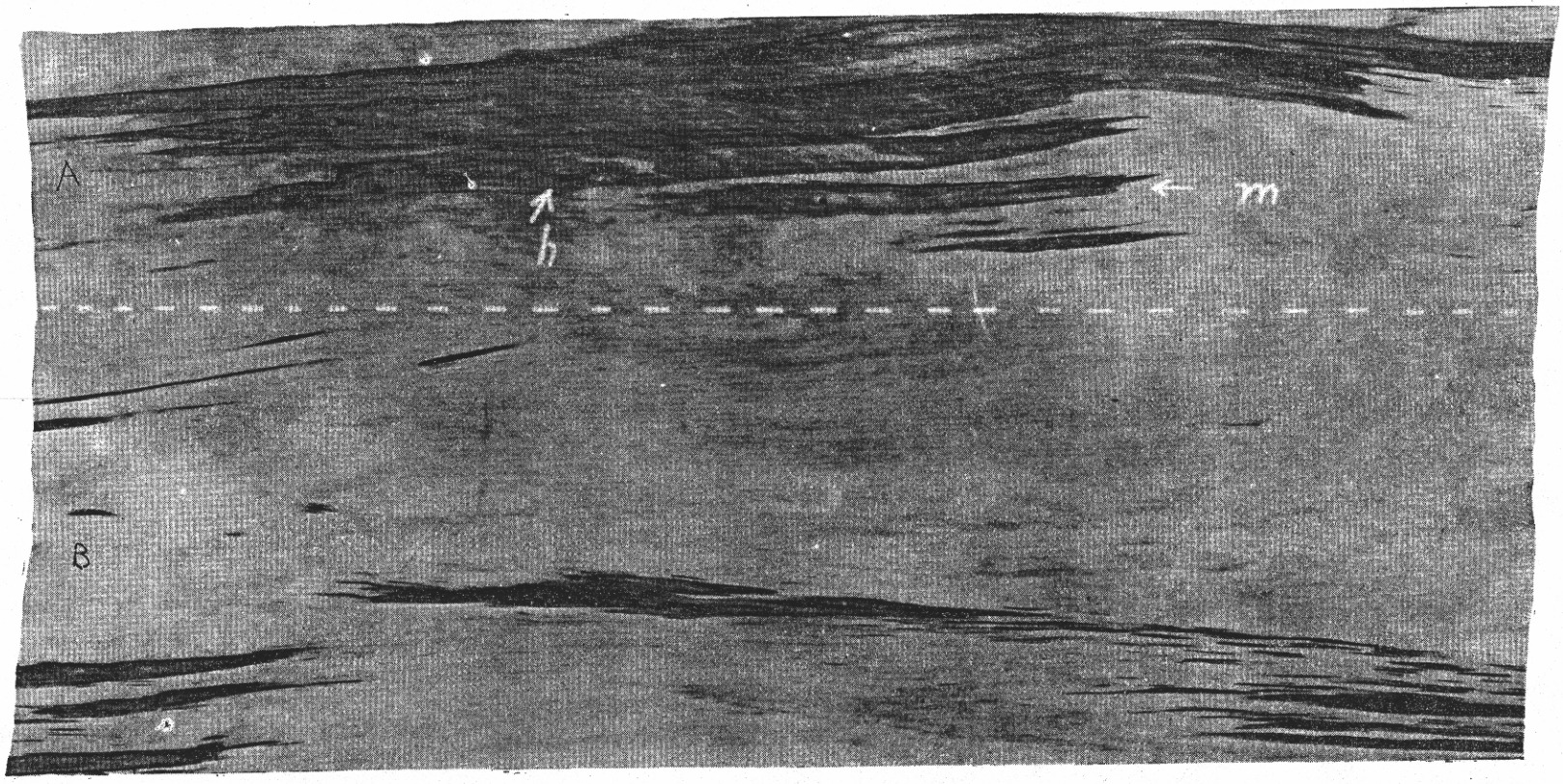

Figure 3.--Pathological heartwood and rust-brown mineral streaks on the same rotary-cut veneer sheet. A, the (h) lighter portions of the darkened wood are pathological heartwood and the (m) darker portions near the ends are typical mineral streaks. B, mineral streaks only.

ZM 42767F

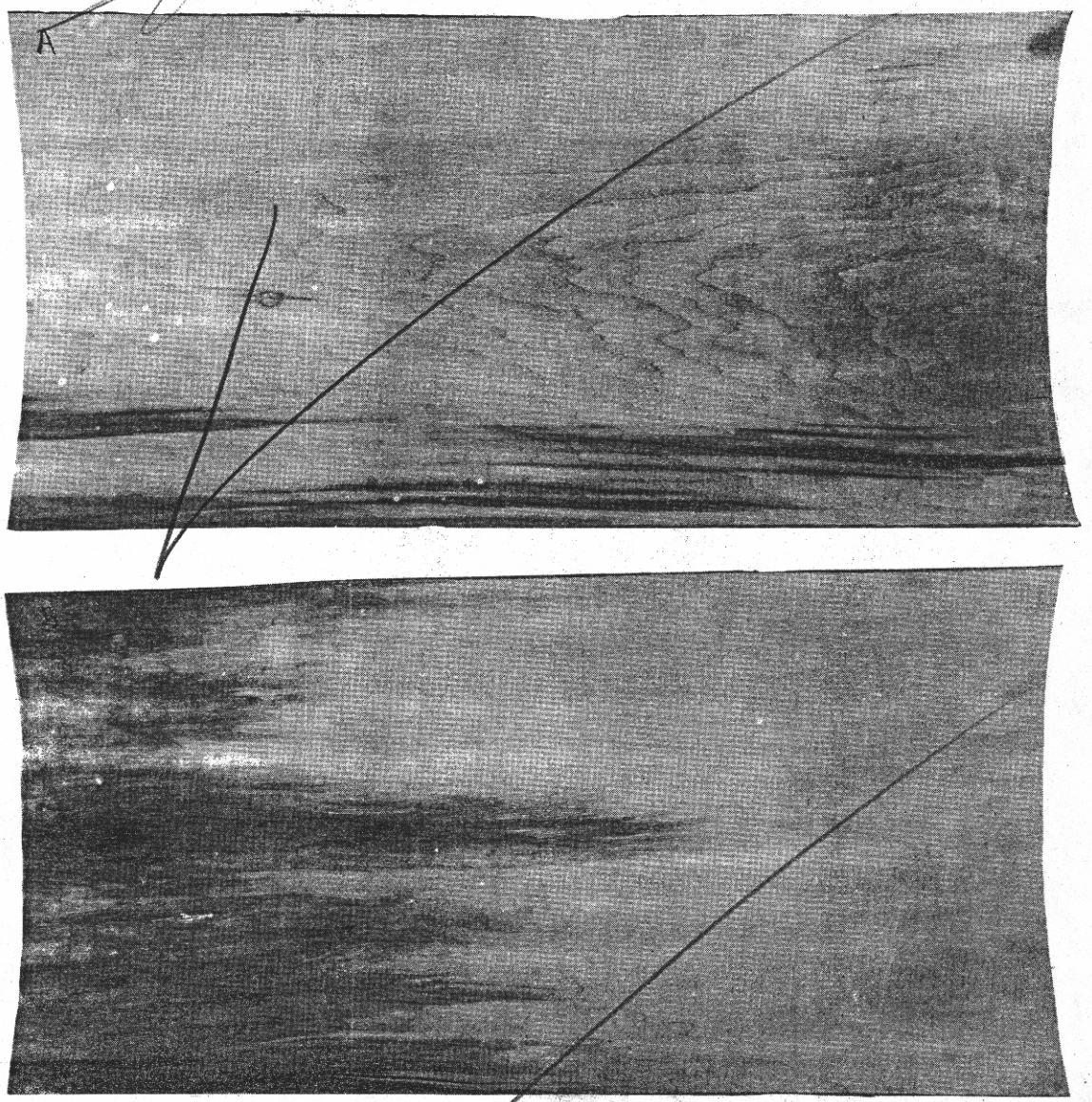

Figure 4.--Blue stain in the sapwood of rotary-cut sweetgum veneer. A, stain resulting from fungi carried into the log by ambrosia beetles; B, stain that originated at and developed inward from the end of the log.

ZM 42765 F

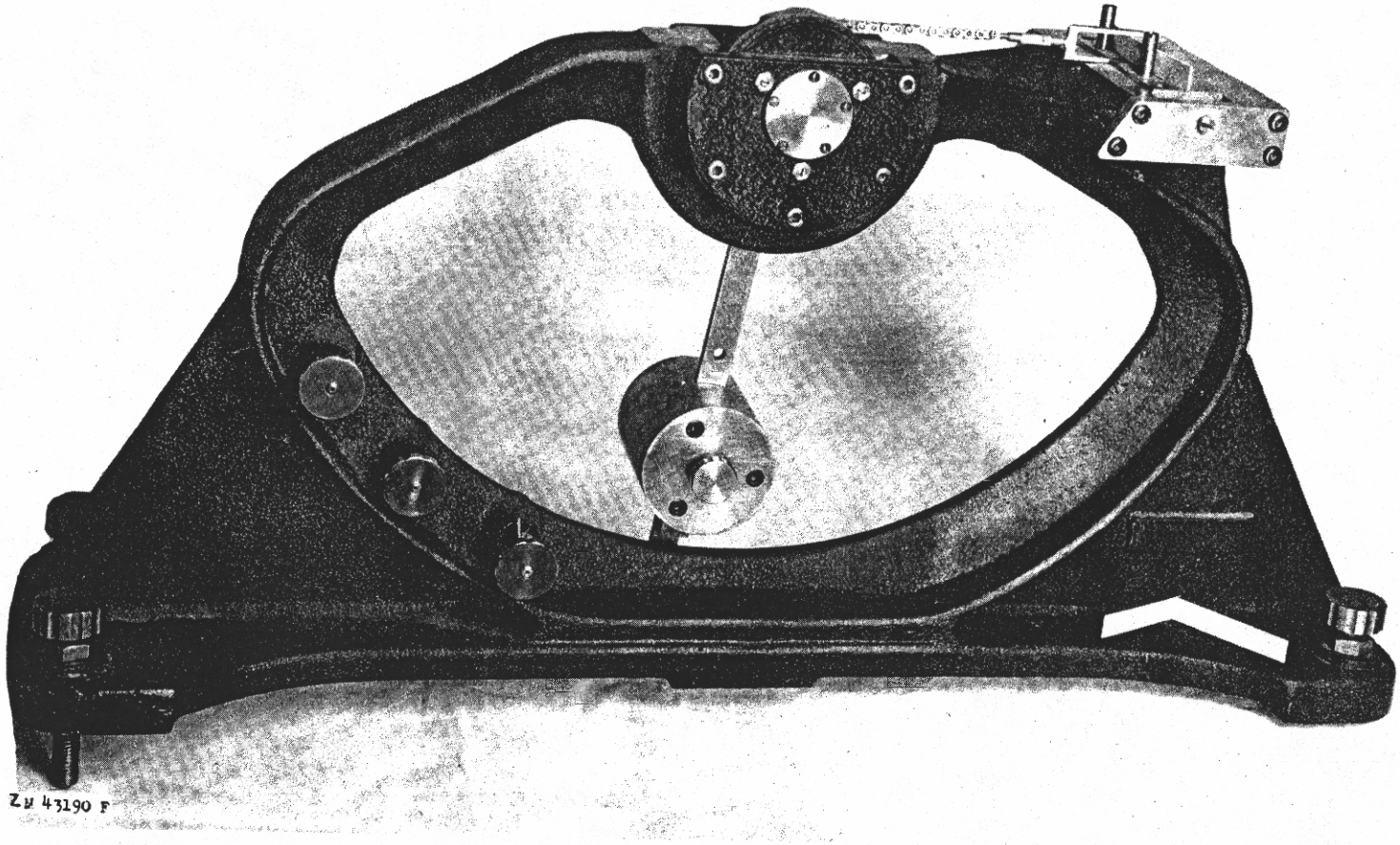

Figure 5.--Machine used for determinations of the toughness of sweetgum veneer.