CHEMICAL STAIN IN NOBLE FIR AS RELATED TO STRENGTH

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CHEMICAL STAIN IN NOBLE FIR AS RELATED TO STRENGTH[1]

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Summary

Noble fir often becomes stained during the drying process. This stain, known as chemical stain, may be present in many boards and may affect all or only a portion of individual boards.

The chemical stain or discoloration is apparently caused by colored materials that are present in the wood and are carried toward the surface during the drying process. It has a reddish-brown color, is rather non-uniform or mottled in appearance, and frequently continues for the full length of a board, often covers only a portion of the width, and usually extends only about 1/8 inch in depth. Apparently only the sapwood becomes stained during drying.

The results of strength tests indicate that no distinction need be made between noble fir that has become stained during drying in accordance with Army-Navy Aeronautical Specification AN-W-2a and unstained material.

Purpose

In the drying of noble fir lumber, a part or all of the surfaces of many boards may become discolored. Such discoloration is known as chemical stain, and it has been the cause of considerable concern to inspectors of wood for aircraft.

It is the purpose of this investigation to determine the effect of chemical stain on the strength properties of noble fir.

Cause and Description of Chemical Stain

The discolorations are apparently caused by colored materials that are oxidation products of the water-soluble cell contents carried by bulk

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[1] This mimeograph is one of a series of progress reports prepared by the Forest Products Laboratory to further the Nation's war effort. Results here reported are preliminary and may be revised as additional data become available.

sap movement toward the surface. The colored materials or extractives seem to be deposited in the zone where the moisture changes from water to vapor. As there can be no liquid movement in wood with moisture content below the fiber saturation point value,[2] it follows that the distance from the surface to the zone where the water changes into vapor depends on the moisture distribution.

Factors that tend to keep the surface moist tend to bring the discolored zone toward the surface. The factors having this effect include: a large amount of water in the wood, a high rate of moisture movement, a high relative humidity, a slow rate of air circulation, and high drying temperatures. If the surface of the lumber is quickly dried to a low moisture content, the zone where the liquid movement stops is below the surface and if the zone is sufficiently deep the surface is not discolored by the concentrated extractives. That different combinations of drying factors affect the degree of chemical stain is indicated by the fact that certain rather well-defined areas, such as those under the sticker pieces used in piling lumber for drying, may be relatively free of discoloration (fig. 3).

The chemical stain here referred to has a reddish-brown appearance. It does not appear as a solid color, in fact, it is usually rather nonuniform in distribution. It often continues from end to end of the board, but may not cover the entire width. On an edge-grained board, there may be a sharp line of demarkation (fig. 4), indicating that all portions of the tree are not equally susceptible to chemical stain. On the basis of present knowledge, it appears that only the sapwood becomes stained during drying.

The discoloration in the material from which test specimens were obtained did not penetrate very deeply and in many boards could be entirely removed by planing off 1/8 inch of material.

Figure 5 shows additional samples of discolored noble fir of somewhat greater length than that illustrated in figures 3 and 4. Board A of figure 5 is not truly edge grained and the discoloration is more or less uniform over the entire board; board B has rather pronounced gradations of color, but no definite limits; boards A and B are all sapwood; board C shows a definite line of demarkation extending the full length with the portion to the left (sapwood) chemically stained throughout while the portion to the right (heartwood) contains no chemical stain.

It is often difficult to distinguish between the sapwood and heartwood of noble fir. When there is a color distinction the heartwood is usually of a very pale purplish hue, particularly near the sapwood, while the sapwood is lighter in color and may have a slightly reddish tinge.

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[2] The stage in the drying or in the wetting of wood at which the cell walls are saturated and the cell cavities are free from water.

Description of Material

The material used for tests was nominal 2-inch stock that varied in width from 4 to 8 inches and varied in length from 8 to 12 feet. Nearly all of it was edge grained. It was commercially kiln dried in accordance with Army-Navy Aeronautical Specification AN-W-2a. The material selected for test was from a carload consigned to an airplane factory. The consignee reported that 60 percent of the material contained chemical stain.

Of 150 to 200 boards examined by a Forest Products Laboratory representative about 60 showing the greatest amount of chemical stain were selected for test.

Marking, Matching, and Conditioning of Specimens

All boards from which test specimens were cut were edge grained. The material was of nominal 2-inch thickness, and since the stain occurred only near the surface, material for 1- by 1-inch unstained control specimens was available from the central portion of the thickness. These control specimens were matched end to end with the stained specimens as shown in figure 1. In cutting out the stained specimens, one surface was planed only enough to smooth it, while the other surface was cut away sufficiently to obtain the desired thickness.

The method of cutting out specimens and marking is shown in figure 2. To obtain a wide representation of material for a limited number of tests, since many boards were only 4 inches wide and since the stain was limited in extent, only the heaviest stained 2-inch portion of the width of each board was utilized. Not more than one set consisting of five stained and five control specimens was obtained from each board. The stained portion of some boards was not sufficient to provide even 2-inch widths of stained specimens.

Before testing, all specimens were conditioned to constant moisture content in a 72° F. 65 percent relative humidity room.

Method of Test

Static-bending, impact-bending, compression-parallel-to-grain, toughness, and shear tests were made.

The static-bending, compression-parallel-to-grain, and shear tests were made in a 72° F., 65 percent relative humidity room.

Static Bending Tests

The 1- by 1- by 16-inch static-bending specimens were tested over a 14-inch span, center loading, with the surface showing the chemical stain on the tension side. Since the material was edge grained, the load was applied on a radial face. The load was applied to the specimen at a rate of 0.05 inch per minute throughout the tests. The loading blocks used had a radius of curvature of about 1-1/2 inches. Load-deflection readings were taken until the load, after reaching the maximum, decreased to one-half the maximum. Work done on the specimen up to this point, and expressed in inch-pounds per cubic inch, is herein termed "total work."

Compression-parallel-to-grain Tests

The 1- by 1- by 4-inch compression-parallel-to-grain specimens were obtained from the bending specimens after test. The rate of loading was 0.012 inch per minute. A 2-inch gage-length Lamb's roller attachment was used in measuring deflections. Load-deflection readings were taken until the load was well past the proportional limit, when the 2-inch gage attachment was removed and the load continued past the maximum until failure in the block occurred.

Shear Tests

The shear-parallel-to-grain tests were made on nominal 1- by 2- by 2-1/2-inch specimens notched to produce failure on a 1- by 2-inch surface. Failures occurred on a more or less tangential surface because the specimens were cut from edge-grained lumber.

The rate of loading was 0.015 inch per minute throughout the test. Only the maximum load was obtained.

Impact Bending Tests

The impact bending specimens were 1 by 1 by 16 inches and were tested (center loading) over a 14-inch span. The chemically stained specimens were placed with the stained surface on the tension side and the load was applied on the opposite radial surface.

The impact bending specimens were tested in the Hatt-Turner impact machine. The heights of drop of a 12-1/2-pound hammer were increased by 1-inch increments until failure occurred. Only the maximum height of drop was recorded.

Toughness Tests

The 5/8- by 5/8- by 10-inch toughness specimens were tested with the surface oriented as described for the bending specimens.

The toughness specimens were tested over an 8-inch span, center loading. Since the stained surface was edge-grained surface, the load was applied on a radial face as in the other tests, and hence differs from the standard procedure for toughness tests which specifies the load to be applied on the tangential face.

Discussion of Results

The chemically stained specimens averaged a fraction of a percent higher in specific gravity than the unstained control specimens. This is consistent with the relation in the board of control to stained specimens and the supposition that a movement of colored materials toward the surface takes place during drying.

The results of the static bending tests of some 40 chemically stained and an equal number of unstained control specimens indicate that the stress at proportional limit, modulus of rupture, and modulus of elasticity are practically unaffected by the chemical stain under consideration (table 1).

Since any decrease in strength is most likely to be reflected first in properties representing shock resistance, these properties are given special consideration. The average value for work to maximum load, a measure of shock resistance, is about 10 percent lower for the chemically stained specimens than for the unstained controls. Total work, however, also a measure of shock resistance and obtained from the static bending tests, shows a reduction of less than 5 percent. The average value for height of drop from the impact bending test, another measure of shock resistance, is only about 1 percent lower for the chemically stained than for the control specimens. Toughness tests, still another measure of shock resistance, give an average value for the chemically stained material about 1 percent higher than for the unstained.

Since shock-resisting properties obtained from static bending tests were the only ones which indicated an average reduction for chemically stained specimens as compared to unstained controls, further consideration was given to these properties. All static bending specimens with work to maximum load values 10 percent or more lower for the chemically stained than for the controls were compared to matched specimens tested in impact bending and in toughness. This comparison showed that even for those static bending specimens which appeared somewhat deficient in shock resistance, the corresponding impact bending specimens showed no reduction and the toughness specimens only a 2 percent reduction.

Considering all properties representing shock resistance, it appears that chemically stained specimens may be slightly lower in this property than unstained material, but that the difference is of no practical significance.

Maximum crushing strength and stress at proportional limit in compression parallel to the grain were practically the same for stained and unstained specimens. This was expected, since a factor which may considerably reduce shock resistance frequently has no effect upon compression-parallel-to-grain properties.

The shear-parallel-to-grain specimens were of necessity cut so that the failure occurred through a more or less tangential plane. As the material was edge grained, only the outer edges of the plane of failure contained the stain. No effect of chemical stain on shear values was apparent. It is not likely that any reduction would have occurred even though the plane of failure had been entirely within the chemically stained portion.

Conclusions

The results of these tests indicate that chemical stain incident to the drying of noble fir in accordance with Army-Navy Aeronautical Specification AN-W-2a has no significant effect upon the strength properties of noble fir.

There is some indication that this chemical stain may cause a slight decrease in shock resistance, but not to an extent to make the material unsuitable for airplanes.

Noble fir dried in accordance with the AN-W-2a Specification should be used without discrimination between chemically stained and unstained boards.

Table 1.--Summary of results of strength tests on stained and unstained noble fir

Type of test value	Static bending									Impact bending				Compression parallel to grain						Toughness				Shear parallel to grain			
	Specimens tested	Moisture content	Specific gravity[1]	Stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work: Proportional limit	Work: Maximum load	Work: Total	Specimens tested	Moisture content	Specific gravity[1]	Height of drop causing complete failure, 12-1/2 pound hammer	Specimens tested	Moisture content	Specific gravity[1]	Stress at proportional limit	Maximum crushing strength	Modulus of elasticity	Specimens tested	Moisture content	Specific gravity[1]	Toughness	Specimens tested	Moisture content	Specific gravity[1]	Maximum shearing strength
	Number	Percent		Lb. per sq. in.	Lb. per sq. in.	1000 lb. per sq. in.	In.-lb. per cu. in.	In.-lb. per cu. in.	In-lb. per cu. in.	Number	Percent		Inches	Number	Percent		Lb. per sq. in.	Lb. per sq. in.	1000 lb. per sq. in.	Number	Percent		In-lb. per specimen[2]	Number	Percent		Lb. per sq. in.
											Stained Specimens																
Average:	42	10.1	0.396	6040	10660	1745	1.18	10.62	17.41	27	10.3	0.398	15.5	69	10.2	0.397	5290	6220	2020	69	10.9	0.398	101.9	40	10.1	0.390	1153
Maximum:		11.6	.462	8060	12760	2111	1.77	16.10	25.40		10.8	.453	19		11.0	.464	6720	7800	2547		12.5	.516	163.1		10.5	.456	1520
Minimum:		9.2	.306	3790	7050	1310	.58	5.98	9.40		9.6	.320	10		9.0	.308	3930	4470	1344		9.3	.308	56.4		9.5	.304	832
											Matched Specimens Free of Stain																
Average:	42	10.0	.395	5990	10800	1709	1.19	11.87	18.24	27	10.2	.397	15.7	69	10.1	.395	5200	6150	1997	69	10.9	.395	100.8	40	10.0	.390	1155
Maximum:		11.3	.475	7820	13640	2108	2.06	17.44	28.30		11.2	.455	20		11.2	.474	6790	7640	2821		12.4	.520	161.3		10.7	.446	1460
Minimum:		9.3	.308	2890	7240	1227	.37	5.98	8.02		9.4	.319	10		9.5	.304	3540	4230	1288		9.3	.314	53.3		9.6	.312	858
											Ratios - Stained to Unstained Specimens - Expressed in Percentages																
		101.0	100.3	100.8	98.7	102.1	99.2	89.5	95.4		101.0	100.3	98.7		101.0	100.5	101.3	101.1	101.2		100.0	100.8	101.1		101.0	100.0	99.8
											Classification of Stained Specimens by Strength and Related Properties as Compared to Matched Unstained Specimens - Expressed in Number of Specimens																
Higher than controls		20	20	23	15	25	19	13	14		15	15	9		33	37	27	36	42		34	41	34		16	20	18
Lower than controls		17	19	19	26	17	23	28	25		8	12	13		22	31	29	32	27		29	27	35		13	14	19
Equal to controls		5	3	0	1	0	0	1	0		4	0	5		14	1	1	1	0		6	1	0		9	4	1

[1]Based on oven-dry weight and volume at test.

[2]Specimen 5/8 by 5/8 by 10 inches, tested over an 8-inch span - center loading - load applied on radial surface.

Z M 49495 F

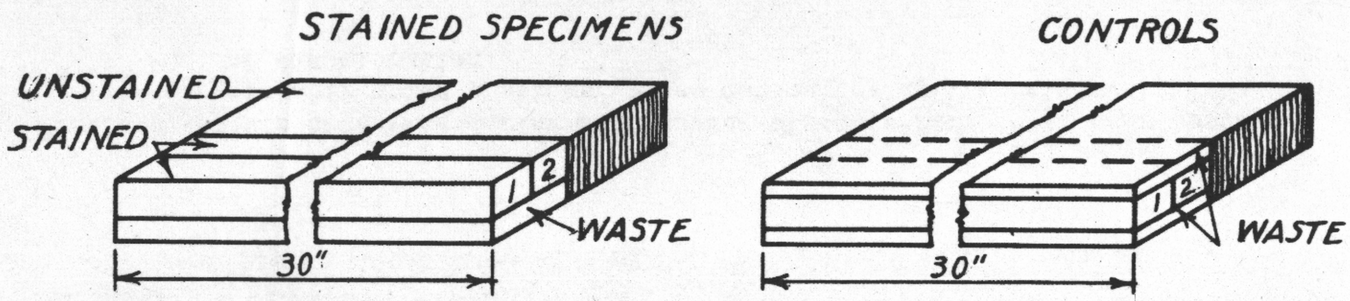

Figure 1.--Method for obtaining stained and control specimens.

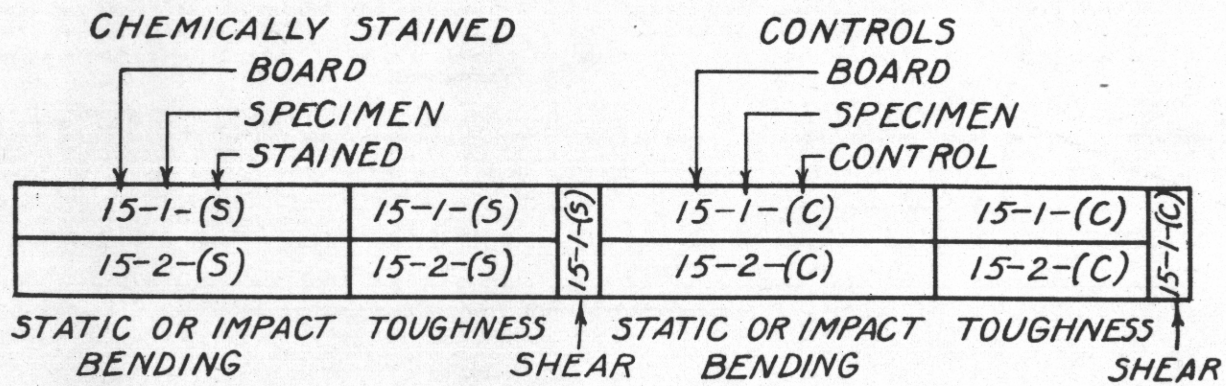

Figure 2.--Method of matching and marking specimens for tests. For the static- or impact-bending specimens, odd numbered specimens were tested in static bending and even numbered in impact bending; compression-parallel-to-grain specimens were cut from bending specimens after test.

Z M 50088 F

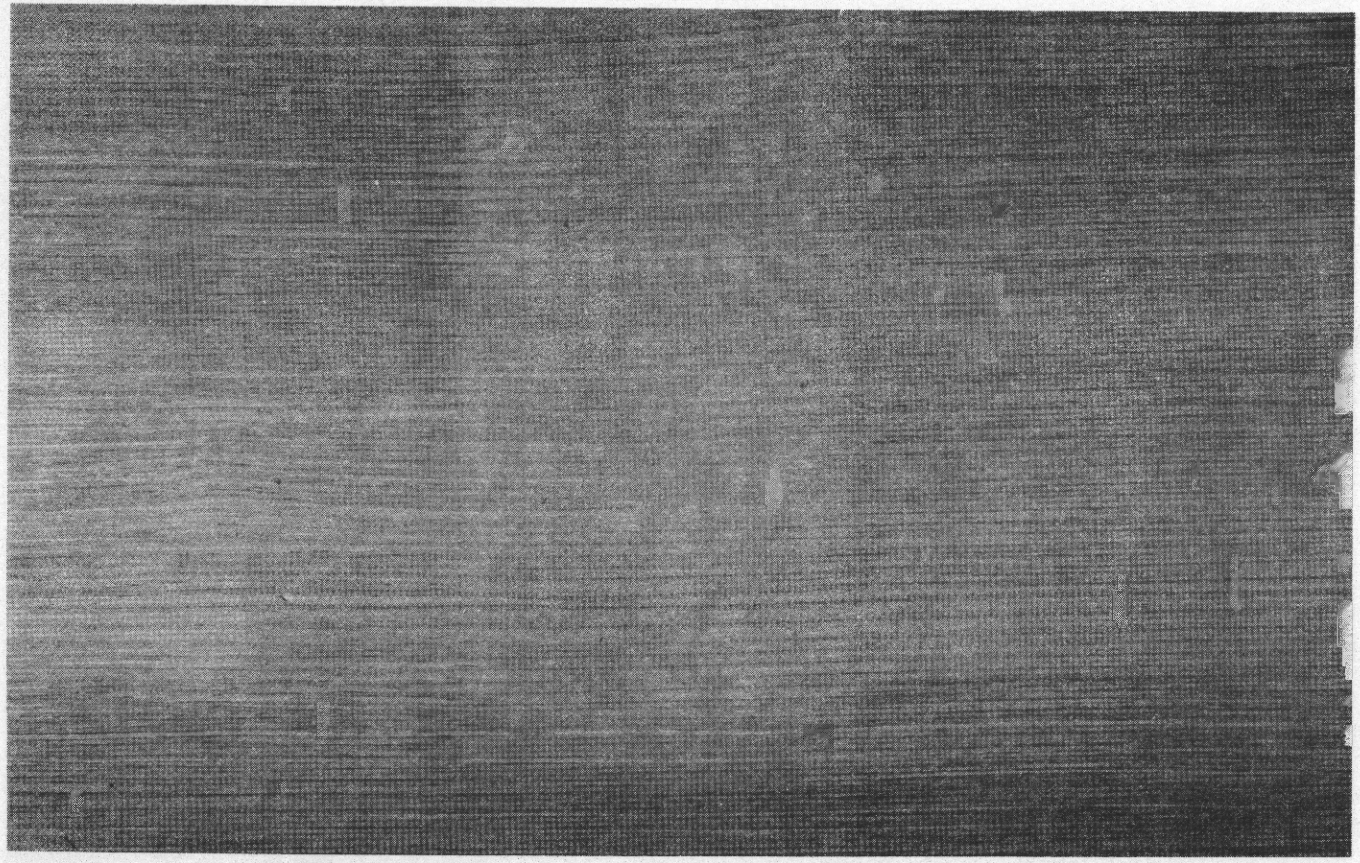

Figure 3.--Stain occurring during kiln drying of noble fir. Area near center, probably under a sticker piece during drying, is relatively free of discoloration.

Z M 50087 F

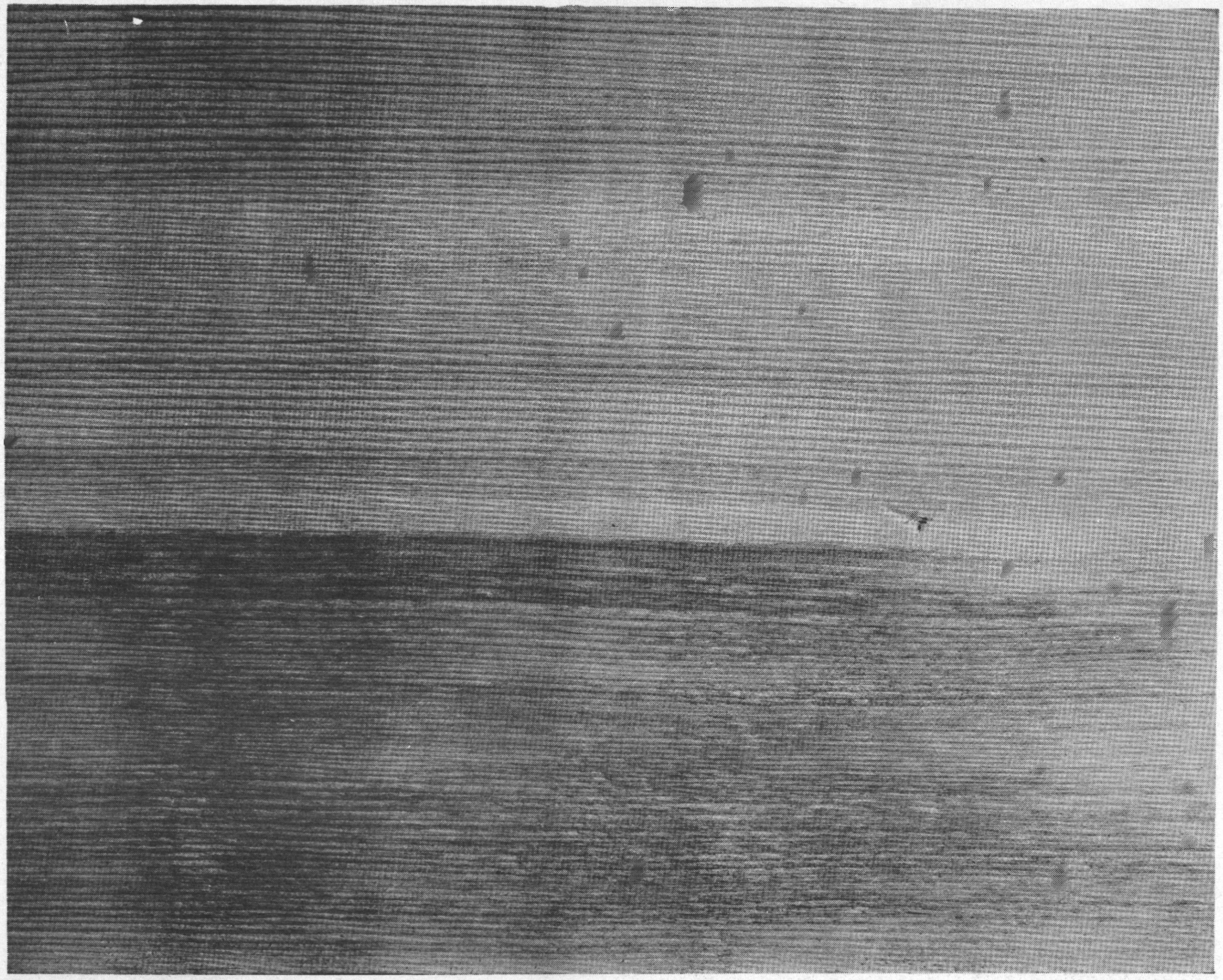

Figure 4.--Edge-grained board of noble fir showing sharp line of demarkation between stained and unstained areas. The stained area is sapwood and the unstained is heartwood.

Z M 50086 F

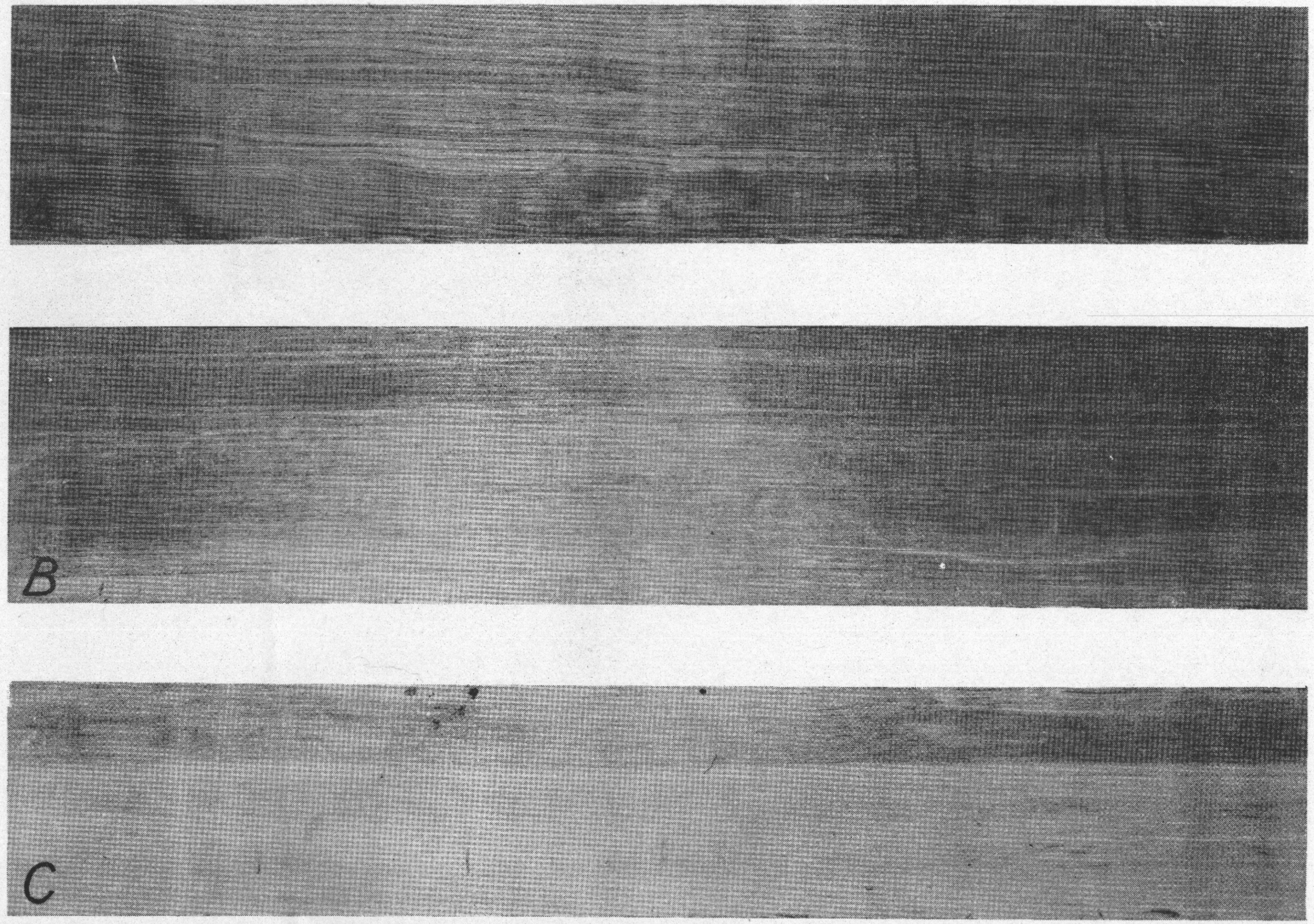

Figure 5.--Discolored noble fir boards. A, board not truly edge grained, discoloration more or less uniform over the entire board; B, board showing pronounced gradations of color but no definite limits. Boards A and B are all sapwood. C, board showing a definite line of demarkation extending the full length with the left (sapwood) chemically stained throughout and the right (heartwood) entirely free of stain.

Z M 50085 F