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# THE SIGNIFICANCE OF THE DISCOLORATIONS IN AIRCRAFT LUMBER: NOBLE FIR AND WESTERN HEMLOCK

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THE SIGNIFICANCE OF THE DISCOLORATIONS IN AIRCRAFT LUMBER:

NOBLE FIR AND WESTERN HEMLOCK

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SUMMARY

A survey was made in Oregon and Washington of the discolorations occurring in noble fir and Western hemlock wood, and the present data are presented as an aid in the inspection of these woods for aircraft and other high-grade lumber.

Recommendations, based on strength tests of similar discolorations in spruce or on tests made by the Forest Products Laboratory, for the acceptance or rejection of the various discolorations occurring in noble fir and Western hemlock follow.

- A. Discolorations that are not indicative of decay and signify no significant loss in strength. They may be disregarded unless otherwise noted.

Black streak.--Thin longitudinal, purplish-brown lines. Common in Western hemlock, occasional in noble fir.

Chemical stain.--Reddish-brown streak or mottling on surface of kiln-dried sapwood. Common in noble fir, occasional in Western hemlock.

Radial red streaks or strawberry marks.--Reddish discoloration across the grain. Disregard unless accompanied by grain deviation greater than allowed by specification. Occasional in noble fir and Western hemlock.

Machine burn.--Dark brown to black scorches made by high-speed planers. Disregard if on surface; reject if deeper than 1/64 inch. Common on finished material.

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<sup>2</sup>Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, in cooperation with the Forest Products Laboratory, Madison 5, Wis.



Vertical purple and red streaks.--Longitudinal streaks that are purplish in noble fir and reddish in Western hemlock. Usually about 1/8 to 3/8 inch wide on edge grain. Occasional in noble fir, infrequent in Western hemlock.

Resin streak.--Narrow, reddish-brown, vertical streaks with resin. Reject if over 1/2 inch wide. Infrequent in Western hemlock.

Bluish cast of outer heartwood.--Bluish color in outer heartwood of noble fir only. Common.

Floccosoids or white flecks.--Small white flecks about 1/8 to 1/2 inch on edge grain. Occasional in Western hemlock, none in noble fir.

Surface molds.--Variously colored spots or patches on lumber, invariably removed by planing. Common on rough air-seasoned lumber.

- B. Discolorations caused by staining or wood-destroying fungi and prohibited by the statement in the specifications that bright sapwood is not a defect and by the requirement of freedom from rot, dote, or decay.

Blue stain.--Blue to bluish-black discoloration of the sapwood. Occasional in noble fir and Western hemlock.

Brown streaks, bands, or zones.--Yellowish to chocolate brown, longitudinal streaks always denoting decay. Common in noble fir and Western hemlock.

Brown spots.--Brown spots in seasoned wood; always denoting decay. Occasional in Western hemlock; not found in noble fir.

Red band or zones.--Light reddish to reddish-brown, about 1/2 to 2 inches wide as seen on edge-grain surface. Incipient decay, usually but not necessarily in outer heartwood. Occasional in Western hemlock, infrequent in noble fir.

White to yellow pits or pockets.--Small oval pockets loosely lined with white or yellow cottony fibers. Decay. Common in both noble fir and Western hemlock.

Black specks.--Tiny black specks or very short lines usually in association with brown streaks or zones always indicate decay. Occasional in noble fir and Western hemlock.

Brown flecks.--Light brown oval spots as seen on edge-grain surface, about 1/16 inch wide and 1/4 to 1/2 inch long. Always indicative of decay. Common in noble fir, infrequent in Western hemlock.

Zone lines.--Dark-colored lines, straight or variously curved usually with other evidences of decay. Infrequent.

## INTRODUCTION

Noble fir and Western hemlock have been used for aircraft construction in place of Sitka spruce and will be used in the future for aircraft or other high-grade uses. The wood of these two species is subject to various discolorations, the significance of which should be understood in order not only to reject defective material, but also to insure the acceptance of sound though discolored wood. The discolorations occurring in noble fir and Western hemlock are described and evaluated in this report insofar as our present knowledge of the defects in these species will permit.

The data on which this report is based were obtained by inspection and collection of noble fir and Western hemlock lumber at Oregon and Washington mills by the authors and laboratory study of doubtful cases, in connection with a similar study of Sitka spruce. Descriptions of the discolorations in Sitka spruce have already been reported.<sup>2</sup> Some of the discolorations in noble fir and Western hemlock are similar to those in Sitka spruce, and in the absence of other data some recommendations as to the amount of wood to be rejected beyond visible decay are given as for Sitka spruce.

## NORMAL COLOR OF NOBLE FIR AND WESTERN HEMLOCK WOOD

The color of normal noble fir and Western hemlock wood may be described as light tan with usually only slight difference between the color of sapwood and heartwood. The general over-all appearance of both woods is similar, although slight differences are common. Noble fir, for example, often has a bluish cast of the outer heartwood, while Western hemlock does not. Western hemlock, on the other hand, may be somewhat more pinkish in color. Both woods may sometimes be confused with Sitka spruce.

## DISCOLORATIONS IN NOBLE FIR AND WESTERN HEMLOCK WOOD

Although noble fir and Western hemlock wood are ordinarily uniform in color, there are various discolorations present in both woods. Some of these are caused by fungi while others are normal color variations in the wood. The discolorations not caused by fungi encountered most frequently in both noble fir and Western hemlock wood are black streak, chemical stain, machine burn, and radial red streak. Floccosoids or white flecks and resin streak were encountered only in Western hemlock, while purple streak and bluish cast of outer heartwood were found in noble fir only.

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<sup>2</sup>Hansbrough, J. R., and Englerth, G. H. The significance of the discolorations in aircraft lumber: Sitka spruce. For. Path. Spec. Release No. 21, 13 pp., June 1944.



Those discolorations associated with fungi and occurring to a greater or lesser extent in both woods are surface molds, sap stain, brown streaks, bands or zones, brown spots, red bands or zones, white to yellow pits or pockets, black specks, brown flecks, and zone lines.

It is not unusual for two or more discolorations to occur in one piece of lumber. For example, black streak and floccosoids are commonly found in association, but it does not necessarily mean that one discoloration is the result of the other.

No mechanical tests were made in connection with this study, and the recommendations for acceptance or rejection are based on tests made on wood of other species having similar discolorations, or on mechanical tests made on similar discolored wood in other studies by the Forest Products Laboratory.

### Black Streak

Black streak, caused by the larvae of a small fly feeding at the surface of newly forming wood, is common in Western hemlock and less so in noble fir. As seen on edge-grain material, the maggot chamber may be open or closed with a thin purplish-brown to black line extending as much as 3 feet in either direction along the grain (fig. 1). Six to 10 inches in either direction is more common, however. The line gradually narrows until it disappears.

Tests made at the Forest Products Laboratory showed that black streaks, except for maggot chambers, are admissible for aircraft construction.<sup>4</sup> Maggot chambers should be treated similarly to pitch or bark pockets, and the length considered only as the wider portion of the black streak as seen on edge-grain surface. Any associated grain deviation should be limited in the same manner as other grain deviations.

### Chemical Stain

Chemical stain of sapwood sometimes occurs when green lumber is exposed to the air. It is more common on kiln-dried material, since rapid evaporation during drying carries water-soluble compounds to the wood surface where these are acted upon by oxidizing enzymes. The color of the stain appears as red to reddish-brown streaks or mottling on edge-grain noble fir and Western hemlock lumber (fig. 2). This stain occurs more frequently in noble fir than in hemlock.

Usually the stain penetrates no deeper than 1/16 to 1/8 inch. Chemically stained wood retains its bright luster. No chemical stain was found to occur in the heartwood of either noble fir or Western hemlock.

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<sup>4</sup>-Luxford, R. F., Wood, L. W., and Gerry, Eloise. "Black streak" in Western hemlock: Its characteristics and influence on strength. FPL Report No. 1500, 7 pp., illus., Dec. 1943.

Medium planing will remove most of the stain. There is no significant loss in strength due to chemical stain and no rejections should be made because of it.<sup>5</sup>

#### Radial Red Streak

Infrequently a narrow reddish streak at right angles to the grain occurs in noble fir and Western hemlock. This red streak is similar to that found in Sitka spruce.<sup>6</sup> On edge grain, the streaks may be several inches long depending mainly on how nearly the cut is truly radial, and 1/4 to 1 inch wide, while on flat grain they are oval. These streaks are often referred to as "strawberry marks" or "birthmarks." They can readily be identified by the greater height of the wood rays in the discolored wood. Oftentimes a grain deviation accompanies the discoloration, and unless this grain deviation is too great to meet specifications radial red streak should not be rejected.

#### Machine Burn

All woods are subject to burns by high-speed machines, especially planers. The color of these burns may vary from light to dark brown or black depending on the severity of the burn. Burns or scorches penetrating deeper than 1/64 inch on finished stock should be rejected, while those less severe or where refinishing is to be done may be permissible.

#### Vertical Purple and Red Streaks

A narrow purple streak running parallel with the grain and about 1/8 to 3/8 inch wide as seen on edge grain is oftentimes encountered in the outer heartwood zone of noble fir. It may occur adjacent to the sapwood or in a short distance from it. The purplish color appears to be concentrated in the tracheids for the most part, and the wood for a distance of an inch to 2 inches on the pith side of the streak is slightly darker in color than adjacent wood.

The origin of purple streak has not been determined. It appears unlikely that it is a response to wounding, but rather a color response similar to that of vertical red streak adjacent to the sapwood in Sitka spruce. Isolations made from this streak and microscopic examination reveal no evidence

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<sup>5</sup>Luxford, R. F., and Krone, R. H. Chemical stain in noble fir as related to strength. FPL Report No. 1329, 6 pp., illus., Oct. 1943.

<sup>6</sup>Gerry, Eloise. Radial streak (red) and giant resin ducts in spruce. FPL Report No. 1391, 2 pp., illus., Aug. 1942.



of fungi. Therefore, this purple streak should not be considered a defect.

Occasionally in noble fir vertical purple streak and bluish cast of outer heartwood occur together. It is not known, however, if there is any connection between the two.

In Western hemlock, vertical streaks about  $1/8$  to  $1/4$  inch wide as seen on edge grain occasionally occur in the outer heartwood. The streaks may be light reddish to reddish-brown in color. The lighter colored streaks are similar in appearance to vertical red streak in Sitka spruce. No fungus was found in association, and no rejections should be made because of this type of streak.

#### Resin Streak

A dark reddish-brown, resinous streak about  $1/8$  inch wide was infrequently found in the outer heartwood of Western hemlock. The streak, while vertical, did not necessarily follow along the growth rings. It apparently was the result of mechanical injury in the tree, and resin produced because of this injury infiltrated the tracheids and wood rays giving the streak its color. No provision is made in the specification for pitch or resin streaks.

#### Bluish Cast of Outer Heartwood

Not infrequently the outer heartwood of noble fir is decidedly bluish in color. This color is best seen on cross sections of logs. On edge-grain lumber the color gives the wood a bluish cast that terminates abruptly at the sapwood and decreases gradually towards the center. No evidence of fungi has been found associated with this bluish color, and it is not to be regarded as a defect.

No difficulty should be encountered in distinguishing this color from those caused by staining fungi. Those caused by fungi are usually mottled or streaked in appearance with the color usually more concentrated in the wood rays, while the harmless bluish cast is less apparent in the rays.

#### Floccosoids or White Flecks

Small white flecks about  $1/8$  to  $1/2$  inch in size as seen on edge grain occasionally occur in Western hemlock. From observations on logging operations and at mills west of the Coast Range in Oregon and Washington, these floccosoids or white flecks were found to occur mostly in the basal portion of trees and frequently in areas where the wood had a high moisture content. That is, the heartwood of Western hemlock commonly contains streaks where the wood is of much higher moisture content than the surrounding wood, and

these floccosoids were found to be numerous in such streaks. Because of the high water content, these streaks when wet are somewhat darker in color than normal wood.

Floccosoids are not an indication of decay. On the basis of existing information it appears improbable that floccosoids significantly affect the mechanical properties of this wood; that is, if Western hemlock lumber is otherwise acceptable the presence of floccosoids should not be cause for its rejection for use in aircraft grades. Floccosoids have sometimes been confused with decay. Several fungi in Western hemlock cause a rot with white flecks or pockets of approximately the same size as floccosoids. These decay flecks usually differ from floccosoids by being soft in texture and associated with color variations in the wood, such as brown streak, pink to red discolorations, zone lines, and yellow pits or pockets. A simple chemical test is available for doubtful cases. Slivers from questionable pieces are dipped in a 4 percent solution of sodium hydroxide;<sup>7, 8</sup> if the white flecks dissolve they are floccosoids, if not they denote a decay and the wood should be rejected.

#### DISCOLORATIONS CAUSED BY FUNGI

##### Surface Molds

Miscellaneous surface molds of various colors will develop on wet and untreated noble fir and Western hemlock. Planing will remove most evidence of these molds and rejection of otherwise sound material is unnecessary because of them. It should be emphasized, however, that conditions favorable to mold growth as well as staining fungi are also favorable for the development of wood-destroying fungi. Consequently, material containing these fungi should be carefully inspected for evidences of decay.

##### Blue Stain

Unless promptly dried and kept dry or treated with toxic chemicals, sapwood will be attacked by staining organisms. Noble fir and Western hemlock, while not as subject to staining as some softwoods, should be given protection against sap-staining fungi. Stain may not only develop in logs left too long in the woods during warm weather, but also in green untreated lumber or lumber that has been dried and again becomes wet.

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<sup>7</sup>Gerry, Eloise. Western hemlock "floccosoids" (white spots or streaks). FPL Report No. 1392, 3 pp., illus., March 1943.

<sup>8</sup>Grondal, Bror L., and Mottet, Arthur L. Characteristics and significance of white floccose aggregates in the wood of Western hemlock. Univ. Washington Forest Club Quart. 16(1):13-18, illus., Dec. 1942.



According to specifications, blue stain (sap stain) is not permissible in aircraft lumber. It was seldom encountered in the heartwood of noble fir or Western hemlock, although it is common in the heartwood of Sitka spruce.

### Brown Streaks, Bands, or Zones

Several fungi in noble fir and Western hemlock produce brown streaks in the incipient stage of rot. The color of such streaks varies from light yellowish-brown to light chocolate brown, and the wood appears dull and lifeless. Occasionally other indications of decay are also present. These include zone lines, white to yellow pits, and black specks. This brown discoloration may extend several inches across the grain and as streaks for several feet beyond the advanced stage of decay. At its extreme limits, the streaks become narrow and the color gradually merges with the color of normal wood.

Brown streaks are definite stages of rot as can be demonstrated by microscopic examination. They should always be rejected for aircraft construction. While no studies have been made in these two species on the distance of fungus penetration beyond the outer limits of discoloration, it is preferable to reject in addition at least 2 inches across the grain and 2 feet with the grain beyond obvious discoloration.

Another type of streak occurring in both noble fir and Western hemlock is that which is usually referred to as hard-grain or compression wood. The annual rings in such streaks have a higher percentage of summerwood than normal wood, which makes them appear darker. There should be no confusion in distinguishing this type of streak. Streaks wider than  $1/4$  inch on edge-grained surface are barred by specification, and the total widths of these streaks exceeding 10 percent of the face on which they appear are also cause for rejection.

Still another type of streak darker in color than normal wood is found in Western hemlock. Such streaks appear on the edge-grained surface of unseasoned wood as dark areas, water-soaked when green,  $1/4$  to several inches in width and 1 to more than 20 feet in length. Upon drying, however, all evidences of the streaks disappear. The color is due to the high water content in these streaks. It is in these water-soaked areas that floccosoids are most numerous.

It has been reported by Eades<sup>2</sup> that the wood fibers in such streaks appear to be short, lack cohesion, and readily split apart. He recommended that these water-soaked streaks be considered cause for degrade in aircraft stock. The writers have seen no evidence of weakness specifically associated with water soak; comparative strength tests would be desirable.

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<sup>2</sup>Eades, H. W. Investigation of brown streak in Western hemlock used for aircraft purposes. Can. For. Prod. Lab. (Vancouver) Mimeo., 4 pp., 1943.

### Brown Spots

Brown spots similar to those found in Sitka spruce occur in Western hemlock. They are always an indication of decay. Although more than one fungus may be involved in producing brown spots or "pile burn" the symptoms are much the same. The first indications are a faint brown spotting similar to those made by drops of oil on dried wood. Usually no other indications of decay are present in this stage, but later brown to reddish-brown streaks or bands may also be present.

This decay is difficult to recognize in its early stages, and may be present in boards as thin as 1 inch without being seen on the outer surfaces. Upon resawing of infected dried material, however, the brown spots may readily be seen. All infected material should be rejected with the preferable plan to reject at least 2 inches across the grain and 2 feet with the grain beyond all visual signs of decay.

This type of decay was not encountered in noble fir, although there is no apparent reason why such rot may not occasionally be present.

### Red Bands or Zones

In otherwise normal wood, light reddish to reddish-brown longitudinal bands or zones have been observed occasionally in Western hemlock and infrequently in noble fir. These may vary in width as seen on edge grain from  $1/2$  to 2 inches, and may be several feet long until they taper and merge with normal colored wood. In logs or long cants, such streaks are always associated with typical rot at one end, but in shorter boards there may not be any obvious connection with rot of a more advanced stage. These bands are not necessarily located in the outer heartwood as are the vertical red streaks that are only from  $1/4$  to  $3/8$  inch wide, and in contrast to these the wood is often dull and lifeless in appearance. Upon exposure to light they become brownish. These bands are a stage of decay and the wood should be rejected. Usually rejection of material 2 inches across the grain and 2 feet with the grain beyond visual discoloration will remove all hidden rot.

### White to Yellow Pits or Pockets

Several kinds of rot in noble fir and Western hemlock are characterized by white, yellow to yellowish-brown pits or pockets (figs. 3 and 4). The most common of these is red ring rot. The wood in this stage of decay loses its luster, and no difficulty should be encountered in diagnosing it as decay. The differences between this and floccosoids have already been described. Single pits are about  $1/16$  inch in diameter, while those that have coalesced are about  $1/16$  inch wide and up to 1 inch long with the long dimensions parallel to the grain. Zone lines may or may not also be present. Material at least 2 inches across the grain and 2 feet with the grain beyond any visible sign of decay should be rejected in order to remove all infected wood.



### Black Specks

Tiny black specks from the size of a pin point up to fine black lines about 1/16 inch long with the grain are commonly produced in connection with some decays of noble fir and Western hemlock. On microscopic examination black specks appear as a mass of dark brown hyphae in the tracheids. While brown streaks and white or yellow pits may be associated with these black specks, with or without such pits black specks are always a positive indication of decay and wood containing them should be rejected in aircraft lumber. In addition, about 2 inches across the grain and 2 feet with the grain beyond the last visible symptoms of decay should be rejected.

### Brown Flecks

Probably the most common rot in noble fir and less common in Western hemlock is one that causes a white pocket or honeycomb rot. It is easily recognized in the late stage, and less so in the incipient stage where brown streak may or may not be present. In the absence of brown streak, light brown flecks are a positive indication of decay. These flecks are the first sign of pocket formation, although at this stage no evidence of pockets can be detected. The flecks as seen on edge-grain lumber are about 1/16 inch wide and 1/4 to 1/2 inch long with the long axis with the direction of the grain. The flecks may be widely scattered, separated by wood that appears normal but is also infected.

For aircraft construction or any highly stressed product, wood containing these brown flecks should be rejected. In addition, wood 4 inches across the grain and 4 feet with the grain beyond the last visible discoloration should also be rejected.

Brown flecks should not be confused with brown pits or pockets as seen in Sitka spruce where actual openings are present. Different organisms are responsible for brown pits.

### Zone Lines

In the development of some decays, lines ranging in color from light brown with shades of green, yellow or red, to dark brown or black are sometimes produced (fig. 5). These are termed zone lines. Oftentimes they are fine narrow lines which may or may not follow the direction of the grain. Zone lines are an indication of decay, and material containing them should be rejected.

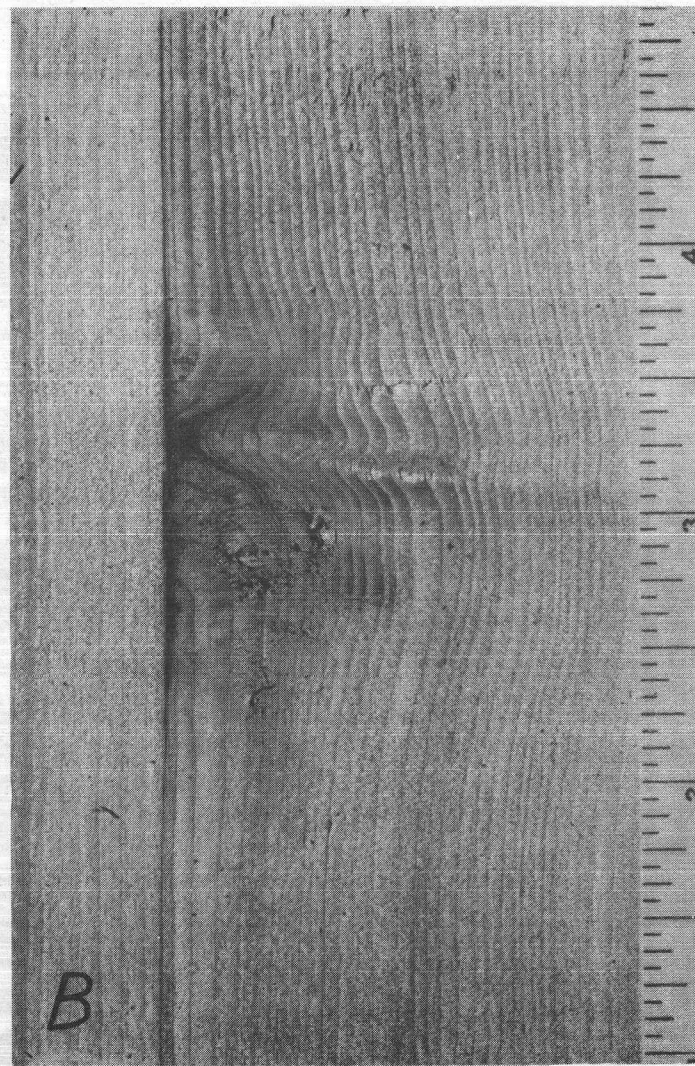
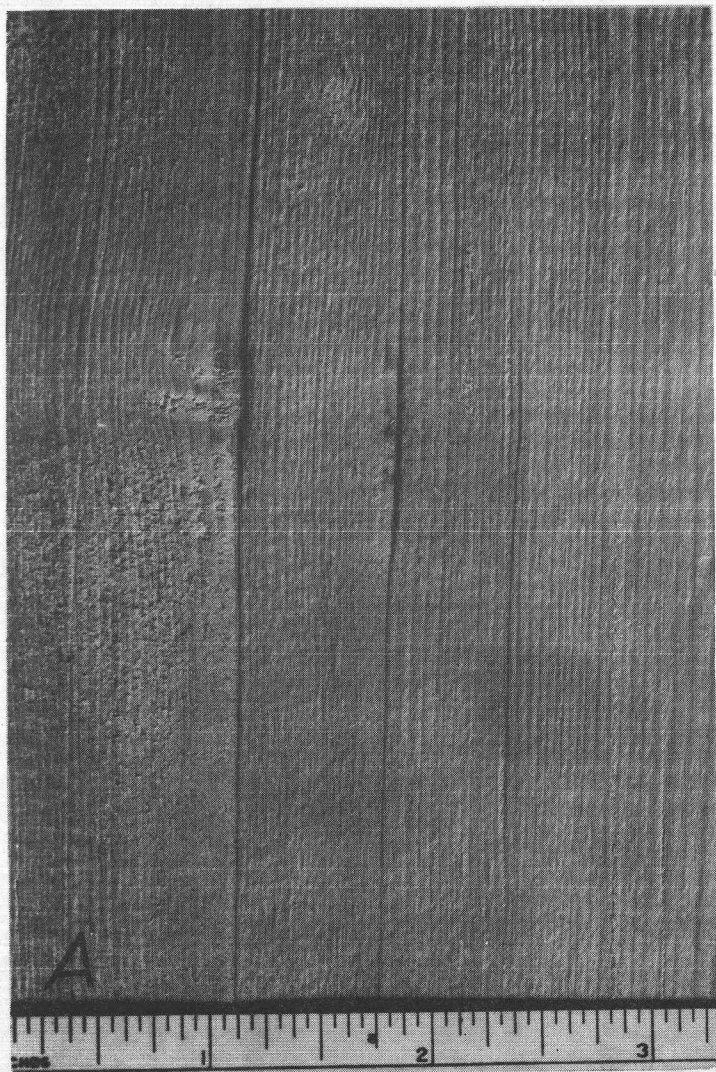


Figure 1.--Black streaks in edge-grained western hemlock boards. A, two black streaks with their maggot chambers (wider portions or included openings). B, a black streak showing greater disturbance of wood formation resulting from longer occupation by the maggot.

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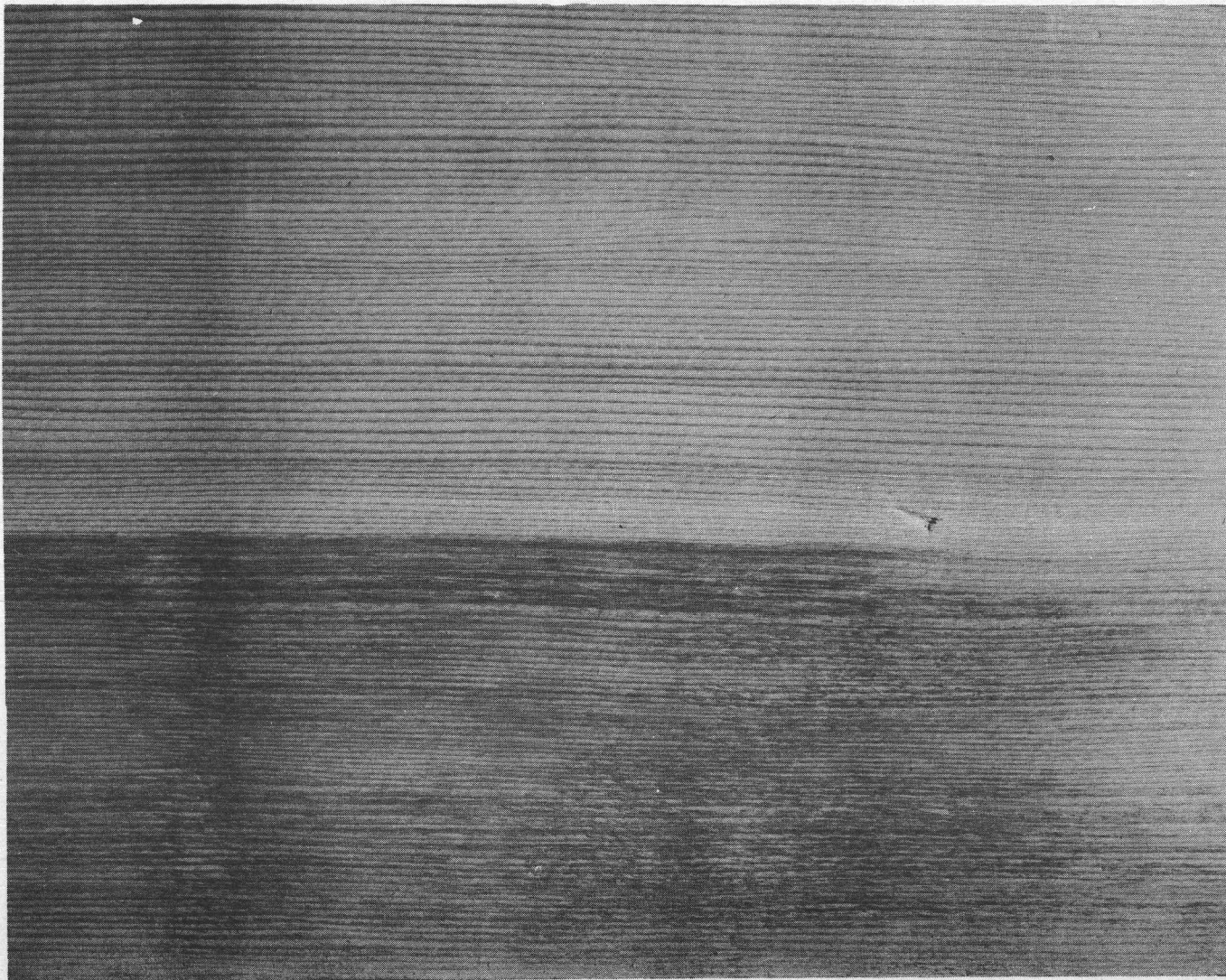


Figure 2.--Edge-grained board of noble fir showing areas with and without chemical stain. The stained area is sapwood and the unstained is heartwood.

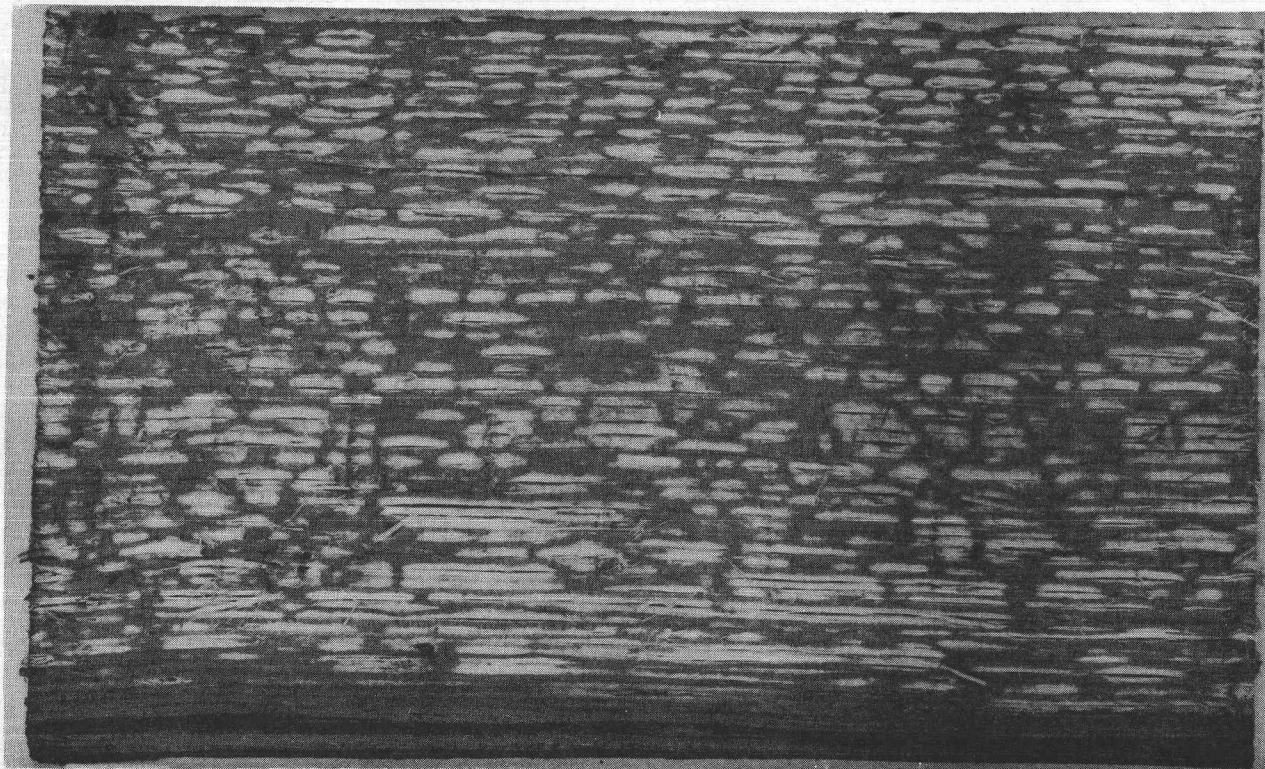


Figure 3.--White pocket rot in Western hemlock.

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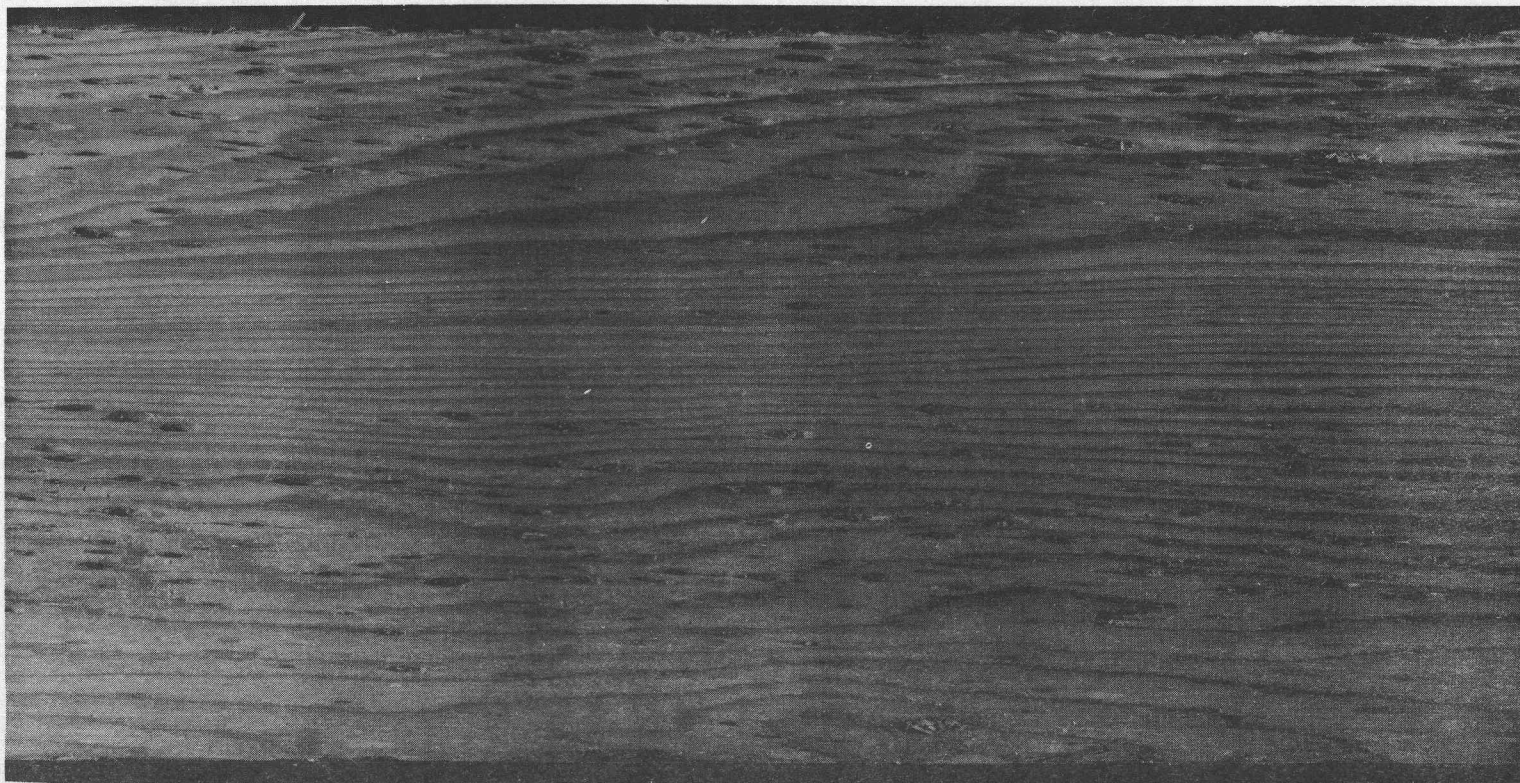


Figure 4.--Pocket rot in noble fir.

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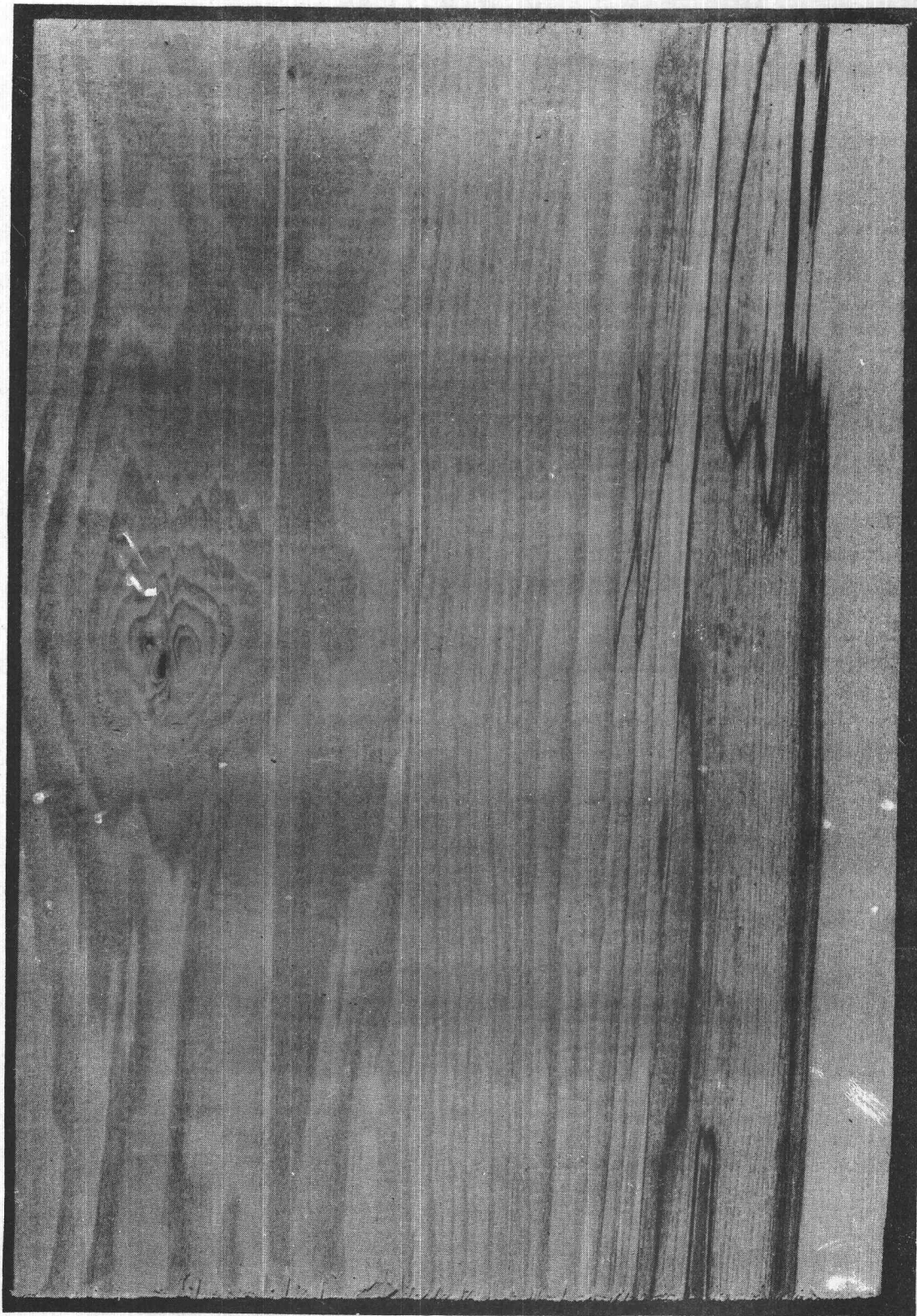


Figure 5.---Zone lines associated with decay in noble fir.  
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